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RENEWABLE ENERGY SOURCES

Mitigation of Dust Impact on Solar Photovoltaics Performance Considering Libyan Climate Zone: A Review

Abdulgader H. Alsharif [1,*], Abdussalam A. Ahmed [2], Yasser F. Nassar [3], Mohamed M. Khaleel [4], Hala J. El-Khozondar [5], Taha E. Alhoudier [1], Esmail M. Esmail [1]

[1] Electrical and Electronic Engineering Department, Faculty of Technical Sciences-Sebha, Sebha, Libya
[2] Mechanical Engineering Department, Bani Waleed University, Bani Waleed, Libya
[3] Mechanical & Renewable energy. Engineering Department., Wadi Alshatti University, Brack-Libya
[4] Research and Development Department, College of Civil Aviation, Misrata, Libya
[5] Electrical Engineering Department, Islamic University of Gaza, Gaza, Palestine

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ABSTRACT

The effects of dust aerosols on solar panels and people can occasionally extend thousands of kilometres across the atmosphere. The research aims to present the evaluation methods on the impact of dust accumulation on the performance of solar panels in the Libyan climate zone. The study conducted a series of experiments to measure the degradation of solar panel efficiency due to the deposition of dust on the surface of the solar panels. The presented results indicate that the accumulation of dust has a significant negative impact on the performance of solar panels, reducing their efficiency. Furthermore, the study listed the frequency and cleaning methods required to maintain the solar panels' performance over time in this harsh climate. The findings highlight the importance of routine cleaning and maintenance of solar panel installations in dusty and arid regions to ensure optimal performance and maximize energy efficiency.

مراجعة في طرق تخفيف تأثير الغبار على أداء الخلايا الشمسية الكهروضوئية باعتبار ظروف المناخ الليبي

عبد القادر الشريف [1,*]، عبدالسلام أحمد [2]، ياسر نصار [3]، محمد خليل [4]، هالة الخزندار [5]، طه الحضيري [1]، اسماعيل اسماعيل [1]

الكلمات المفتاحية:
ليبيا
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تأثير الغبار
طرق التنظيف
الكفاءة

الملخص

تمتد تأثيرات الغبار على الألواح الشمسية والناس لآلاف الكيلومترات عبر الغلاف الجوي. يهدف البحث إلى عرض طرق تقييم تأثير تراكم الغبار على أداء الألواح الشمسية في ليبيا. أجرت الدراسة سلسلة من التجارب لقياس انخفاض كفاءة الألواح الشمسية نتيجة ترسب الغبار على سطح الألواح الشمسية. تشير النتائج المتحصل عليها إلى أن تراكم الغبار يقلل من كفاءة الواح الخلايا الشمسية. علاوة على ذلك، قدمت الدراسة عرضا لطرق التنظيف المتبعة للحفاظ على أداء الألواح الشمسية في المناخ الصحراوي. تسلط النتائج الضوء على أهمية التنظيف والصيانة الروتينية لمنظومات الألواح الشمسية في المناطق ذات العواصف الترابية لضمان الأداء الأمثل وتحقيق أقصى قدر من كفاءة الطاقة.

Introduction

Electrical power generation systems based on fired fossil fuels cause harm to the ecosystem and are considered the main cause of global warming and climate change. In Libya, the electricity generation sector is considered one of the most polluted sectors among all other sectors, as the CO2 emissions from the chimneys of electric power plants is about 34% of the country's total CO2 emissions. [1]. Since Libya is one of the countries that ratified the Paris Agreement on Climate Change, therefore, it had to bear its responsibilities and contribute with the international community in reducing the rate of greenhouse gas emissions. Accordingly, the Libyan government launched the Renewable Energy Strategic Plan for the upcoming 30 years, which aims to achieve a contribution of renewable energy to the electric energy mix of 25% by 2025 and 30% by 2030. By 2050, this will come mainly from Concentrated Solar Power, solar PV and solar heating systems [2].

Libyan climate zone is known to have high levels of dust events [1], which can have a significant impact on the performance of solar systems such as, photovoltaic (PV) systems [3] and concentrated solar power [4]. The accumulation of dust on the surface of solar panels can cause a reduction in their efficiency [5], ultimately leading to a decrease in power output estimated at about 7% [6]. Figure 1 is a sankey diagram that illustrates the percentage of energy losses in PV solar systems according to several studies [7-10]. Dust, which can be characterized as tiny particles with a diameter of 500 µm or less, affects several applications of solar panels, including traffic lights, street lighting, and home energy assistance [11]. The amount of dust that accumulates on the solar panels must be first measured in order to assess the effect that dust disposition has on them [12]. One of the most popular forms of renewable energy is solar power, which is produced by solar panels, which harness sunlight to produce electricity [13]. Many governments throughout the world are promoting the use of solar panels in place of non-renewable sources of energy like coal and petroleum [14].

*Corresponding author: alsharif@ctss.edu.ly

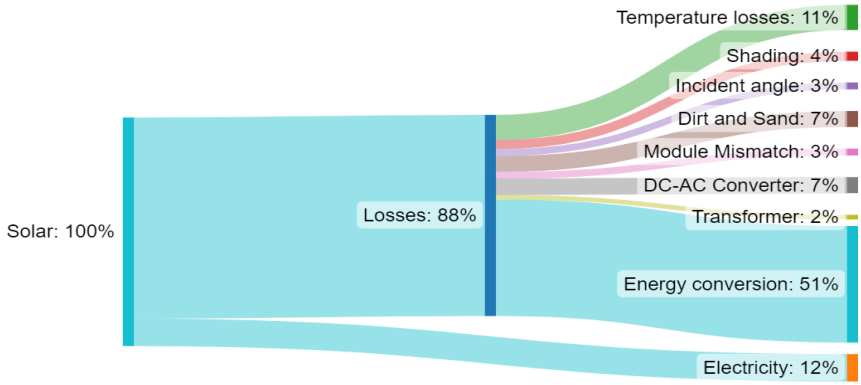

Figure 1: Breakdown the energy losses in PV solar

Solar panels still face significant difficulties that prevent them from reaching their full potential, despite the fact that their low environmental effect is a major incentive for increased use [15]. Dust buildup on the solar panel is considered one of these challenges. Dust creates a layer on the solar panels causing the same effect as shading [16, 17]. Consequently, it prevents sunlight from entering the cell and being converted into electrical energy [11]. The Middle East and North Africa, which are arid regions, have some of the highest levels of dust in the world. Curiously, these places also receive the greatest solar energy [18].

The main contribution of the article is by providing a general view of dust impacts on solar photovoltaics along with the limitations of the dust and the future perspective of the aforementioned problem. the remainder of the paper is structured as follows: Section 2 consists of the general background of the dust impacts on the solar panels and the environment. The case study region details are placed in Section 3 along with dust mitigation methods. The disadvantages of dust on the solar panels are positioned in Section 4. Eventually, a summary of the conclusion and a list of recent references end the article.

Background history on dust impacts

The dust impacts have taken the place of scholars as one of the faced challenges that reduce the productivity of solar photovoltaics. Based on numerous climatology changes in various regions, solar panels were affected [11]. The most common renewable energy source (RES) that has some issues dependent on the site's radiation that affects the power outcome is solar energy. Besides, various studies on calculating the amount of dust in photovoltaic and thermal systems [12]. Additionally, the main consideration of this article is met along with cited studies in order to measure the impacts on solar panels and present solutions [19].

Libyan geography zone

Libya is located in the North African region as figured out in Figure 2, and it is a part of the northern hemisphere with 25° N and 17° E latitude and longitude affected by dust and some storms.

Figure 2: Libyan geographical map.
[Source: https://www.turkey-visit.com/libya-map.asp]

Methodology

The presence of dust in the air can negatively impact air quality by increasing levels of particulate matter, which can have adverse effects on respiratory health and reduce visibility [20]. If you are concerned about air quality in a specific location, it is recommended to check with local air quality monitoring agencies or authorities for more information. There are several methods for mitigating the impact of dust on PV performance as formulated in Table 1. Various software and tools can be used to track and mitigate the dust on the solar panels, one of them is MATLAB as presented in Figure 2.

Dust accumulation on solar Photovoltaic (PV) panels can significantly reduce their performance and efficiency [23]. Dust can have an insulating effect, reducing the amount of sunlight that reaches the solar cells and decreasing the amount of electricity produced [24].

Table 1: Mitigation Methods for dust impacts on the solar panels [11, 21].

Mitigation Methods	Remarks
Regular cleaning	By regularly cleaning the surface of solar panels, the accumulation of dust can be reduced.
Tilted panels	Tilting the panels at a certain angle can help dust slide off the surface, reducing its accumulation.
Anti-reflective coatings	The use of an anti-reflective coating can reduce the accumulation of dust on the surface of solar panels.
Dust-resistant materials	Choosing dust-resistant solar panel materials can reduce the accumulation of dust on the surface.

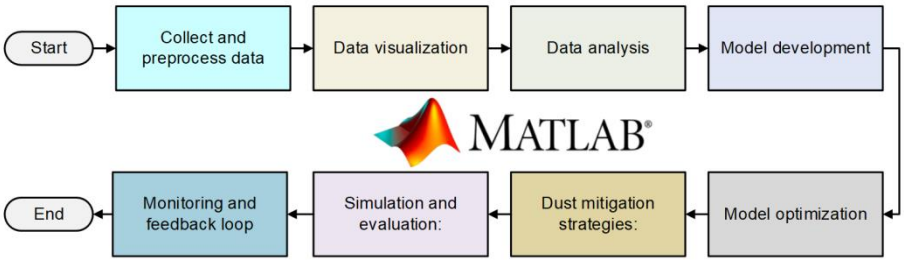

Figure 3: Dust mitigation steps using MATLAB.

Table 2: Monthly solar, wind, and temperature data analysis [22].

Months	Solar Irradiance (W/m^2)	Wind Speed (m/s)	Temperature (°C)
January	322	11.7	23
February	387	15.4	25.8
March	438	14.4	34
April	624	14.9	34
May	503	12.9	41
June	473	14.4	44.5
July	451	12.9	45.6
August	496	10.3	40.6
September	504	11.3	42.4
October	400	12.9	44
November	339	20.5	34
December	322	11.3	24

In areas with high levels of dust or pollution, the impact can be even greater [25]. Therefore, it is important to regularly clean the solar PV panels to prevent dust buildup. Regular cleaning can help maintain optimal performance and increase the lifespan of the solar panels [26]. Additionally, it is important to choose a location for solar panels that is less prone to dust accumulation. In terms of gaining a sustainable environment, solar power is a great alternative to traditional sources of energy that rely on fossil fuels [27]. By reducing our reliance on fossil fuels and using clean, renewable energy sources like solar power, we can work towards a more sustainable future with less pollution and a healthier planet [28].

Figure 4: Comparison of dust impacts on solar panels.

The first important term to be specified is dust, which can be summed up as tiny particles with a diameter smaller than 500 µm. It is made of solid substance, can be seen or unseen, floating or firmly planted [12]. To evaluate the impact of dust deposition on the solar panels, it is necessary to first determine how much dust accumulates on the panels [29]. We can define the thickness (Td) and volume (Vd) of dust on the solar panel which is defined by the formula that is mathematically expressed in Eq. (1) and Eq. (2).

$$Td = \frac{volume\ of\ dust\ collected}{area\ of\ solar\ panel} \quad (1)$$

$$Vd = \frac{mass\ of\ dust\ collected}{density\ of\ dust} \quad (2)$$

The majority of research publications quantify the amount of dust on the panel as grams per meter squared and calculate the power loss from the solar panel per gram of dust. Geographically, different amounts of dust collect on the panel. For instance, an Iranian experiment conducted in Tehran revealed that the dust concentration on a local solar panel (accumulated over the course of 70 days) ranges from 4.0599 g/m^2 to 10.3129 g/m^2. The rate of dust accumulation across the Middle East and North Africa was estimated to be about 0.3 g m^{-2} day [30]. If we contrast that figure with Tehran's, $0.3 \times 70 = 21$ g/m^2, which is a reasonable amount given that these areas contain the largest quantities of dust on Earth [11].

Disadvantages of dust

The dust causes a negative impact, and some of the disadvantages of dust's impact on PV performance as tabulated in Table 3 [31]. Regular cleaning and maintenance can help mitigate the disadvantages of dust impacts on PV performance to ensure that the panels are generating as much energy as possible.

Cleaning solar panels

To clean solar panels, there are a few well-known techniques. One of these involves the use of tractors with water-cleaning wipers, brushes, and cleaning wipers, and is carried out by the Adani group in India [11]. However, the aforementioned method uses a lot of water and physical labor, which is both environmentally unsound and not profitable. Electrostatic dust removal is a different method of cleaning solar panels that uses a strong AC voltage to reject dust particles from dirty solar panels [32]. In the Middle East and North Africa, where dust accumulates over a period of three days, this has a maximum cleaning efficiency of 100% when the dust concentration is around 1 g/m^2 [29].

In comparison to the power generated by the solar cells, this cleaning mechanism uses extremely little power. A 1 m x 1 m solar panel needs about 0.9 Wh of electricity to clean, and it takes about 5 minutes.

Table 3: Disadvantages of Dust Impacts on PV.

Disadvantages	Features
Reduced energy output	• When dust accumulates on the panels, it reduces the amount of sunlight that can reach the solar cells. • It leads to a reduction in the amount of energy the panel can produce and can reduce the efficiency of the panel.
Overheating	• Dust can also act as an insulator and trap heat on the surface of the panel. • This can cause the temperature of the panel to rise and reduce its efficiency as well as shorten the lifespan of the solar cells.
Damage to the surface	• The accumulation of dust and debris on the surface of the panel can scratch or damage it. • It can affect the panel's ability to absorb sunlight and can also impact the aesthetic appearance of the panel.
Low maintenance	• Dust accumulation requires regular maintenance to ensure that solar panels are performing to their best ability. Otherwise, there will be a decline in their performance over time.

Eq. (3) can be used to determine the portion of the energy gathered by the panel that has to be used for cleaning (f) if we assume that the power generated by the panel averages 120 W/m^2over the course of 7 $hours/day$.

$$f = \frac{0.9}{120 \times 7 \times 3} = 1.43 \times 10^{-4} = (0.035\%) \qquad (3)$$

Where the value 3 indicates period of cleaning process in $day/clean$.

Mega solar panels in arid environments can benefit from the aforesaid cleaning procedure to become more effective [33]. Numerous approaches are still being investigated and developed in order to maintain net positive power generation and to be sustainable for the long term, even if more and more power plant firms are cleaning their solar panels to prevent dust settlement [34].

Possible solution in future perspective

Some of the proposed solutions may implemented in order to avoid the dust's impact as tabulated in Table 4. Hence, self-cleaning by ensuring regular maintenance and cleaning can increase the lifespan of solar panels and promote sustainable energy practices. This not only helps to reduce our reliance on non-renewable fossil fuels but also decreases our carbon footprint and contributes to a cleaner environment [35,36]. In addition, promoting sustainable energy practices and maintaining solar panels can also lead to job creation in the renewable energy sector and stimulate economic growth. Therefore, it is essential to prioritize sustainable energy and take steps towards promoting it in our daily lives.

Conclusion

The energy sector has undergone enormous growth and

Table 4: Proposed solution for the impact of dust accumulation on solar panels.

Proposed solutions	Explanation
Regular Cleaning	• Cleaning the solar panels at regular intervals is an effective way to remove dust and debris. • Depending on the local climate and dust levels, you may need to clean the panels every few months or as needed. • Use soft brushes, sponges, or microfiber cloths to avoid scratching the surface of the panels. • Avoid using abrasive materials or harsh chemicals that could damage the panels
Automated Cleaning Systems	• Some solar panel installations incorporate automated cleaning systems that use robotic devices or water jets to clean the panels automatically. • These systems can help reduce the maintenance effort and ensure optimal panel performance. However, they may require additional investment during the initial installation.
Tilted Panel Mounting	• Mounting solar panels at an angle can help reduce dust buildup. When panels are tilted, rainwater can wash away some of the dust naturally. • Additionally, wind can blow away loose debris. However, it's important to consider the local climate and the optimal tilt angle for solar energy production when implementing this solution.
Hydrophobic Coatings	• Applying hydrophobic coatings to the surface of solar panels can make them less prone to dust accumulation. • These coatings repel water and reduce the adherence of dust particles. While they can be effective, the longevity of such coatings may vary, and periodic reapplication may be necessary.
Weather Conditions	• Depending on the local climate, weather conditions like rain or snow can naturally clean solar panels. However, in dry or dusty regions, these weather events may be infrequent. Therefore, it's important to account for these factors when determining the cleaning frequency and maintenance requirements.
Location and Surroundings	• When choosing the location for your solar panel installation, consider the surroundings. Avoid areas with high levels of dust, such as construction sites or heavily polluted areas, if possible. • If you have control over the surroundings, you can take measures like planting trees or installing barriers to reduce the amount of dust reaching the panels.
Mechanical Vibrator	• Wind energy was transformed into mechanical energy i.e. vibration. The mechanical vibrator attached to a panel produced harmonic excitation force to overcome the adhesive force between the dust particles and the surface of the solar panel

development on a global scale and attempts to improve energy efficiency are now seen as necessary to build a power generation infrastructure that is sustainable. The impact of dust on solar photovoltaic performance is significant as it reduces the efficiency of the panels by blocking sunlight and reducing the amount of energy produced. Therefore, regular cleaning of solar panels is crucial to maintaining the efficiency of the system. If left uncleaned, the dust can accumulate and cause permanent damage to the panels, leading to costly repairs and replacements.

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