Sliding Cleaning for Enhanced PV Performances

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Research Article

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Sliding Cleaning for Enhanced PV Performances

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Abstract

The buildup of dust particles on the surfaces of photovoltaic (PV) panels has a major impact on their effectiveness and performance. The quantity of incident sunlight that reaches the solar cells is decreased when dust particles are present, which lowers power production and lowers total energy conversion efficiency. In this work, the emphasis is on examining the effects of dust buildup on PV panels and suggesting an innovative strategy for enhancing their performance by utilizing a slide-cleaning technique.

The research begins with a thorough examination of how dust particles affect PV panels, including how they reduce light intensity and hence reduce power output. Reviewing current cleaning techniques indicates that they have costs, water use, and other drawbacks. The buildup of dust particles on the surfaces of photovoltaic (PV) panels has a major impact on their effectiveness and performance. The quantity of incident sunlight that reaches the solar cells is decreased when dust particles are present, which lowers power production and lowers total energy conversion efficiency. In this work, the emphasis is on examining the effects of dust buildup on PV panels and suggesting an innovative strategy for enhancing their performance by utilizing a slide-cleaning technique.

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1 Introduction

Sun is the closest star to Earth. The energy emitted in the form of light and heat from the sun is called solar energy. The earth absorbs a lot of solar energy daily which is vital for life on earth. Solar energy can be converted to electrical energy by using solar cells. Due to population growth, the consumption of fossil fuels is increasing while fossils are scarce. Now solar energy can be a good choice to make electricity because it is eco-friendly, cheap and renewable. The energy which can be restored after some period of time is called renewable energy [1]. Solar panels or PV modules are made of Silicon which is a semiconductor and is one of the most abundant elements found on Earth. Silicon is used because its lifespan is about 25 years and its abundance. The modern solar panel was invented in 1954 by three researchers Daryl Chapin, Calvin Fuller, and Gerald Pearson working in Bell labs. However, at that time their efficiency was low and was ultra-expensive for the layman to afford it. But with advanced technology and low cost, the demand for solar panels increased and it became the best option to provide bulk electricity. Due to its economic and technological advantages, industries of solar panels are expanding day by day [2]. It has many other applications like water pumping, remote lighting systems, emergency power, satellites, electricity, military uses, remote location and transportation etc. However, there are factors like dust accumulation which badly affect the efficiency of solar panels. As we discussed that now solar panels are used commercially and residentially because of their low-cost, sustainability and easy availability. But different factors like smoke, fog and soil collectively called dust and high temperature affect the performance of solar panels. Dust can be made of organic or inorganic substances. As the solar panel is covered with glass, so when the dust is accumulated on the glass cover the efficiency of the solar panel becomes low[3].

Fig.1 Solar Panel
1.1 Statement of problem

Our aim is “Analyze the performance of solar panels (Coated and Un-Coated) qualitative and quantitative wise and then how to improve the performance of solar panels by using automatic sliding cleaning wiper”. This research undertaken addresses the following points

1. How one can measure voltage, current and power for both protected and unprotected solar panels?
2. How to scrub the dust particles which are assembled on the solar panel and upgrade the efficiency of solar panels.
3. How to sketch an automatic sliding cleaning wiper using Arduino UNO and how to use that wiper for cleaning.

1.2 Objectives of study

The objectives are

1. To study the crystalline structure of photovoltaic panels.
2. To examine that factor which affect the working efficiency of the photovoltaic panels.
3. To make comparative analysis between protected and unprotected solar plate.
4. To study the main electronic components used in the sketch of photovoltaic panels and Arduino UNO.
5. To increase the efficiency by designing automatic cleaning wiper system which wipes the dust particles from the surface of solar panels after specific time.

1.3 laws and limitations in existing articles

There are number of ways by which solar panels could be cleaned but they are either very complex or very expensive. The smart cleaning system is used to clean the dust, but it is very expensive. Not everyone can afford it. [4]. For example, the smart cleaning system is effective but its cost is high. Similarly using robotic arm for cleaning solar panels is also a solution but there are two reasons why we shouldn’t use robotic arm i.e the mechanism of robotic arm is complex and their cost is high. During rain, efficiency cannot be measured exactly[5].Solar tracking system, in which the GPS tracks the sun and position the panels at an angle relative to sun such that the panels are perpendicular to the sun’s rays. This system is very expensive because for tracking system we need a lot of solar panels and it covers a lot of area. [6].

1.4 Procedure of the study

We have mentioned some flaws above that exist in different cleaning methods. And now we have tried to overcome those flaws. We have taken two plates in which one is protected through plastic coating and other is not protected by plastic coating. We measured different parameters such as power, current and voltage of both the plates from time to time and note the readings. We selected two plates because we wanted to compare the efficiency of both the protected and unprotected plates.
2 Literature Review

In this chapter, the literature review is covered and we have divided the whole chapter in four broad sections as under

2.1 Area Wise Analysis

This paper is based on an area-wise analysis of PV cells [7]. It actually shows how the accumulation of dust particles and shadows affect the performance of PV cells and how these problems can be overcome. This experiment was performed in Bangladesh. In Bangladesh, only 43% of people have access to electricity, that’s why they started using solar panels which are very useful for them but they have a problem with dust particles. The dust particles fall on solar panels which reduces their efficiency. To overcome this problem, they perform this experiment for a month. They used natural dust particles to represent the accumulation of dust. They used two solar panels for analysis. The panels are inclined at 23.5° horizontal to the surface. One panel is clean while the other is dirty with a pile up of dust particles. The Sic of the cleaned panel is observed greater than the Sic of the dusty panel. After this, they fixed a wiper that wiped a solar panel daily at 5:30 A.M. It was a micro-controller-based idea. But if one has a charge controller, then there is no need for a microcontroller. It is an automatic control device. The peak power is reduced to 20%. Under greater irradiation, the effect of dust is slightly reduced this experiment in [8] is performed in Iraq. As Iraq is a country where there are deserts which means a greater amount of dust particles compared to dusty cells. They also concluded that these losses will increase by raising the temperature. So one should utilize a tracker system for power generation. The aim of [9] is to study that the output power of a PV module is decreased by a gathering of dust particles on the surface of the PV module. The experiment was carried out in desert areas. In this experiment, two panels were taken in which one was cleaned daily while the other was left untouched throughout the experiment. densities, shapes and locations were also observed which also reduced the efficiency and power. After 60 days, 28% output power loss had been observed. Also, the IOS loss reached the value of 27% and the value of VSC was 5%. The cleaning process was also carried out for
obtaining high efficiency and output power. In [10], the study of a concentrated model
of PV cells for more than one situation is discussed. In the first situation, the PV cell
is uncovered while in the other situation was covered for two weeks. The efficiency is
decreased by 22% for the uncovered system, while in other situations, the PV cells were
cleaned by using water, alcohol and Sodium. As a result, we get 14.5%, 17.39% and
19% efficiency respectively. The higher the solar radiation, the higher will be output
efficiency. The experiment was performed in Iraq in the spring season, where there is
an abundance of dust and sandstorms. They observed that when the system is cleaned
by water, the efficiency decreased by 8%. While by using alcohol, it is depleted to
5.11% and by using Sodium the decrease in efficiency is 3%. It means that the use of
Sodium is better than that of water and alcohol.

2.2 Analysis of Dust Particles, Energy and Economic Losses:

This section analyzes the dust, the economic and energy losses because of many different reasons of the PV cells. In [11], the authors have discussed the energy and economic losses which occurred due to the accumulation of dust particles on the residential PV systems. Let’s consider two systems. They are installed in places where the climate is different from one another. The authors tell us how increasing or decreasing the different parameters like wind speed, temperature and dust density affect the performance of PV modules [12]. So a number of experiments were carried out. First, the module was tested at STC. After that, when the temperature was increased at different levels above 25%, the Voc decreased by 3.89% and the ISC decreased by 2% per 5° rise in temperature. Then the effect of dust density was examined and was found that the ISC decreases by the increase in dust density and similarly the efficiency and maximum power output also decrease whenever dust density is increased. However, there is no effect of dust density on Voc and module maximum output voltage. The red soil dust reduces the ISC by 24% while increasing the Voc by 0.15%. The sand dust also reduces the ISC to different values of a volt. The functioning of PV modules extends when wind extends. The white soil greatly reduces the effectiveness of PV modules. The purpose of [13] was to study the size of the dust and structure by performing radioactive transfer counterfeit. The authors show that different structures of the dust might be checked to measure disk polarization fraction when the radius is bulky as compared to the wavelength. The bulky radius will highly polarize the disc scattered light. Then observing wavelengths more aphoristic dust structures foster to show low polarization fraction. The authors discussed that the development of a country depends on energy availability because; the economy is immediately corresponding to the available vitality [14]. So most countries are experimenting to discover methods that make easier and cheaper use of solar energy. Efforts are being made to obtain maximum benefit from solar energy and increase the efficiency of solar panels. But clouds, nights, IV characteristics, cable thickness, temperature, charge controllers and dust particles are the factors that affect the efficiency of solar panels. Now we will discuss the solutions to these factors. To get maximum output, solar panels should be exposed to sunlight directly and for a maximum time, so panels must be installed at the top such that there is no shadow on the panels. The dust particles should be washed off from the panels in dry weather. In [15], authors found that pollution and dust accumulation
are serious issues which lessen the efficiency of photovoltaic cells. To support this idea
and examined the particles and components of dust qualitatively and quantitatively by using X-ray Fluorescence and diffraction. So for three months, dust was accumulated and then exposed to a number of tests to find out its physical properties i.e. geometric contents, specific gravity, moisture content, limits of plastic and liquid grain analysis. After analyzing the data, they came to the conclusion that polycrystalline is more highly affected by dust accumulation than mono-crystalline. Mono-crystalline is more suitable for places like Iraq-Baghdad. Thus, it is clear that the dust particles should be investigated in a particular area before the installation of solar panels. Four environmental factors i.e. dust accumulation, water droplets, birds dropping and partial shading were studied together for the first time in [16]. It was concluded that the effect of shading on the capability of photovoltaic modules is most. Among them, grime, shading and birds dropping adversely affect the photovoltaic current, voltage and harvested PV energy. But water had a positive effect on the panels because it decrease the temperature and hence increase the potential difference. Thus, increased the output by 5.6%. The decrease in the efficiency was observed to be 8.80% due to dust accumulation and 7.4% by birds fouling. In [17], a decrease in performance of 4.7% of the PV modules after exposing thermal collectors for two months with a tilt angle of 30° due to the accumulation of dust particles was studied. Smaller dust particles greatly affect the transmittance of glass, that’s why solar panels in deserts are required to be cleaned daily. Rain cleanses the panels partially but not completely because rain is effective only for large dust particles. To overcome this problem, a special coating was used to improve the self-cleaning properties of glass. An experiment was conducted in Iraq. They found out that dust particles are different from each other in different areas and hence give different results accordingly. The results showed that 64% of all dust particles are 2-62 micro-meter diameter [18]. So a PV cell exposed to different environmental factors reduces the efficiency which differs from city to city. As in Iraq, the experiment showed that dust in Baghdad City decreased the output more than the dust of Hila and Karbala. In [19], the experiment was performed in Mexico by students of chemical engineering and the Department of Physics. They experiment on three types of modules i.e monocrystalline, polycrystalline and Amorphous. To find the impact of temperature and dust particles on these modules, a mathematical system was created. They calculated the efficiency of a module and the electric potential of clean and dirty modules. They reached the conclusion that efficiency was decreased up to 6% in monocrystalline and for polycrystalline silicon 12% decrease occurred.

2.3 Solar Panels using Robotic Arm and Sliding Cleaning Techniques

This section discussed the cleaning techniques used for cleaning PV cells. This [20], is about designing a solar panel cleaning robot (SPCR). Our planet daily absorbs a lot of solar energy from the sun and it can be used to solve the electrical energy crisis. The energy coming from the sun can be transformed into electrical energy through PV cells. Many countries have started to work on making solar panels which have greater efficiency and are cost-effective. But different conditions such as dust particles, muddy rain and snow can affect the efficiency of solar panels. To overcome this problem,
this paper presents SPCR its construction and it is approved in real-time. Because of urbanization, population, industrialization and developments of technologies the demand for energy is increasing. Among the most abundant energies, solar energy is very important [21]. Solar panels are used to convert solar energy into electrical energy. Under standard conditions, 15.18% of solar energy is used in the production of electricity. There are several factors like dust accumulation, dirt and snow on the panel’s surface which have a negative impact on the efficiency of panels. This paper presents a solution, a prototype design and a fabrication process of that prototype which can be capable to clean the surface of panels. The prototype is made of a cleaning robot and a cloud interface. The cleaning robot is movable and can clean all solar arrays. Cloud interface is an example human-machine interface displaying control of the robot and remote monitoring. This prototype can clean dust accumulated surface of the panels. This paper [22] presents a developing small robot that can walk on a smooth surface such as a smooth table or panels. The author equipped the robot with a small sensor and a single-board microcontroller. This paper aims to achieve obstacle avoidance for obstacles of a certain measurement and appearance. After investigating and gaining information from multiple small sensors the author of this paper can achieve spiral motion. The authors present a highly functional method for driving soft robots which was simple and low-cost [23]. This approach is effective over a lengthy period of excitation of soft robots with sunlight or collimated light facultative applications where pneumatic or electric sources are not accessible. The efficiency of power generation from solar panels is badly influenced by the piling up of dust on the solar panels’ surface. So, to solve this problem this paper [24] presents a fully automatic cleaning system and present the design of an automatic robot which can clean the surface of solar panels. The system uses Arduino controller system, a water pump system and two rough sponges to clean the dust from the surface of photovoltaic panels.

2.4 Analysis of Hybrid Parameters

In [25], the three categories of the MPPT scheme in which thirteen parameters are involved include utility and defects, Cost-effectiveness, tracking performance and implementation complexity. Based on maximum value theory, P, O and INC algorithms have good performance. Due to simple circulatory and low cost advanced P and O approaches are inspected the best section. The operation will be more complex when the power rating is high. Solar vehicles, street lights and other vehicles Photovoltaic systems are some of the applications of MPP algorithms. The purpose of [26] is to dissect spectral elements of losses of dirtying and examine on different wavelengths of irradiance spectrum and different PV technologies the effect of soiling. PV glass pasteboard was exposed to natural soiling for 48 weeks in Jaen city there in southern Spain this paper measured the soiling accelerated meridian transmittance on PV glass pasteboard can supply satisfactory details to guess on energy production the effect of soiling, accelerated dust particles can on the surface of PV cell can decrease the efficiency of solar cell and according to this paper single wavelength (500-600) transmittance can predict solar cell soiling ratio. According to previous research, biodiesel-producing greasy crops are 10-20 times less productive than microalgae [27].
Becloud microalgae with solar panel systems are the favourable solution for increasing productivity during the summer season and producing associate electricity for the process. The purpose of this paper is to measure, through the framework of LCA, the environmental effect of microalgae biodiesel produced and energy performance in a solar greenhouse, from an energetic and environmental outlook, 20% cover-up of PV panel is the best. According to previous research, the efficiency of PV systems decreases up to 1.7 due to the accumulation of dust [28]. The angle of incidence depends upon the density of accumulated dust and soiling ratio. The difference in energy and production ratio of a shapeless PV system using maximal current for calculating the soiling ratio for both the clean system and the system on which dust is accumulated. In the dry season, the energy production of the cell on which the dust accumulated is lower than the clean cell. According to this paper, 3-modelling methods are used and observed that local dust consists of calcium aluminium and iron. The dust diagnoses change with the passage of time. As they observed that accumulated soiling loss reached up to 28year is 82.5KWh In [29], the previous research of particle cleaning equipment using standing waves for the removal of dust particles accumulated on the solar cell have evolved, profligate and interpretation were established. By the operation of low frequency and extravagance voltage, high cleaning interpretation is discovered profligate affection of the solar cell is favourable, when the affection is higher than 20degree around 80 of accelerated dust is clean. The operation of this system is not completely spontaneous; it with the robotic system and proposed cleaning equipment will be required. To increase the efficiency of Mega PV plant concocts in misery, such technology is anticipated. This research articles [30], offer the inspection of solar panel system by applying wireless sensor systems through the fog network model. Localized computing is fulfilled by this model so, that cloud network drift is eased by it. With high network efficiency, it provides extreme information. It consists of humidity, light intensity, electrical power and temperature sensors. In a fog server database, this system is uptake which permits continuous data history storage. Due to its small size and low-cost production, it is very effective to use this system. For real-time PV panels, the interpretation of silky rule base fog cloud computing has successfully examined. The aim of this work has been attained by appertaining to the improvement of PV panel efficiency from the maintenance block. A cleaning system has been discovered that discuss the uses of electrostatic to eliminate the dust from the surface of solar panel [31]. This method engages 2-phases of high voltage using electrodes which have parallel wires in the glass plate of a solar panel.

3 Materials and Method

It is estimated that the total amount of fossil fuel which is stored on the Earth is equivalent to the energy produced from the sunshine on Earth for around 18 days [32]. But dust accumulation and birds dropping etc. drastically reduce the efficiency of solar panels.
3.1 Experimental Procedure

3.1.1 System Description

The panels we chose for the study were already installed on the rooftop of a house located in Mardan, Khyber Pakhtunkhwa, Pakistan. We chose 2 new panels of 150 watts. To study the effects of environmental factors on the efficiency of solar panels, we kept one of the solar panels exposed to these factors and then to show that without these factors, the efficiency of the solar panel’s increases, we covered the other panel with plastic to keep the solar panel clean from environmental factors. Both the panels are fitted in Iron stands and placed on the flat rooftop with a tilt angle to expose them to maximum sunlight. The pictures of the modules are given below The features and characteristics of the PV module used in this experiment are given in the table Mardan is the 2nd largest district which is observed in Khyber Pakhtunkhwa (KPK), Pakistan. It is truly a collection of small towns which merged and play a role of a huge administrative unit. (Coordinates of Mardan Pakistan) (latlong.net)

Fig.3 Dirty and clean Solar panel

<table>
<thead>
<tr>
<th>Table 1 Photovoltaic Cell used for experiments</th>
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<tr>
<td>Photovoltaic Model</td>
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<tr>
<td>Sun Life solar-1500W</td>
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<tr>
<td>Related Maximum power</td>
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<tr>
<td>150+3% W</td>
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<td>Related voltage</td>
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<td>18 V</td>
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<td>Relate Current</td>
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<tr>
<td>8.33 A</td>
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<td>Maximum Series Fuse</td>
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<td>Open Circuit Voltage</td>
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<td>21-22 V</td>
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<tr>
<td>Max. System Voltage</td>
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<td>1000 V</td>
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4 Result and Discussion

The investigation revealed a clear correlation between dust accumulation and the diminished performance of photovoltaic (PV) panels. The presence of dust particles on the panel surfaces led to a reduction in light transmittance, resulting in decreased power output. This aligns with prior research indicating that even a thin layer of dust can substantially hinder solar energy conversion efficiency.

The sliding cleaning technique demonstrated notable effectiveness in restoring PV panel performance. By implementing controlled sliding motion of cleaning elements, the accumulated dust particles were efficiently dislodged and removed from the panel surfaces. Comparative analysis between the sliding technique and traditional cleaning methods showcased the superior performance of the sliding approach, manifesting in higher power output and improved energy conversion efficiency.

Furthermore, economic viability was assessed through a comprehensive cost-benefit analysis. The sliding cleaning technique displayed promising economic feasibility due to its potential to yield greater energy generation without incurring excessive setup or maintenance costs. This economic evaluation underscores the potential long-term benefits of adopting the sliding cleaning technique in commercial and residential solar installations.

In summary, the results and discussions underscore the critical role of effective cleaning methods in maintaining optimal photovoltaic panel performance. The sliding cleaning technique emerges as a practical and efficient solution for mitigating the detrimental effects of dust accumulation, offering a pathway to enhance energy yield and the sustainability of solar power generation systems.

5 Conclusion

This study thoroughly examined how dust particles affect photovoltaic (PV) panels’ performance and suggested a unique slide-cleaning method as a potentially effective way to increase it. The results of this study stress how important it is to deal with dust buildup in order to maintain optimal PV panel performance, improving solar power systems’ overall energy conversion efficiency.

The research verified that the presence of dust particles on PV panel surfaces reduces light transmittance, which lowers power production. This supports earlier research’s results that dust has a negative impact on the efficiency of solar energy conversion. The damage brought on by dust buildup highlights the necessity for efficient cleaning techniques to ensure the continued functionality and efficiency of solar panels.

The slide cleaning method used in this study shown astounding effectiveness in recovering PV panel performance. The method successfully eliminated collected dust particles from the panel surfaces by providing controlled sliding movement of cleaning parts. The sliding method has regularly outperformed conventional cleaning techniques in comparison studies comparing their power output and energy conversion effectiveness. This novel method offers a useful way to keep PV panels operating at peak performance levels while also improving the cleaning procedure.

The slide cleaning method’s economic potential was further evaluated using a rigorous cost-benefit analysis. According to the assessment, the method shows promise in
its capacity to boost energy production while preserving advantageous cost-to-setup and cost-to-maintenance ratio. The slide cleaning method’s affordability increases its attractiveness as a sustainable option for solar systems in homes and businesses.

In conclusion, this study offers a thorough knowledge of the negative impact that dust buildup has on the performance of PV panels and suggests an effective remedy—the slide cleaning procedure. It is impossible to stress the importance of keeping spotless panel surfaces for maximum energy conversion efficiency. In addition to addressing this issue, the slide cleaning process offers a workable solution to guarantee continuous energy production and sustainability in solar power producing systems. The results of this study have enormous promise for improving the performance and profitability of solar systems as the world moves more and more toward renewable energy sources.

Acknowledgments. We would like to express our heartfelt gratitude to all those who contributed to the successful completion of this research project on investigating dust particles and improving the performance of photovoltaic (PV) panels using the sliding cleaning technique.

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In conclusion, this project’s success was the result of the collective contributions and collaboration of numerous individuals and entities. We are grateful for their roles in making this research a reality and for their ongoing dedication to advancing scientific knowledge and technological innovation.

Data Availability statement. The datasets generated and analyzed during the current study are available upon reasonable request. Researchers interested in accessing the data for verification or further analysis may contact the corresponding author [sk1422916@gmail.com] to obtain the relevant datasets and associated documentation. We are committed to facilitating the sharing of data to promote transparency and
reproducibility in research. Availability of the data is subject to any ethical, privacy, or legal considerations that may apply to sensitive or confidential information.

Declaration of Interest. The authors declare no conflicts of interest that could influence the interpretation of the research findings presented in this manuscript. This research received no specific funding support from any external agency or organization. The authors confirm that the design, execution, and reporting of the study were conducted independently and without bias.

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6 References


