

Combined Effect of Dust and Temperature on Solar PV Panel Performance

Laith Abduljabbar Hamdi

Mosul Polytechnic College, Northern Technical University, Iraq

ORCID: 0009-0007-2706-4919

laith.hamdy@ntu.edu.iq

Abstract

The objective of this work is to study the effect of dust and temperature on PV panels. These panels are significantly influenced by environmental conditions, most notably surface dust accumulation and weather temperature. While PV panels require sunlight to generate electricity, the particulate and heat matter that often accompany high-irradiance environments act as primary stressors that degrade power output. Practical measurements have been adopted in this study. The results showed the effect of dust and weather temperature on the electrical parameters of the PV panel. Finally, it has been concluded that the clean PV panel gave a higher amount of power than the dusty one, at the same temperature; also, weather temperature (23°C) gave more power as compared with (27°C) for both clean and dusty panels.

Keywords: PV Panels, P-V Characteristics, I-V Characteristics, Clean Panel, Dusty.

List of Symbols/ Acronyms:

PV: Photovoltaic.

I-V characteristics: Current–Voltage characteristics.

°C: degrees Celsius.

1. Introduction

The market for photovoltaic solar cell modules has expanded quickly in recent decades. Over 85 GW of solar energy was installed worldwide in 2017. An alternative to traditional energy that has garnered a lot of interest globally is solar energy. Devices known as solar photovoltaic PV cells employ semiconductors' photovoltaic effect to transform light electromagnetic radiation's energy into electrical energy. It is considered one of the main answers to the current energy problem because to its renewable, highly efficient, and ecologically friendly characteristics [1]. Typically, photovoltaic power plants are constructed in wide spaces like wastelands and deserts because they need large grounds. Dust can easily cover the PV surface in these locations because the surrounding areas are deserted and the ground surface is generally composed of sandy soil, especially during stormy weather. Therefore, it is crucial to investigate how dust affects photovoltaic systems' operational

characteristics and increase the power generation efficiency of solar systems [2].

The effect of dust on photovoltaic systems has been the subject of numerous studies conducted in various locations across the globe with varying climates. The impact of dust on photovoltaic modules for different kinds of PV modules in Thailand is being studied. Based on the findings, a mathematical model for the local site was developed. Soiling reduces the efficiency of solar PV plants, as evidenced by a study of a PV site in Santa Clara, California that produced power for a year. According to the findings, the panel's dry exposure period had a significant impact on the soiling effects [3]. During the long dry summers, soiling losses are most noticeable. Dust buildup was projected to result in daily reductions in relative solar conversion efficiency of -0.0021. Solar electricity is electricity produced by sunshine, and the photovoltaic process is the process of turning solar light into electricity. Among the world's most promising renewable energy sources is photovoltaic solar power. The ability of PV technology to generate electricity is well-established. In tiny power systems, PV systems can be connected to the grid or run off of it. Direct current (DC) is used in the solar PV process to generate power. The solar cell's output is directly proportional to the intensity of the sun [4]. The Standard Test Conditions (STC) that manufacturers use to rate PV output are: temperature = 25°C; solar irradiance (intensity) = 1000 W/m²; and the solar spectrum as filtered by passing through 1.5 layers of atmosphere. A factory may easily replicate these circumstances, but the external environment presents a distinct challenge. Given the growing popularity of PV systems, it is critical to understand how active meteorological factors, including dust, solar radiation, air humidity, wind speed, air temperature, and surface temperature of PV panels, affect their efficiency [5]. As of the time this article was conducted, there was no research on the impact of dust on PV system output in Iraq in the literature. Therefore, the purpose of this study is to look at how dust affects the energy output of solar PV systems installed in the particular area of Surabaya, East Java, Indonesia. As was already established, the local area where the PV system is situated determines how much of an impact the dust has [6]. Because Iraq is located in south-western Asia, close to the equator, between longitudes 38°45' and 48°45' E and latitudes 29°5' and 37°22' N, Surabaya experiences just two distinct seasons throughout the year: the dry season and the rainy season. While October through July is typically the rainy season, July through October is typically the dry season [7]. Temperatures range from 10 to 45 degrees Celsius per year, while wind speeds range from 5 to 19 kilometres per hour. The PV system under test in this study was mounted on a house's roof, and it was surrounded by no buildings or other higher structures that could provide shade for the panels. The impact of cleaning modules is evaluated based on how dust affects PV modules each season. Larger-scale PV application development in Indonesia is anticipated to benefit from the findings and data from this study [8].

2. Contribution

Studying the specific effects of dust and temperature on the voltage and current of PV panels has provided the blueprint for modern solar systems; while both reduce the total amount of power they do so in different ways:

- Dust acts as a physical filter: Studies show that dust buildup reduces the optical transmittance of the glass. Because current is directly proportional to the number of photons hitting the cell, the layer of dust doesn't just block light; it acts as an insulating blanket. This prevents the panel from shedding heat via convection, thereby raising the cell temperature.
- Weather temperature affects the power and current of PV panels. While sunlight provides the energy, temperature acts as the "governor" that controls how much of that energy actually becomes electricity.

3. Literature Review

In 2017, Hussein Kazem, Miqdam Tariq, Ali Al-Waeli, and Kavish Mani investigated how dust buildup affected a photovoltaic panel, resulting in a warming of the panel's cells. In addition to the impact of shadows on solar PV performance, this tendency resulted in a notable drop in output power and the creation of hotspots [9].

Amer Aldawoud, Abdelsalam Aldawoud, Yashar Aryanfar, Mamdouh El Haj Assad, Shubham Sharma, and Reza Alayi (2022) discovered that PV panels are impacted by condensation and soiling in arid regions with a high frequency of dust; power production has been reduced. They developed a new method to lessen the effect of soiling accumulation on the performance of PV panels, and the damage was successfully reduced by this technique. They reduced the PV soiling and condensation using a hydrophobic coating with a brush and controllable curtains [10].

According to a 2021 study by Engy Elshazly, Ahmed Abd El-Rehim, Amr Abdel Kader, and Iman El-Mahallawi, environmental factors had a significant impact on solar PV panel efficiency. According to the findings, the power decrease was 27% up to an angle of 30 degrees. It has been determined that the PV performance was significantly impacted by the elevated panel temperature and dust [11].

4. Materials and Methods

The steps involved in this work are illustrated by the following.

4.1 Photovoltaic Cell:

The PV cell, commonly known as a solar cell, is the fundamental component of a photovoltaic system. Direct electrical current (DC) can be produced from sunlight using this semiconductor device. Figure 1 shows the solar cell unit. Sunlight can be absorbed, reflected, or passed via a photovoltaic (PV) or solar cell [12].



Fig. (1): PV cell

4.2 Efficiency of the Solar Cell:

The electrical output of a solar cell divided by the incident energy from sunlight is known as solar cell efficiency. The proportion of solar radiation that a solar cell is exposed to that is transformed into electrical energy is known as its energy conversion efficiency (η). Efficiency is determined by dividing the power output (in watts) of the cell at its maximum power point (P_m) by the surface area (A_c in m^2) of the solar cell and the incoming light (E in W/m^2) [13].

$$\eta = \frac{P_m}{E \cdot A} \quad (1)$$

Where P_m is the power point of maximum, E is the input light, A is the solar cell's surface area, and η is the energy conversion efficiency.

4.3. Fill Factor (FF):

The fill factor basically serves as a gauge for solar cell quality. The computation involves contrasting the maximal power with the theoretical power (P_T) generated at both the open circuit voltage and the short-circuit current, where [14]:

$$FF = \frac{I_{mp} \cdot V_{mp}}{I_{sc} \cdot V_{oc}} = \frac{I_{mp} \cdot V_{mp}}{I_{sc} \cdot V_o} = \frac{P_m}{P_T} \quad (2)$$

4.4. Dust and Light Absorbance:

Dust buildup on the glass cover attenuates light transmission, which is the reason why solar cell power is decreasing. Dust accumulation is a relatively basic process that starts with a simple buildup of

layers covering the whole surface. It is then covered with a second layer, and so on [15]. Assuming that the dust particles are spherical and primarily made of SiO₂, the scattered light efficiency was calculated using the silicon oxide's refractive index as a function of wavelength. This phenomenon, which is controlled by Extinction efficiency, is the ratio of particle size to incident light wavelength. When illuminated, their particles will scatter and absorb light, reducing the beam's intensity [16]. Combining the effects of absorption and scattering can yield the particle extinction efficiency. A computational process for finding the scattering and absorption of light as a function of wavelength can be based on Mie theory. This effect has been shown in earlier research, which demonstrates that while small particles are dependent on the wavelength of light, larger particles produce more. However, because of computational constraints, we did not account for internal particle scattering [17].

4.5. Dust Characterization:

The region's desert dust makes up a significant portion of the naturally occurring particles, which are primarily made up of feldspars, gypsum, chart, and mica, with quartz being the predominant constituent. The efficiency of solar cells can be affected by the ability of these particles, which have sizes up to several microns, to scatter and absorb both solar and terrestrial radiation. Further details on the grain size distribution were obtained by analyzing a sample of dust from a solar cell panel using an Olympus CX211 microscope and the image J analyzer program. Different-sized and shaped particles. Furthermore, particles in the same image overlap, making particle analysis more challenging. The clean panel and dirty panel figures are displayed [18].

4.6. Dust Effect on Solar Panel:

Dust is made up of microscopic solid particles that are transported by air currents. The process of disintegration, which involves breaking down objects into tiny fragments by impact, crushing, grinding, and other means, is what creates these particles. According to the Mine Safety and Health Administration (MSHA), dust is defined as finely split materials that have the potential to break apart and become airborne without undergoing any physical or chemical changes [19]. Typically, dust is measured in micrometers. The solar panel naturally has dust on it. With each passing day, the dust coating on the solar panel gets thicker. Additionally, it serves as a shield between the sun and the solar panel. The two main ways that dust impacts the solar panels are as follows. The solar photovoltaic panels are first obscured from the sun's beams by dust that falls straight on them. Dust may cover the tracking sensor, making it impossible for the panels to track the direction of the sun. The amount of dust on the solar panel affects the short-circuit current and power values [20].

4.7. Temperature Effect on Solar Panel:

PV panels, like other panels, are usually made of silicon semiconductor material; their performance is influenced by a number of environmental factors. For example, the temperature of the panel's surface is dependent on the ambient temperature. Furthermore, the I_{sc} of the PV panel witnessed a

very slight incremental increase when its surface temperature rises for c-Si PV panels, which lose their V_{oc} at a rate of $-0.45\%/K$. As the temperature of the PV panel increases, its V_{oc} , I_{sc} , and FF decrease. Comparably, the PV panel's power output and fill factor decline at a rate of $-0.65\%/K$ and $-0.2\%/K$, respectively, in response to a rise in panel surface temperature. An attempt was made to comprehend how surface temperature affects PV panel performance in this paper [21].

5. Experimental Methods

The purpose of the experimental setup was to examine the effects of dust on the effectiveness and output power of PV panels while they are operating. The experiment used two 180W monocrystalline solar modules to measure the open-circuit voltage (V_{oc}) and short-circuit current (I_{sc}) of the two monocrystalline solar panels. To determine the amount of dust on the solar panel, one of the PVs was set up and left outside for a month [14]. The studies were carried out over three days from 8:00 am to 5:00 pm using a Lurton DM-9080 digital multimeter to measure the output voltage and current. Global sun irradiance was measured using a pyranometer. The dust accumulation in this study was represented by natural dust. The basic idea of the dust impact is not a difficult subject to study. Table 1 provides the PV panel specifications [22]; Figure 2, illustrates two panels: a clean one on the left and a dust-covered one on the right.

Table (1): Electrical characteristics of module

ADRC Output (W)	SSO Output (W)
power of maximum (PM)	180W
Maximum power voltage (V_{mp})	36.663V
Maximum power current (I_{mp})	4.370A
Voltage in the open circuit (V_{oc})	44.322V
Current in a short circuit (I_{sc})	4.677A
Maximum system operating voltage (V)	1000V
Rating for fuse series	15A
Cell technology	mono-Si
Application class	class A
Standard test condition (ste)	25°C, 1.5Am, 1000W/M ²



Fig. (2): Solar PV panels. a. Clear panel. b. Dusty panel

6. Results and Discussion

From the practical readings of electrical coefficients for both clean and dusty PV Panels. A comparison of experimental data has been taken of clean versus dusty PV Panels. Tables 1 and 2 illustrate the electrical coefficient readings at different irradiances with respect to time for a clean and dusty panel, respectively in 10/March/2025.

Table (2): Practical readings for clean PV panel (23°C)

Case	Day&Temp.	Irradiance (W/m ²)	Efficiency (%)	Power (W)	Current (A)	Voltage (V)	Time (s)
Clean	10/3/2025 Temp. 23oC	9	400	7.2	96.88	5.6	17.3
		9:30	440	7.9	97.44	5.6	17.4
		10:00	570	10.26	98	5.6	17.5
		10:30	620	11.16	98.2	5.6	17.6
		11:00	730	13.14	97.9	5.5	17.8
		11:30	800	14.40	83.7	4.7	17.81
		12:00	900	16.2	81.9	4.6	17.82
		12:30	870	15.66	81.6	4.58	17.83
		1:00	860	15.48	81.3	4.56	17.84
		1:30	810	14.58	81.08	4.54	17.86
		2:00	740	13.32	80.8	4.52	17.88
		4:00	700	12.6	80.55	4.5	17.9

Table (3): Practical readings for dusty PV panel (23°C)

case	Day &Temp.	Irradiance (W/m ²)	Efficiency (%)	Power (W)	Current (A)	Voltage (V)	Time (s)
Dusty	10/3/2025 Temp. 23°C	400	6.21	75.5	4.99	15.1	9
		440	7.2	76	4.985	15.2	9:30
		570	9.49	77	4.984	15.4	10:00
		620	10.27	78	4.983	15.6	10:30
		730	12.33	78.8	4.981	15.8	11:00
		800	13.19	79.1	4.977	15.9	11:30
		900	15	79.5	4.97	16	12:00
		870	14.53	80.3	4.96	16.2	12:30
		860	13.81	82.17	4.95	16.6	1:00
		810	13.42	95.8	4.94	19.4	1:30
		740	11.52	91.08	4.6	19.8	2:00
		700	11.07	82	4.1	20	4:00

The same procedures have been taken but at temperature 27 as shown in table 4 and 5.

Table (4): Practical readings for clean PV panel (27°C).

Case	Day &Temp.	Irradiance (W/m ²)	Efficiency (%)	Power (W)	Current (A)	Voltage (V)	Time (s)
Clean	15/3/2025 Temp. 27°C	400	6.63	67.2	4.2	16	9
		440	7.3	68.04	4.2	16.2	9:30
		570	9.5	68.88	4.2	16.4	10:00
		620	10.34	70.14	4.2	16.7	10:30
		730	11.63	73.74	4.19	17.6	11:00
		800	12.72	76.07	4.18	18.2	11:30
		900	14.85	78.39	4.17	18.8	12:00
		870	14.83	78.87	4.16	19.2	12:30
		860	13.63	80.09	4.15	19.3	1:00
		810	13.78	80.31	4.13	19.4	1:30
		740	13.6	80.94	4.12	19.6	2:00
		700	13.4	69.3	3.5	19.8	3:00

Table (5): Practical readings for dusty PV panel (27°C)

Case	Day &Temp.	Irradiance (W/m ²)	Efficiency (%)	Power (W)	Current (A)	Voltage (V)	Time (s)
Dusty	15/3/2025 Temp. 27°C	400	7.91	68.8	4.2	16	9
		440	8.2	69.66	4.2	16.2	9:30
		570	10.5	71.38	4.2	16.6	10:00
		620	11.57	72.24	4.2	16.8	10:30
		730	13.68	73.1	4.19	17	11:00
		800	14.8	74.37	4.18	17.5	11:30
		900	16.44	75.32	4.17	17.6	12:00
		870	15.92	75.97	4.16	17.7	12:30
		860	15.49	75.82	4.15	17.8	1:00
		810	14.9	76.07	4.13	17.9	1:30
		740	13.7	76.14	4.12	18	2:00
		700	12.99	65.16	3.5	18.1	3:00

From the above tables, when the working temperature of a PV panel exceeds 25°C (the standard test condition), a dusty surface creates a compounding negative effect on performance; while heat naturally reduces the voltage of solar.

Cell, the presence of dust adds an optical barrier that slashes the current, leading to a much steeper decline in overall efficiency than heat alone would cause.

Figure 3, represents the relationship between voltage and power of PV panel under condition (temperature 23°C without dust).

From figure 3, the maximum value of power has been obtained at irradiance (620W/m²) instead of (900W/m²) because the temperature 23°C is lower than the standard test conditions (1000W/m² and 25°C).

Figure 4, represents the relationship between voltage and current of PV panel under temperature 23°C without dust.

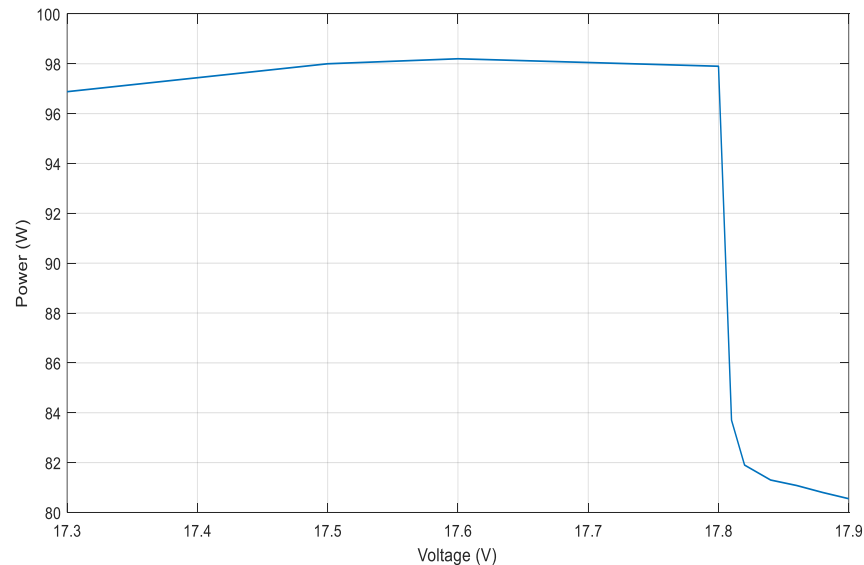


Fig. (3): Solar PV panel voltage versus power (clean case)

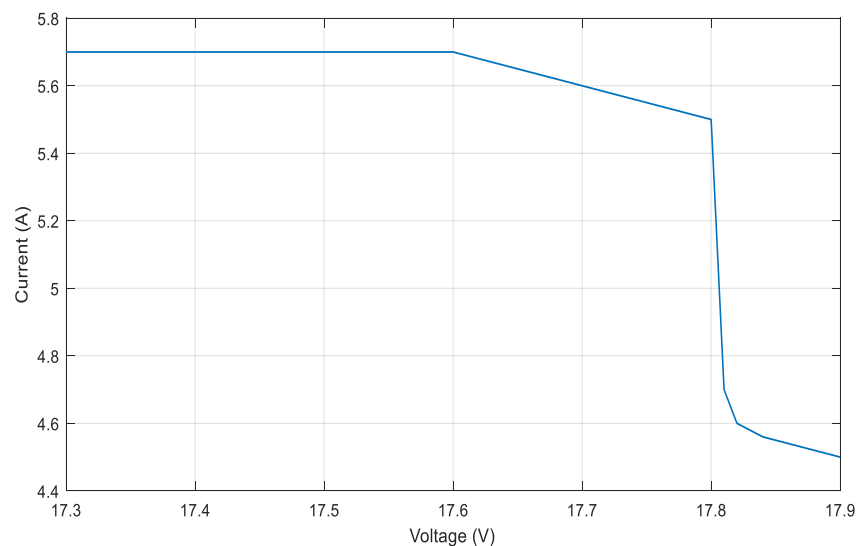


Fig. (4): Voltage vs current of solar PV panel (clean case)

From above figure the peak value of PV current remains constant (5.6A) until irradiance (620W/m²) after that reduced in spite of increasing the irradiance value because the temperature less than 25°C and the solar panel is rather cold.

Figure 5, represents the relationship between voltage and power of PV panel under condition (temperature 27°C without dust).

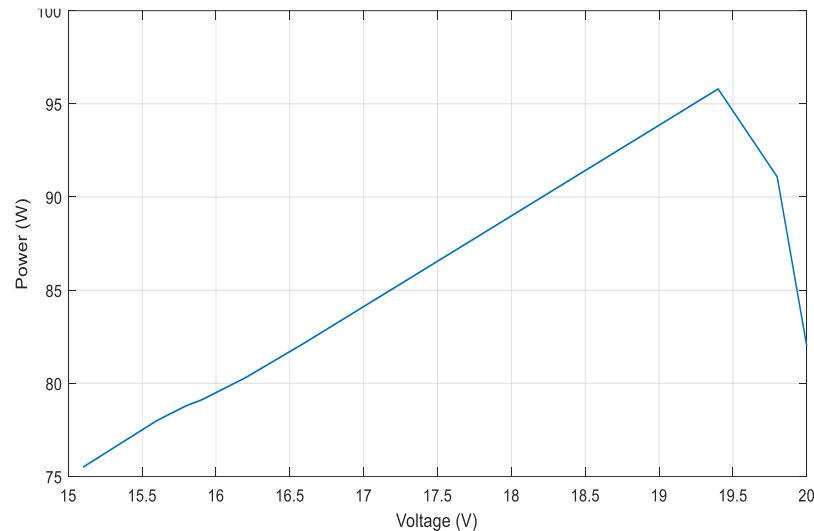


Fig. (5): Voltage vs power of solar PV panel (clean case)

From above figure the maximum value of power has been obtained at irradiance (810W/m^2) instead of (1000W/m^2) at constant temperature 27°C .

Figure 6, represents the relationship between voltage and current of solar PV panel under temperature 27°C without dust.

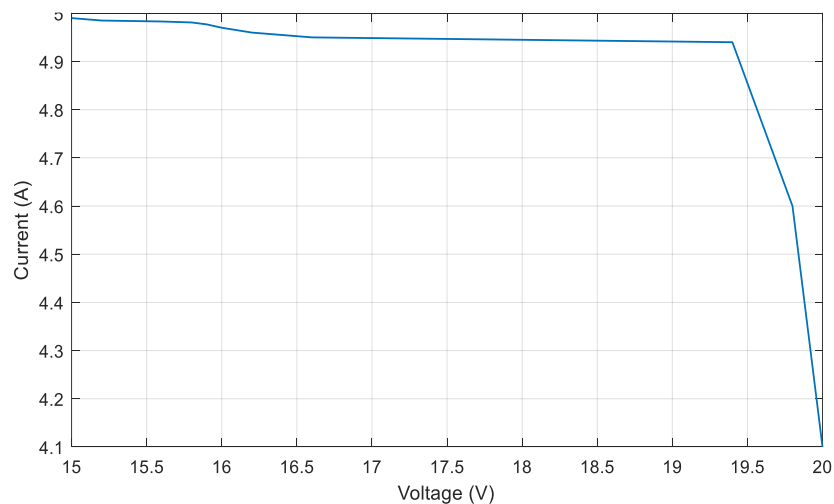


Fig. (6): Voltage vs current of solar PV panel (clean case)

From above figure the peak value of PV current remain approximately constant until irradiance (810W/m^2) after that has been reduced gradually.

Figure 7, represents the relationship between voltage and power of PV panel under condition (PV panel completely covered in dust and temperature 23°C).

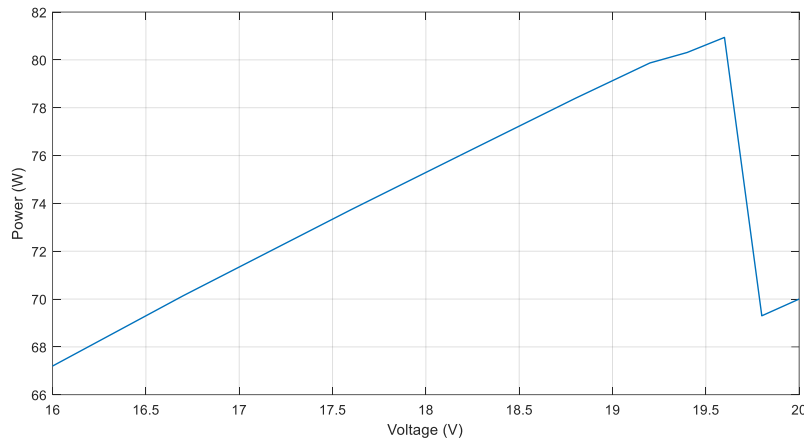


Fig. (7): Voltage vs power of solar PV panel (dusty case)

From above figure the maximum value of power has been obtained at irradiance (740W/m^2) but the temperature remains with standard test conditions 23°C .

Figure 8, represents the relationship between voltage and current of solar PV panel under (PV panel completely covered in dust and temperature 23°C).

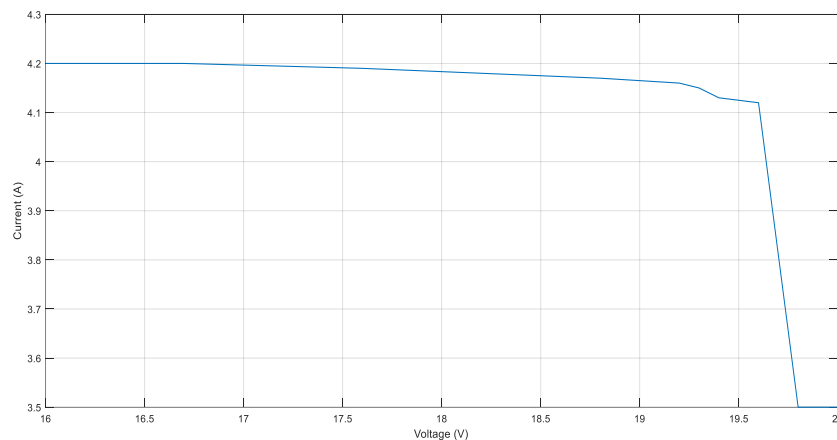


Figure (8): Voltage vs current of solar PV panel (dusty case)

From above figure the peak value of PV current remains constant until irradiance (620W/m^2) after that reduce in spite of increasing the irradiance value where the voltage increases the current reduces in order to give the expected power generation capacity.

Figure 9, represents the relationship between voltage and power of PV panel under condition (completely clean solar PV panel and temperature 27°C).

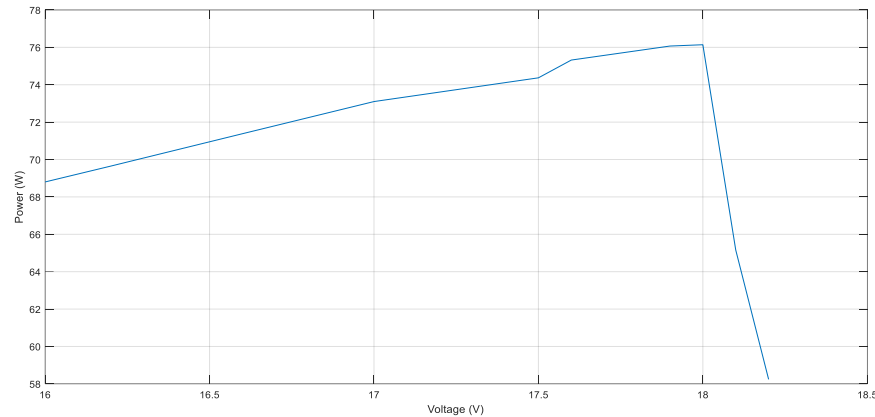


Fig. (9): Voltage vs power of solar PV panel (dusty case)

From above figure the maximum value of power has been obtained at irradiance (740W/m^2) but the temperature remains with standard test conditions 27°C .

Figure 10, represents the relationship between voltage and current of solar PV panel under (PV panel completely covered in dust and temperature 27°C).

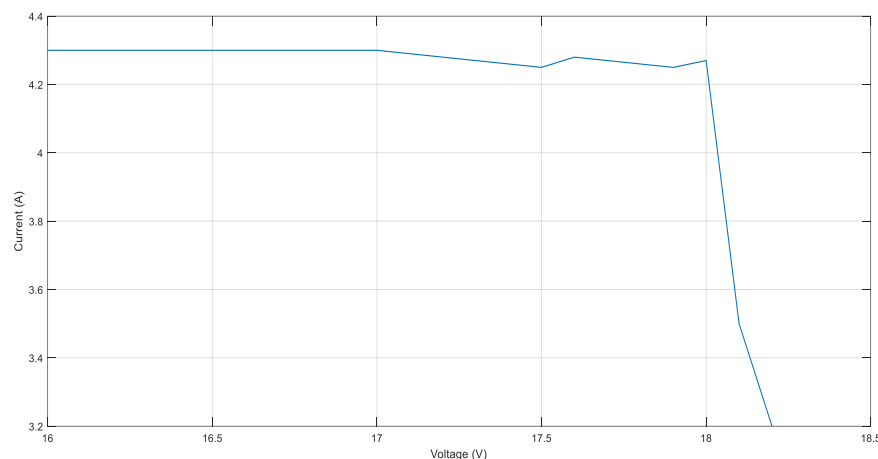


Fig. (10): Voltage vs current of solar PV panel

From above figure the peak value of PV current remains constant until irradiance (620W/m^2) after that reduce in spite of increasing the irradiance value in order to simulate the behavior of current – voltage characteristics.

Figure 11, illustrates the digital contact thermometer (Model number LYWSD03MMC) designed for precise surface measurements, it is used to measure the rear back sheet temperature of a solar panel to approximate the actual silicon cell temperature, which is essential for calculating efficiency losses due to heat and dust.

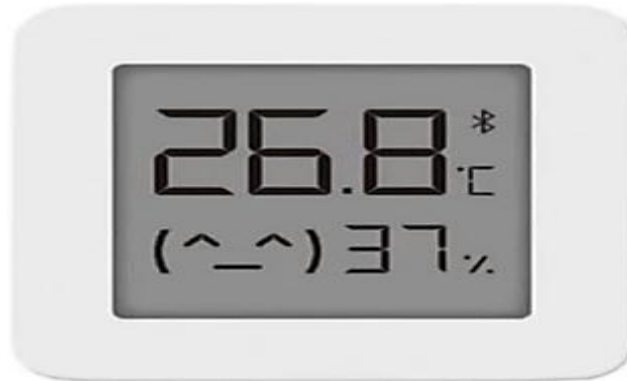


Fig. (11): Digital contact sensor

At 15:00, as shown in Figure 12, the average surface temperatures of clean and dusty PV panels are 37.2°C and 36.2°C, respectively, indicating a difference of 1.0°C. The presence of dust reduces the cooling effect on the PV panel, leading to an increased surface temperature and consequently lowering the power generation efficiency.

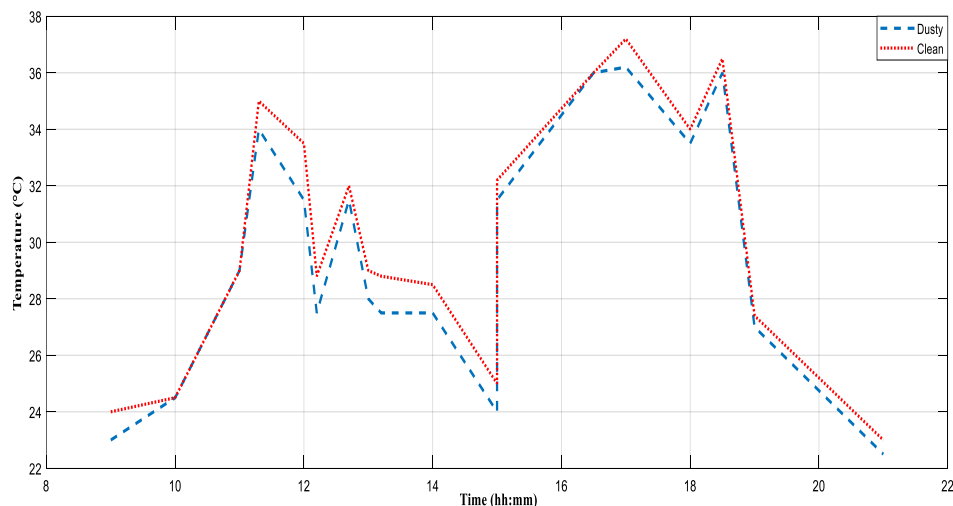


Figure (12): Effect of dust on PV surface temperature

From above figure 12, when the temperature has been increased for PV panel covered by dust as compared with clean panel at same time.

7. Conclusions

1. At temperature 23°C, clean panel gave the highest difference with an amount of power equivalent to 20.2 higher than the dusty one at irradiance 620W/m², also the efficiency has been increased by 0.89%.
2. At temperature 27°C, clean panel gave the highest difference with an amount of power equivalent to 4.8 higher than dusty one at irradiance 740W/ m², also the efficiency has been increased by 3.1%.
3. From table 1 vs 3, clean panel at temperature 23°C gave the highest difference with an amount of power equivalent to 5.31 as compared with the same panel but at temperature 27°C. That means when the temperature increases above 25°C the PV panel power decreases (taking into consideration the irradiance equal to 800 W/m² in this case).
4. From table 2 & 4, dusty panel at temperature 23°C gave the highest difference with an amount of power equivalent to 19.74 as compared with same panel but temperature 27°C (taking into consideration the irradiance equal to 810 W/m² in this case).

References

1. Chen Y, Liu Y, Tian Z, Dong Y, Zhou Y, Chen X, Wang D. Experimental study on the effect of dust deposition on photovoltaic panels. Energy Procedia.2019;159:483489.doi:10.1016/j.egypro .2019.01.139.
2. Hasan M, Ahmed J. Effect of dust on output power of conventional solar panels in Bangladesh. Asian Journal of Convergence in Technology. 2015. Available from: <https://scispace.com/pdf/effect-of-dust-on-output-power-of-conventional-solar-panels-45e68c047r.pdf>.
3. Kazem HA, Chaichan MT, Al-Waeli AHA, Sopian K, Darwish ASK. Evaluation of dust elements on photovoltaic module performance: An experimental study. Renewable Energy and Environmental Sustainability. 2021; 6:30. doi:10.1051/rees/2021027.
4. Safwan AA, Hamoodi AN, Mohammed RAN. Design and simulation of smart grid based on solar photovoltaic and wind turbine plants. J Eur Syst Autom. 2024; 57(4):953-961. Doi:10.18280/jesa.570403.
5. Saidan M, Abdul Ghani AA, Emil A, John K. Experimental study on the effect of dust deposition on solar photovoltaic panels in desert environment. Renew Energy. 2016; 92: 499-505. doi:10.1016/j.renene.2016.02.031.
6. Tarigan E. The effect of dust on solar PV system energy output under urban climate of Surabaya. In: Journal of Physics: Conference Series.2019; 1373(1):012025.doi:10.1088/1742-6596/1373/1/012025.

7. Adnan S, Ehab A. Impact of dust and shade on solar panel efficiency and development of a simple method for measuring the impact of dust. J Sustain Dev Energy Water Environ Syst. 2023; 11:1-14. Doi:10.13044/j.sdewes.d11. 0448.
8. Ali N, Rasha A, Safwan A. Automatic speed control of DC series motor by using Arduino. Prz Elektrotech. 2023; 99(3):137-141. doi:10.15199/48.2023.03.24.
9. Hussein KH, Chaichan MT, Al-Waeli AH, Mani K. Effect of shadows on the performance of solar photovoltaic. In: Mediterranean Green Buildings and Renewable Energy: Selected Papers from the World Renewable Energy Network's Med Green Forum. Cham: Springer; 2017. doi:10.1007/978-3-319-30746-6_27.
10. Amer A, Abdelsalam A, Yashar A, Mamdouh E, Shubham S. Reducing PV soiling and condensation using hydrophobic coating with brush and controllable curtains. Int J Low Carbon Technol. 2022; 17:919-930.doi:10.1093 /ijlct/ctac056.
11. Jaszczur M, Hassan Q, Teneta J, Styszko K, Nęcka W, Hanus R. Study of dust deposition and temperature impact on solar photovoltaic module. MATEC Web Conf. 2018; 240:04005. doi:10.1051/mateconf/20182400405
12. Elshazly E, Ahmed A, Abdel-Rehim A, El-Mahallawi I. Effect of dust and high temperature on photovoltaics performance in the new capital area. WSEAS Trans Environ Dev.2021;17:345-356. Doi:10.37394/232015. 2021.17.36.
13. Muhammad S, Tanimun Y, Abdulmumin M. Effect of dust accumulation on the performance efficiency of photovoltaic module. Int J Adv Eng Manag. 2022;4:957-964.doi:10.35629/5252 - 0402957964.
14. Shi Y, Fathi M, Girard A. Impact of dust and temperature on photovoltaic panel performance: A model-based approach to determine optimal cleaning frequency. Heliyon. 2024;10:e35390. doi:10.1016/j.heliyon.2024.e35390.
15. Safwan A, Ali N, Bashar M, Muna H. Performance evaluation of grid-connected solar PV system: Case study under the effect of irradiance and temperature. J Eur Syst Autom. 2025;58(8):900-912. doi:10.18280/jesa.580811.
16. Hammad B, Al-Abed M, Al-Ghandoor A. Modeling and analysis of dust and temperature effects on photovoltaic systems' performance and optimal cleaning frequency: Jordan case study. Renew Sustain Energy Rev.2018; 82:2218 -2234. doi:10.1016/j.rser.2017.08.070.
17. Skoplaki E, Palyvos JA. On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations. Sol Energy. 2009; 83(5):614-624. doi:10.1016/j.solener.2008.10.008.

-
18. Bashar M, Safwan A, Ali N. Enhancing the behavior of small-scale wind turbine based on fuzzy logic system. J Eur Syst Autom. 2024; 57 (1):147-153. doi:10.18280/jesa.570115.
 19. Ahmed H, Ahmed M, Abdel-Gaied S. Effect of dust and ambient temperature on PV panels performance in Egypt. Jordan J Phys. 2015; 8: 113-124.
 20. Ali N, Safwan A, Rasha A. Partial discharge calibrator of a cavity inside high-voltage insulator. Open Eng. 2022 ;12: 468- 476. Doi:10. 1515/eng-2022-0048.
 21. Ali A, Miqdam T, Hussein A. Dust effect on photovoltaic utilization in Iraq: Review article. Renew Sustain Energy Rev. 2014; 37:734-749. doi:10.1016/j.rser.2014.05.073.
 22. Bashar M, Khaleel N, Safwan A. Enhancing the maximum power of wind turbine using artificial neural network. Bull Electr Eng Inform. 2023;12(5):2535-2542.