

Increasing the Efficiency of Photovoltaic Systems by Cleaning

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Abstract

Jordan is considered one of the countries that suffer from high prices of oil, gas, and coal, in addition to the high cost of these non-renewable sources. The lack of these sources has prompted scientists around the world to think about solutions to this problem. Solar energy, wind energy, or any other energy is the real shield that provides energy sources. Although renewable energy sources have solved many problems, many challenges remain, and among these challenges is the issue of the cost of such projects and whether they are efficient and reliable. In addition, these systems are greatly affected by climatic conditions, including temperature rise due to high temperatures, the accumulation of various pollutants, the accumulation of dust due to abandoned areas, the problem of humidity in some areas, and the problem of shading or even reflection. Made from the same boards. These problems encourage researchers and scientists to search for practical solutions to reduce the economic impact of the damage caused by these forcing events and increase the efficiency of these systems. In this research, we studied the impact of some factors affecting the performance of photovoltaic panels, such as dust and other pollutants coming from industrial areas, with the hope of applying these studies to Jordanian lands in the Ma'an region in southern Jordan, which is considered a desert region and has a hot climate compared to other regions of Jordan, which has a lot of dust. This paper helps clarify the difference between some of the detergents that have been used to clean photovoltaic panels, and this leads to increasing the electrical efficiency of photovoltaic panels.

Keywords. Solar energy, PV efficiency, PV cleaning.

1. Introduction

The photovoltaic solar module industry has witnessed rapid growth over decades in accordance with the tremendous development witnessed in various technologies. Nowadays, PV systems are not limited to off-grid systems or even homes as they have already been used on very wide scales including large power plants. Photovoltaic systems are now being applied in various places around the world. Nowadays, large-scale PV systems are being implemented in Jordan by specialized companies, the largest of which is a 247 MW solar power plant. According to the enormous advantages of photovoltaic systems; They are very attractive for large and small investments [1]. For example, they are long-lasting, require almost no maintenance when there are no mechanical parts in use, and require minimal operational control. Of all these systems, these systems provide the maximum electricity production during periods of peak load demand, which is summer. and noon times [2, 3, 4]. The main problems associated with the process of investing in photovoltaic cells are the effects of dust and high temperature, as the accumulation of dust becomes an obstacle to the arrival of solar radiation to the photovoltaic panel, as the current production has a

direct relationship to the amount of solar radiation. In other words, the greater the solar radiation, the greater the current, while the higher the degree of Temperature leads to a decrease in voltage Ismail et al [5], meaning that as the temperature increases, the voltage decreases. These two factors appear strongly in most sites [6]. The presence of photovoltaic cells in different environments makes them vulnerable to external weather factors. For example, solar radiation intensity, humidity, temperature, and wind Bahattab et al. [7]. Unfortunately, these factors can lead to a decrease in the energy production of the photovoltaic cell. Ismail et al [8] addressed the problem of high temperature by cooling the cells with porous materials, and through the results, the electrical power increased with the decrease in temperature. The panels were also cooled in many ways, including the use of water in cooling, nanotechnology, and all of them. It was positive in raising electrical Masalha et al, [9].

2. The effect of dust

Numerous investigations have explored the influence of dust on solar panels, revealing a wide range of reported performance losses [10,11,12,13]. In India a study of Kumar and Chaurasia 2014, documented a 4.7% degradation in collector performance due to dust

deposition [10]. Conversely, projects installed in Saudi Arabia experienced a significant 40% performance degradation over a span of six months. Another region in Saudi Arabia reported a performance decline of approximately 32% after eight months of installation. These performance degradations suggest a substantial impact on the efficiency of solar systems [10]. In Thailand, Tagi et al 2014 did a one-month study which indicated an 11% reduction in performance [11]. In Kuwait, Althuwaini 2023 project revealed performance reductions ranging from 17% to 65%, dependent on the tilt angle [12]. Similarly, in Egypt, performance reduction reached up to 65.8% after six months of installation. Unfortunately, all these studies primarily focused on performance degradation due to dust accumulation [13].

A study in Iraq [14,15] conducted on three PV modules were subjected to outdoor environmental conditions and the effect of the dust and dirt deposition on the system performance was evaluated. The examined samples of accumulated dust and dirt showed high rate of hydrocarbon particulate matter resulting from exhausts of traffic and generators.

Other study by Mani and Pillai [16] examined the efficiency of reflection of solar mirrors and the effect of dust accumulation on the efficiency of electricity generation. The study showed that the accumulation of dust on the surfaces of mirrors reduces the efficiency of reflection and need in this case to clean repeatedly to avoid deterioration of efficiency. The use of the electrodynamic screen (EDS) provides an effective way to maintain mirror reflection above 90%. Repeated dust removal keeps the reflectivity of the mirror above 90%.

Molki [17] suggested that it is important for educators to demonstrate to students not only the benefits of renewable energy sources, but also their limitations. Therefore, a simple experiment is proposed that would allow science educators to demonstrate the effect of dust on the efficiency of photovoltaic cells in the classroom in a short period of time. This can lead to interesting in-class discussions about the limitations and appropriate choice of renewable energy sources, or result in student projects on how to address the problem.

This study seeks to examine the effects of dust accumulation on the performance of solar photovoltaic (PV) modules at the Shams Ma'an power plant. To accomplish this objective, the study aims to:

- Review the impact of dust accumulation on PV modules of different studies to find out the best option of cleaning the PV panels.
- Assess the daily energy yield of PV modules under the influence of dust deposition and evaluate the overall system efficiency, to find out the cleaning method and its effect on overall performance.
- Investigate potential additional factors influencing PV module performance, to highlight the best operation.

This study showed that the losses caused by dust deposition and its impact on the efficiency of solar systems. The study focused on PV systems. The study also compared between some studies that have been addressed with energy productivity and performance losses in several regions of the world.

3. Case study

Shams Ma'an Power Plant Shams Ma'an Power Plant is a 52.5MW photovoltaic power station located in Ma'an (30°9'3.6"N 35°49'28.4"E), it's the second largest plant in Jordan, the construction began in 2014 and it was opened in 2016. The plant produces 1% of Jordan's total electrical energy production, with a \$160 million project cost. The owner of this plant is Shams Ma'an Company. The type panels are flat type, while the operator of the company is the Jordan National Electric Power Company (NEPCO).

The plant is owned by a consortium of investors consisting of Diamond Generating Europe Ltd., Nebras Power Q.S.C. and the Kawar Group. First Solar significantly contributed to the development of the project before divesting its stake and being appointed the Engineering, Procurement and Construction (EPC) contractor. Shams Ma'an has a 20-year Power Purchase Agreement (PPA) with the National Electric Power Company (NEPCO), the country's power generation and distribution authority.

"First Solar has delivered a high-performance solar energy asset on schedule and with an excellent safety record. There is no doubt that this power plant will deliver on its promises, reliably generating energy over its lifetime and forming the cornerstone of Jordan's energy security strategy," said Karim Kawar, Chairman of Kawar Energy. [15]

Shams Ma'an station produces 160 GWh annually distributed over the months as following.

Table 1: The monthly power generated at Ma'an plant.

January	February	March	April
9 GWh	11 GWh	14 GWh	14.5 GWh
May	June	July	August
17 GWh	17 GWh	16 GWh	16 GWh
September	October	November	December
15 GWh	12.5 GWh	9.5 GWh	8.5 GWh

3.1 Experimental setup

Jordan contains many regions considered to be the highest regions of solar radiation intensity including Ma'an, Mafraq, Al-Muaqqar, these regions are the most affected regions by different pollutants including air bone dust, and overheating. The frequency of the occurrences has increased rapidly in the last decade and still increasing constantly and continuously. The events of sand and dust storms are classified into regional or local. Dust deposition on the surface of the photovoltaic modules blocks the radiations from reaching the solar panels which causes a reduce in performance and hot spots in other positions of the cell. Hence, if the dust deposition increases, the corresponding electricity generation reduces

To investigate the photovoltaic (PV) performance of Shams Ma'an in the presence of dust accumulation, the following components are required [18]:

1. Two identical monocrystalline silicon PV panels, each with a maximum power of 125W, an open-circuit voltage of 21.8V, a short-circuit current of 7.45A, a weight of 3.5 kg, and dimensions measuring 1.43 m in length, 0.63 m in width, and a total area of 0.9m². One PV panel is maintained in a clean state, while the other accumulates dust for comparison.
2. A digital voltmeter with a voltage range of DC 0–100V and a dual display.
3. The contaminated setup underwent testing from March 28 to March 30. After that we cleaned the mirrors and glass casing of the receiver, with water. The system was tested again from April 1 to April 3. Subsequently the system was left exposed to conditions without cleaning for two weeks spanning from April 4, to April 18. Finally, the mirrors and receiver casing were cleaned using alcohol and further testing took place from April 19 to April 21.
- 5- The system was left exposed to the external conditions for two weeks without cleaning, for the period from 4 to 18 April.
- 6- The mirrors and the receiver casing were cleaned using alcohol and the system was tested for 19-21April. The system remained unprotected, from the

elements for a duration of two weeks from April 22nd to May 5th. Following this the mirrors and receiver cover were cleaned using a Sodium detergent and testing was conducted between May 6th and May 8th. Furthermore, the current voltage curve indicates the short circuit current, in absence of resistance.

To calculate the power production, we used this equation: = days per month×Solar radiation per day× total kW (peak) × System yield.

The system yield differs according to the amount of solar radiation per month:

- 1-The maximum amount of radiation per month is 150 hours, then the system yield is 0.85.
- 2- The average amount of radiation per month is 140 hours, then the system yield is 0.8.
- 3-The minimum amount of radiation per month is 130 hours, then the system yield is 0.75.

For the studied region Shams Ma'an, the best cases are predicted for calculating its energy production so the system yield used is 0.8 We have 605400 panels to calculate the total kW (peak) The dc to AC ratio is (dc/AC = 1.5), this ratio is taken according to studies performed by ABB, the best financial outcomes exist between a DC to AC ratio of 1.3 and 1.6, however, for best system yield the DC to AC ratio can be closer to 1.5. Then, the kW_{peak} = 78.702 kWp.

4. Result and discussion

Jordan is considered to be one of the highest countries of solar radiation intensity in the world. The amount of energy falling to the horizontal surface is between (5-7) kW every day. According to the National Energy Research Center, Jordan has more than 300 sunny days per year. The testing of the power output of Maan station were measured by accurate measuring devices installed in the PV station. So that we have taken the results from there measuring devices.

Figure 1 shows the production of electrical energy in the Ma'an region in Jordan during the months, as it is expected that the months of June and July will be the highest among all months, exceeding 14000- 16,000 MWh, as this region is characterized by the bright and distinct sun throughout the day and month, and therefore it must be exploited effectively to produce the largest amount of electricity. of energy, but the main problem is the accumulation of dust on the photovoltaic panels because the area is semi-desert and has many factories.

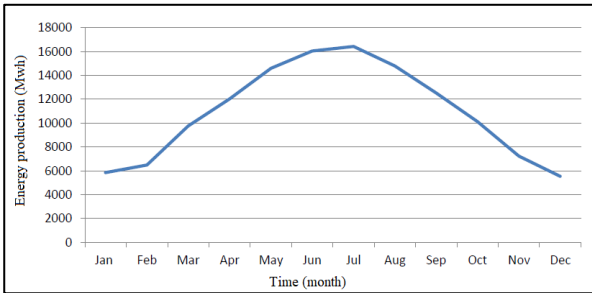


Figure 1: Energy production.

Figure 2 shows the effect of dust on photovoltaic panels in many countries, including Saudi Arabia, Egypt, Iraq, and others, as the accumulation of this dust reduces the production of electrical energy. The loss of produced energy in Saudi Arabia reached 40%, Egypt 65%, Oman 13%, Kuwait 65, and Dammam 32%, and this indicates the effect of dust. Negatively, therefore, a cleaning system must be added to the photovoltaic panels.

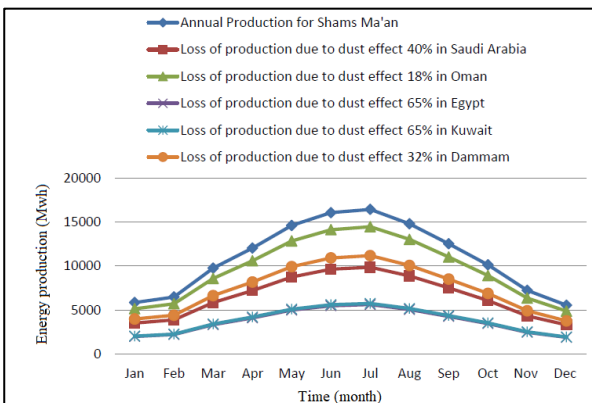


Figure 2: Power reduction rate due to dust effect.

Figure 3 shows the production of electrical energy in the Ma'an region in southern Jordan during the day, week, and month, in the presence of dust accumulation on photovoltaic panels and the absence of dust. Therefore, it is clear that the production of electrical energy increases in the absence of dust because it works to reflect solar radiation, as the production of electrical energy during the month reached more than 35,000MWh in the absence of dust, but it decreased to approximately 29,000 MWh in the presence of dust, while the production of electrical energy during a week reached 8,000 MWh during A week when there is no dust and we drop to less than 7000 MWh when there is dust.

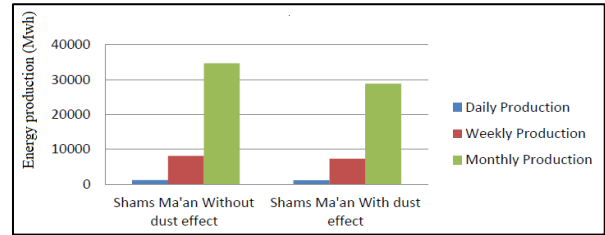


Figure 3 The degradation of energy production.

Figure 4 shows the noticeable variation in the power output resulting from photovoltaic panels when there is no dust and the presence of dust during the months throughout the year present on the photovoltaic panels, where in terms of power it is approximately 17,000MWh in the absence of dust accumulation and approximately 10000MWh in the event of the presence of dust. The graphic clearly depicts the harmful effect of dust accumulation on energy production. As shown, power output experiences a noticeable drop in the presence of dust, underscoring the importance of regular cleaning of the panel for optimal performance.

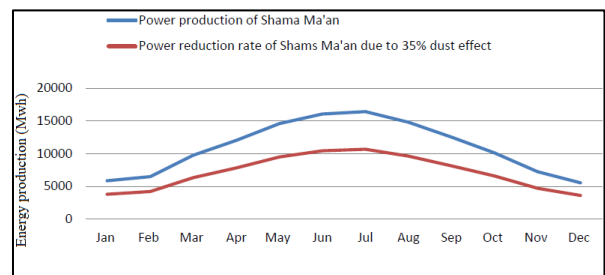


Figure 4: Power reduction rate for Shams Ma'an due to 35% dust effect

The effect of cleaning tools and chemicals used in the power reduction rate

To delve deeper into the results, the contrast between the two scenarios is a visual testimony to the harmful effects of dust on the efficiency of the PV system and the reduction of electrical energy. The decrease in energy production, shown graphically in Figure 5, emphasizes the importance of addressing and mitigating dust accumulation to maximize the energy productivity of solar panels. Choosing the appropriate cleaning materials is also effective in increasing the production of this electrical energy. The process of cleaning photovoltaic cells plays a very important role in the rate of change and decrease in electrical energy generation. In some cases, the decrease reached 50% of the generated energy. Areas are classified into industrial and non-industrial areas. In non-industrial areas, the cleaning process using water may be somewhat useful, but this does not work in industrial

places that suffer from air pollution in addition to dust. Some contaminants stick to solar panels such as fine particles, magnesium, calcium oxides, soot, and sodium chloride. These pollutants cannot be removed with water, so other materials were used. Based on Figure 5, the difference between the cleaning fluids used is clear, as sodium was the best among all the fluids used and the cleaning rate reached 97%.

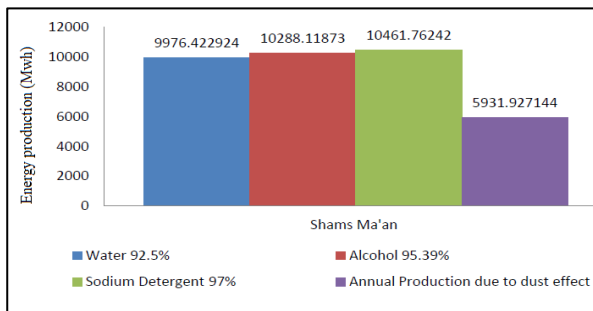


Figure 5: The effect of cleaning materials on the power reduction rate.

5. Conclusions:

The outcomes derived from our experimental investigation unequivocally affirm the profound impact of dust accumulation on photovoltaic panels, with a substantial decrease in electrical energy production exceeding 34%. This underscores the imperative need for proactive measures to address and mitigate the adverse effects of dust, ensuring sustained and optimal performance of solar energy systems.

Based on these findings it's clear that traditional water-based cleaning methods might not be enough, in environments where dust buildup is more significant specially near industrial regions. Using alternative cleaning agents like sodium detergent seems to be an option as our study shows that it can achieve a cleaning rate of up to 97%. This highlights its potential as a choice for keeping panels clean and efficient. Also, to avoid a tracing spot on the panel.

These findings have implications for the energy sector indicating the need to adopt more advanced cleaning techniques to ensure the long-term sustainability of photovoltaic systems. Implementing cleaning strategies such as using sodium detergent is essential not for maximizing energy generation but also, for reducing financial losses linked to decreased panel efficiency and power. This study emphasizes the importance of customized maintenance approaches to enhance the performance and durability of setups in various environmental conditions.

6. References

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