Journal of Energy Engineering and Thermodynamics
ISSN 2815-0945
Vol: 04, No. 04, June-July 2024
https://journal.hmjournals.com/index.php/JEET
DOI: https://doi.org/10.55529/jeet.44.33.41

The Effect of Dust Accumulation on Photovoltaic (PV) Panel Surface in Politeknik Mersing, Johor, Malaysia

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Received: 22 March 2024 **Accepted:** 09 June 2024 **Published:** 23 July 2024

Abstract:** One of the initiatives aiming at supporting green technology sustainability education in the Politeknik Mersing is the generation of power using renewable energy sources like solar. Considered as more efficient and able to meet current power needs of the community, the generation of electricity from limitless green energy sources is Dust accumulation on the photovoltaic (PV) panel surface has been one of the main environmental elements influencing the declining sun irradiation since Politeknik Mersing located in a tropical rainforest and coastal location. Moreover, in humid environments the accumulation of dust forms mud and contamination on the PV panel surface, which subsequently reduces the relative power efficiency of PV by up to 30%. Therefore, the study has been carried out to investigate the effects of dust accumulation on PV panel surfaces on the amount of output power generated by the PV system. While the lowest relative performance of 69.6% occurred at a 30° tilt angle, the best relative performance of 97% was obtained at a 0° tilt angle during peak solar hours. The relative power efficiency was used to analyse the performance of PV panels under clean and dusty conditions since there was no pyranometer to measure solar irradiation. Several tilt angles (0°, 10°, 20°, and 30°) were assessed in order to situate the panel optimally with respect to the latitude of the location and peak solar hours (10:00 am, 11:00 am, 12:00 pm, and 1:00 pm). The performance of the PV system was evaluated using total output power that is derived from open-circuit voltage (Voc) and short-circuit current (Isc). Results showed that dust accumulation affects the efficiency of PV panels thus necessitating effective maintenance strategies within such environments.

***Keywords:** Dust Accumulation, Photovoltaic (PV), Relative Power Efficiency, Renewable Energy, Tilt Angle.*

1. INTRODUCTION

The global focus on renewable energy sources has generated a lot of interest in photovoltaic (PV) technologies as a workable method of producing sustainable electricity. A major part of

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green technology projects as PV systems uses the photoelectric effect to turn solar radiation into electrical energy. Part of its dedication to sustainability, Politeknik Mersing, which is situated in a tropical rainforest and coast location in Johor, Malaysia, includes PV panels that harvest solar energy.

Politeknik Mersing as shown in Fig. 1 is located within a tropical rainforest and coastal area making it an ideal location for dust density and humidity affecting its PV panels, thus being used as a case study for the effects of environmental factors on PV performance. The tropical rainforest and coastal region of Politeknik Mersing are both considered to have a high dust density. The objective of this study is to analyse the influence of dust accumulation on the surface of PV panels and investigate the effects on their performance, given the high dust density in Politeknik Mersing. Additionally, the study aims to evaluate the percentage reduction in output power production efficiency due to dust accumulation.

Fig. 1 Location of Politeknik Mersing, Mersing Johor (source: Google maps)

The study employs a comparative analysis of PV panel performance under clean and dusty conditions, using data collected from Politeknik Mersing. The power output (P) of the PV panels is calculated using the formula given by (1):

P = Voc x 1sc (1).

where Voc is the open-circuit voltage and Isc is the short-circuit current.
Power efficiency (η) is usually determined by the ratio of output power to input solar irradiance. However, due to the limitation of not having a pyranometer to measure solar irradiance in this research, relative power efficiency was used to assess PV panel performance under clean and dusty conditions.

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Relative power efficiency, $\eta = \frac{P\ dusty}{P\ cleaned} \times 100\%$ (2).

where P_{dusty} is the output power under dusty conditions and $P_{cleaned}$ is output power under cleaned conditions.

This paper investigates the effect of dust accumulation on daily performance of Solar Photovoltaic (PV) panels at Politeknik Mersing, Johor Malaysia. The objective of this study is to gain an in-sight on the extent understanding dust impacts can provide assistance towards maximizing PV panel efficiency at tropical-coastal environment.

2. RELATED WORKS

The accumulation of dust on PV panels significantly affects the efficiency of solar energy conversion. Very few descriptive experimental studies were available on this issue and no detailed consequences of various environmental stress may have led to high accumulation. In part, relevant literature on dust accumulations effects, the environmental impact in PV performance and some techniques presented to reduce it.

A preliminary and comprehensive investigation into the effect of dust on PV performance underscores that the accumulation of dust could reduce efficiency by up to 50% without cleaning [1]. A field study conducted in Malaysia demonstrated that the accumulation of dust causes a significant reduction in PV efficiency, referring to the significance of routine maintenance [2]. The review discusses the effect of climatic factors, such as humidity and temperature, on the consequences of dust formation on PV panels in the MENA and Far East regions [3].
This leads to a substantial reduction in capacity performance, especially for coastal areas, since dust and humidity impact PV efficiency concurrently [4]. Different strategies to minimize dust accumulation have been explored like mechanical cleaning or implanting coatings that operates by repelling the oil [5]. Studies on different PV cleaning techniques based upon a multi-criteria decision-making process has determined that scheduled, interval cleaning of PV panels is important to maintain their performance and support the establishment of sustainable solar energy objectives [6], [7]. In coastal areas, the combined effects of dust and humidity necessitate effective maintenance strategies to sustain PV efficiency [8].

Nevertheless, to the best of our knowledge there is no research that focus on dust accumulation effects from tropical rainforest and coastal areas such as Johor (Malaysia). Moreover, the effect of different tilt angles and peak sun hours on dust accumulation and PV performance has not been fully investigated. A large study in rainforest and coastal tropical regions such as this is useful to validate the effects of dust accumulation on PV panels using real case studies. This study investigates the impact of different tilt angles and peak sun hours, offering valuable insights into optimal panel positioning and maintenance strategies to enhance PV performance in similar environmental conditions.

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3. METHODOLOGY

A Solar PV panel with a maximum power output (Pmax) of 100 watts from the manufacturer Ablelogic was cleaned using tap water under constant low pressure as shown in Fig. 2. This low-cost and simple method was employed to extend the PV panel's lifetime by preventing surface scratches [6]. The PV panel was then mounted on a tilt-adjustable rack equipped with a meter to measure various angles (0°, 10°, 20°, 30°) of inclination relative to the horizontal surface. The cleaned PV panel was placed outdoors in an unshaded area at Politeknik Mersing and angled facing true south (180°) to ensure maximum solar irradiation [9]. Concurrently, the PV panel was connected to an Arduino microcontroller integrated with a Sharp GP2Y1010AU0F Dust Sensor and a DHT22 sensor for measuring humidity and temperature, as illustrated in Fig. 3. The initial values displayed on the LCD indicator were 0.03 mg/m³ for dust density, 29°C for temperature, and 70% for relative humidity.

Fig. 2 PV panel cleaning process.

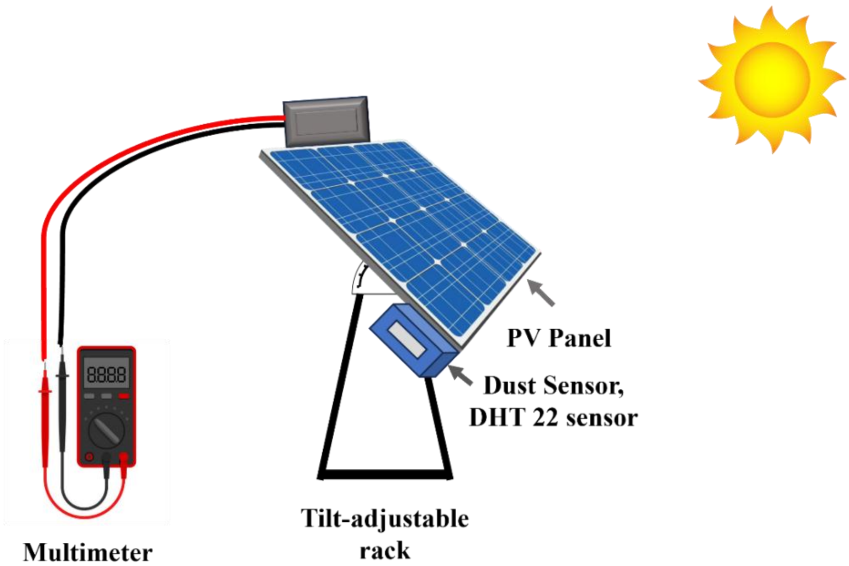

Fig. 3 Experimental setup.

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The positive and negative cables of the solar panel were identified. The multimeter was set to the voltmeter mode, with the DC voltage setting and the appropriate range selected to measure the Voc. The red probe was connected to the voltage terminal, and the black probe to the COM terminal. The voltage was measured by placing the red probe on the positive MC4 connector and the black probe on the negative MC4 connector. To measure the Isc, a DC clamp meter was connected by clamping it around the probe wire connected to the PV panel. The reading on the clamp meter indicated the Isc of the PV panel. The Voc and Isc readings were recorded using the voltmeter and clamp meter, respectively. These values were used to calculate the output power.

Fig.4 Adjustment of tilt angle and Voc - Isc measurement process.

4. RESULTS AND DISCUSSION

The study investigated the effects of dust accumulation on the performance of PV panels at Politeknik Mersing. The performance was assessed by comparing the output power of clean and dusty PV panels at various tilt angles (0°, 10°, 20°, and 30°) during peak sun hours (10:00 am, 11:00 am, 12:00 pm, and 1:00 pm).

4.1 Impact of Dust on PV Performance

Fig. 5 presents the dust accumulation readings from the Sharp GP2Y1010AU0F Dust Sensor over the course of a day, specifically at peak sun hours: 10:00 am, 11:00 am, 12:00 pm, and 1:00 pm. These readings reflect the amount of dust that accumulates on the PV panel surface under typical environmental conditions at Politeknik Mersing.

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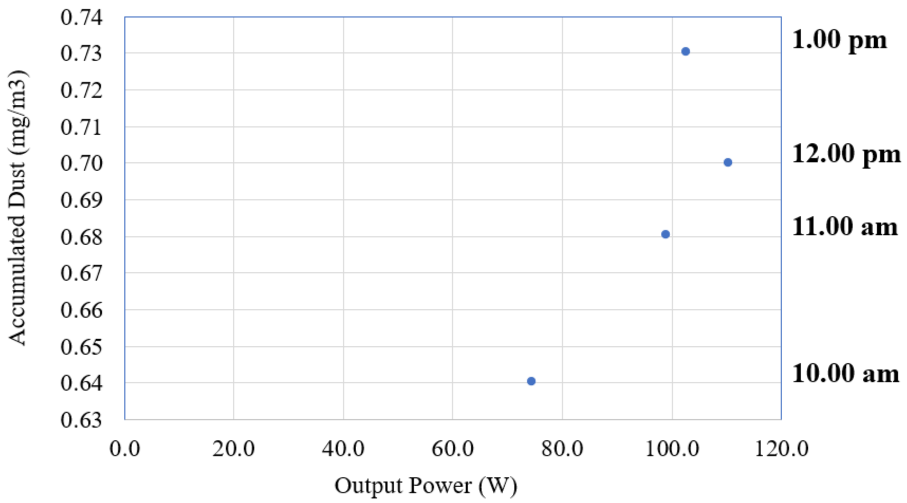
Fig.5 Output power by accumulated dust and peak sun hour at 0° tilt angle.



4.2 Comparison of Clean and Dusty PV Panels

The output power of dusty PV panels was substantially lower than that for cleaned PV panel as the results showed. Solar irradiance is depicted to decrease as a result of accumulation of dust, which in turn resulted into the direct influencing of PV system performance. Overall, under both clean and dusty conditions the average total output power of the PV panels relatively decreased by increasing tilt angle. This trend was consistent for all peak sun hours as shown in Fig. 6.

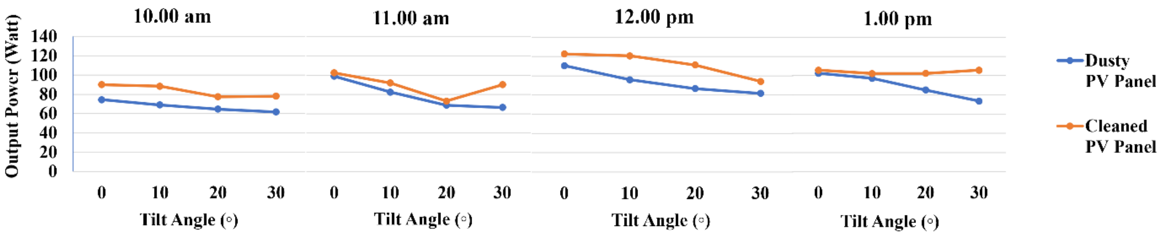


Fig.6 The output power vs. tilt angle for peak sun hours (10.00 am, 11.00 am, 12.00 pm, and 1.00 pm)

Clean PV panels consistently demonstrated higher output power compared to dusty panels across all tilt angles and times [1]. The difference in output power between clean and dusty panels was most pronounced at higher tilt angles and later peak sun hours.

4.3 Impact of Tilt Angle and Peak Sun Hour on Output Power

The maximum output power for both clean and dusty panels was observed at 12:00 pm, while the minimum was recorded at 1:00 pm. At 12:00 pm, the clean PV panel achieved an output power of approximately 130 W at a 0° tilt angle, while the dusty panel reached about 110 W. Additionally, the highest output power was recorded at a tilt angle of 0°, with a gradual decline

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at 10°, 20°, and 30° (Fig. 7). The optimal tilt angle for solar panels in Mersing, Malaysia for year-round tilt angle is around 4 degrees from horizontal and for dry season in June is almost 0º [10]. The tilt angle is crucial in maximizing solar power from PV panel. Inclining solar panels at the optimum angle will increase the total power generation. This value is defined based on the exact geographical coordinates, latitude and longitude of Politeknik Mersing, Malaysia. The tilt angles used in this study were based on the findings of [10], which reference the optimal tilt angle for Johor Bahru. Given the proximity and similar longitudinal positions of Johor Bahru and Mersing, this reference is applicable. The slight difference in latitude is negligible in terms of its effect on solar irradiation patterns.

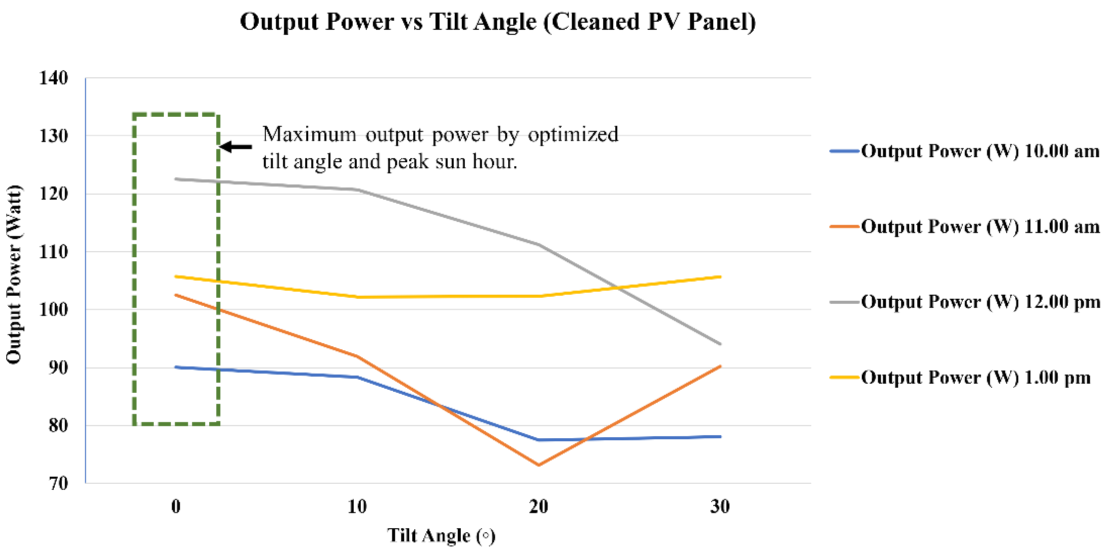

Fig.7 The output power vs. tilt angle for cleaned PV panel (10.00 am, 11.00 am, 12.00 pm, and 1.00 pm)

4.4 Relative Performance and Output Power Reduction Due to Dust Accumulation

Based on the summary in Table 1, the maximum relative performance of 97% was observed at a 0° tilt angle at 1:00 pm, indicating optimal alignment with the sun's rays during peak solar intensity, while the minimum relative performance of 69.6% occurred at a 30° tilt angle at 1:00 pm, suggesting that steeper angles are less effective in capturing solar energy in this geographical location. Dust accumulation significantly impacts the relative performance of PV panels, with clean panels generally showing higher relative performance compared to dusty panels.

Discussion

The data indicates a reduction in relative performance with increased dust density, particularly noticeable at higher tilt angles and later peak sun hours. The maximum reduction in output power due to dust accumulation was 30.4% at a 30° tilt angle at 1:00 pm, highlighting the severe impact of dust combined with suboptimal tilt angles. Conversely, the minimum

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reduction in output power was 3% at a 0° tilt angle at 1:00 pm, showing that even minimal dust can affect performance but to a lesser extent when the panel is optimally angled.

Table 1: Summary of PV panel performance and output power reduction

			Tilt Angle (◦)	**Peak Sun Hour**
Relative Performance (%)	Maximum Value	97	0	1.00 pm
	Minimum Value	69.6	30	1.00 pm
Reduction (%)	Maximum Value	30.4	30	1.00 pm
	Minimum Value	3	0	1.00 pm

5. CONCLUSION

This study demonstrated that dust accumulation significantly reduces the relative efficiency of PV panels at Politeknik Mersing, with clean panels consistently outperforming dusty ones by up to 30%. The highest relative performance of 97% was achieved at a 0° tilt angle during peak sun hours, while the lowest relative performance of 69.6% occurred at a 30° tilt angle. Due to the limitation of not having a pyranometer to measure solar irradiance, relative power efficiency was used to assess PV panel performance under clean and dusty conditions. Furthermore, relative power efficiency decreased further with higher tilt angles. These findings highlight the need for regular cleaning to maintain PV panel efficiency, especially in areas with high dust and humidity. The study confirms that dust is a major factor in reducing solar panel performance and emphasizes the importance of maintenance.

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