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Enhancing the efficiency of rooftop solar photovoltaic panel with simple cleaning mechanism

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ABSTRACT

In today's world, use of renewable energy source is increased to decrease the usage of coal and water for generating electricity. One of the methods is, using solar energy for generating electricity. The efficient use of solar energy is an essential path which can deal with electricity crises. Even it has some problems, like aggregation of dirt and dust on the surface of the solar PV panel decreases the quantity of sunlight to penetrate and reach the solar cells, thereby shrinking the efficiency of PV panel. There are various techniques like manual cleaning, vacuum cleaning, electrostatic precipitator cleaning etc. With this cleaning mechanism, there can be an increase in the efficiency of the panel to about 15–20%. But each of the techniques has some disadvantages associated with it. Manual cleaning requires more manpower and there are some possibilities for damages to the Photovoltaic Panel on continuous usage of water or fluid. Vacuum cleaning mechanism results in scratches on the panel. So, we are using Automatic wiper cleaning using Arduino for cleaning the panel. In this paper we aim to reduce those disadvantages and enhance the efficiency and effectiveness of solar PV panel.

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1. Introduction

The sources of energy are classified into two variety, conventional energy and non-conventional energy resources. The conventional energy sources are depleting rapidly. This leads the world towards the growth, development, and usage of renewable energy sources. So, the new era of energy resources started, where friendly to the environment and sustainable in nature were mandatory. Therefore, solar energy was accepted and tested and by people, as this could fulfils all the requirements and demands.

Once solar panels are erected on rooftop, it starts to generate power without any pollution with natural sun light. It generates electricity with fixed structure without any noise, so lifetime of the plant increased. It can be installed anyplace and any capacity range with short duration of time. Solar power plants are installed near to the load center, so transmission and distribution losses are neglected.

The main objective of this paper is to utilize the solar radiation properly by maintaining the PV panels always clean. The dust and dirt dropping on the panel decreases the light fall over the panel,

due to this the efficiency of the PV system decreased even during good solar radiation. This problem is common for a large scale to small domestic rooftop system. In case of small rooftop system, manual cleaning is easy and possible. But in case of large-scale cleaning, like MW PV power plants, more manpower required and manual cleaning consume more time also difficult to clean entire panels at a time. So many cleaning techniques of PV panel with water are also studied, but water is essential for all those methods. Due scarcity of water in so many places we are not able to use that method in all places.

Hence, this paper is being developed in taking consideration of the above parameters. Many methodologies are already available for cleaning the PV panel. Those are mainly classified into two categories 1. Dry Cleaning 2. Wet Cleaning. In the above two methods of cleaning they used fabrics or brushes, forced air, chemical additives and water.

Before starting our work, we have gone through some of the research papers which handed out some of the ways by which a solar panel can be cleaned. Here are some of the points which we consolidated after going through all the research papers.

Authors of this paper discussed a cleaning mechanism which consists of bracket having one frame structure. Spray motor is supplied by water which is used to perform cleaning. A cleaning brush

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moves on the PV panel from top to bottom and it removes the dust particle towards downward direction. The systems focus on large arrays and are mostly not suitable for small size arrays [1]. In this system, the cleaning system operates immediately after sensing the accumulation of dust on the PV panel; it operates till the efficiency matched with normal value [2]. In this system consists of both cleaning and cooling system combined, the DC-motors of the cleaning mechanism was controlled by the microcontroller with the help of dust sensor signal. Also, the cooling system cools the PV panel when the temperature increases above the set value [3]. Authors of this paper designed the automatic wiper-based cleaning has a rubber wiper in cooperated on the solar panel and water pot is used to spray the water along with additive for cleaning the solar panel [4]. Authors of this paper used a robotic system to clean the PV panels. IR sensor used to detect the dust particle accumulated on the PV panel. Also, the Microcontroller activates the sprinkler system to spray the water on solar panel [5,6].

It is an automatic tracking system; the sensors are installed on corner of the solar PV panel. When the direction of sunlight changes, imbalance happens in output of the sensor. So, the tracking system operate to make the solar panels are vertical to the sun [7]. In this system authors are designed the sensor with dust infrared (IR) LED, Photo diode. IR ray falls on the PV panel always, if any dust particle falls on the PV panel IR rays detect and reflects back to the photo diode. The controller compares the signals of input signals with pre-programmed data for motor movement [8]. This system uses a microcontroller which signals the DC motor via AT mega 328 connected to the wheels which glide over the solar panels. After 10 rotations the microcontroller signals the DC motor to stop. After this cleaning process motors are signaled at the same time to start the cleaning operation, similar process is repeated continuously [9]. Authors of this paper designed the system consists of a LDR sensor, wiper unit and sprayer. Depending on the solar output the presence of dust on the surface of solar panel is detected. Microcontroller is either used to clean the panel with the Wiper and Sprayer Mechanism or continue to charge the battery with the Battery Charger [10]. Authors of this paper identified the rate of degradation the PV panel due to dust fall on it. The rate of degradation is 17.13% of the unclean module with the clean module. The clean module and dirty module degradations of 10.16 and 24.09% respectively. A polynomial relation among the

degradation and the density of dust drop on the facade of the modules is calculated with a coefficient of determination of 0.9933 [11]. The circuit uses a standard power supply comprising of a step-down transformer from 230 V to 12 V and 4 diodes forming a bridge rectifier that delivers pulsating DC. The motors are being supplied by the microcontroller [12]. This system cleans the solar panel by using pressurized water. The method chosen is for domestic cleaning purpose i.e. "Wet cleaning". Device mounted on the surface can be used manually or automatically for cleaning purpose [13]. Authors of this paper designed the system proposes an auto cleaning robot to works on the surface of flat solar panel. It consists of DC motor with belt system connected with the brushes. The motion of the brushes is limited with signal produced by a microcontroller with the dust sensor LDR [14]. This system provides cells against a reference pyranometer Kipp and Zonen CMP21. One of the reference cells has been cleaned daily and the other cell has not been cleaned during the experiment. The recorded irradiance values are compared and the dust influence on the received radiation can be noted [15]. The LDR used in this system will detect the sunlight and actuate the servo motor. If the presence of dust is detected on the solar panel, the IR sensor will detect it and actuate the cooling fan to remove it and cool the solar panel. The microcontroller is used to program the circuit and setting the servomotor [16]. The self-cleaning system consists of software and hardware parts. The PV Solar cleaning system designed with DC motor, gear arrangement with conveyor belt, software for control operation, rechargeable battery, solar panel, brush. Once switch on the system DC motor, gear system starts to operate thereby moving the rolling brush on the panel clean the solar panel [17]. Authors of this paper proposed the system consists of a microcontroller, actuator and wiper. When microcontroller activates the wiper, it cleans solar panel using geared DC motor, this motor rotates forward and reverse to move the panel up and down. The study after this system being operated shows that the reduction in the peak power can be up 10% [18]. The automated cleaning mechanism is implemented using brush, rod & sliding wheels. The brush is fitted in the rod and the rod is fitted with the wheels at both the ends [19]. Authors of this paper identified that this system handed out the following points: Electrical performance measurement, Investigation of dust properties, determining the contribution of dust [20]. This paper will detail the



Fig. 1. Real time roof top panel and their condition.

methodology employed to investigate the dust deposition on tilted glass samples. For cleaning aspects different types of water were chosen and poured on glass samples, sunk for 1 mm, 3 mm, and 5 mm. The experiment shows the results of the transmittance measured for every case [21]. The basic concept of this experimental procedure is to compare the power output, energy yield and efficiency variation of the two identical pairs of PV-panels, the first being clean one and the second being artificially polluted [22].

The experiment has been conducted in the laboratory by the authors, with a solar simulator and various types of dust of known materials, the properties of the materials were carefully determined. The major apparatus of the experimental setup was the solar simulator, PV panel and the experimental dust. After the experiment I/V characteristics of the photovoltaic panel were determined [23]. This paper reviews the current state of research into the impact of dust deposition on the performance of solar systems, particularly PV panel. The characteristics of dust settlement on PV systems is influenced by 2 factors, the property of dust and the local environment [24]. The experimental program was planned to be conducted in the laboratory using a solar simulator

in order to set all variables under control. The specification of this system at a solar intensity was set at 1000 W/m^2 [25].

Referring to all these research papers which hand out some of the cleaning mechanisms to enhance and improve the efficiency of the solar panel, we however formulated some of the adverse effects that might alter the efficiency and the lifetime of Solar Photovoltaic panel.

One of the repercussions is that of using water in the cleaning system. Use of water might be an effective source of cleaning solar panel, however using water as a variant to clean solar panel will result in the degradation of the solar cells present in the solar panel which in turn reduces the lifespan of the panel.

The second adverse effect which we could come up with is, some of the cleaning mechanisms use a lot of power to take out the debris of dirt and dust present on the solar panel. If a system uses more power just to clean a solar panel then the input power given to the solar panel might turn up to be more than the actual output power generated by the Solar Photovoltaic panel.

The third and the most important effect which we came up with, after researching some of the cleaning methods is the

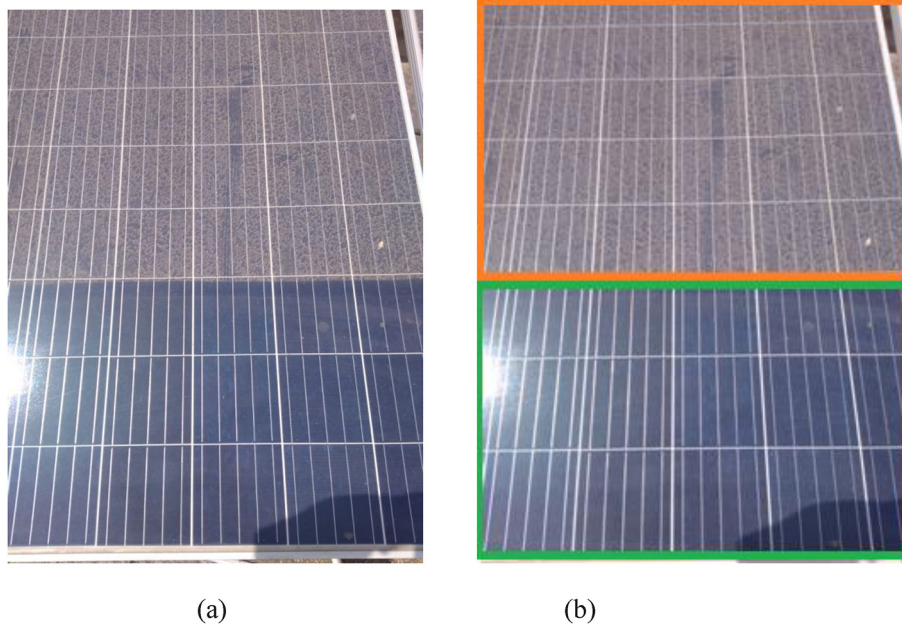


Fig. 2. (a) Part of Solar PV panel manually cleaned by cloth (b) Top un-cleaned part bottom cleaned part.

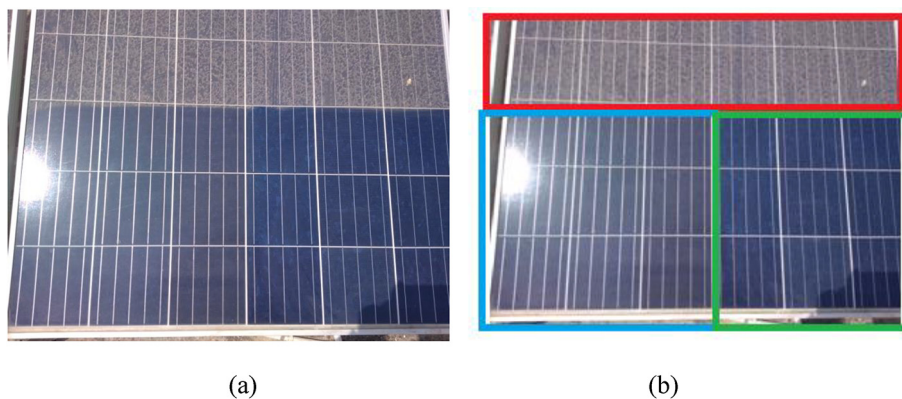


Fig. 3. (a) Difference in Solar PV panel cleaned with water, cloth and un-cleaned part (b) Red-Un cleaned, blue- cleaned with cloth, green- cleaned with water. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

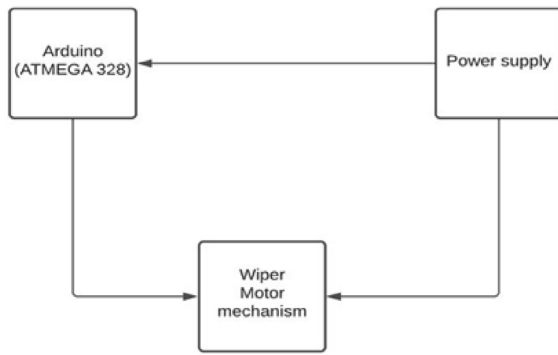


Fig. 4. Block diagram of simplified system.

“Shadow Effect”. A cleaning system might work at a time where the sun is exactly vertical to the solar panel (for ex 12:00 noon) which might lead to the formation of the Shadow of the cleaning machine on the solar panel. Formation of shadow on the solar panel might alter as well reduce the generation of electricity as the shadow blocks the sunrays from entering the solar panel.

Keeping in mind all the effects and impacts made on the solar panel we are therefore proposing an Automatic Cleaning mechanism using Arduino system without using water and with a minimum input given to operate. Our proposed system will operate at a time where the sun is not naturally seen, that is it can operate either before sunrise or after sunset which eliminates the formation of shadow.

Fig. 1. Shows the real time dust accumulated on the panel which we have tested. In Fig. 2(a) and (b) the part of the panel cleaned manually with cloth; this will remove the dust particle more than 90%. But some of minute particle are not able to remove. For removing those particles, we used wet cloth with water as shown in Fig. 3. But the panel output will not change more compare to dry cleaning and wet cleaning process.

2. Methodology

The simplified system is shown in Fig. 4. The wiper motor mechanism is directly connected and controlled by Arduino controller. We need to operate daily with regular intervals. For this methodology doesn't require any sensor, feedback signal, additional components and water. Everyday morning around 6.00am, automatically the Arduino gives signal to the wiper motor to move

Table 1
Solar PV panel specification.

Parameter	Value
Pmax	250Wp
Vmp	31.08 V
Imp	8.05A
Voc	37.20 V
Isc	8.47A
Max system voltage	1000VDC

Table 2
Operating time of the system.

Motor	Time
On	6.00am
1st Forward run	30 sec
1st Reverse run	30 sec
2nd Forward run	30 sec
2nd Reverse run	30 sec
Off	6.02am

Table 3
Size of the single panel.

width	3feet 9 in.
Length	5 feet 14 in.

over the PV panel. The brush connected with the motor cleans the PV panel with constant speed operation. Again, the system comes back to original position after two set of run on the panel.

We have considered a 250Wp panel with 6*10 number of cells, the specification of the PV panel is given in the Table 1 and the size of the PV panel details are given in the Table 2. The total operation consists of 2 cycles with two forward and two reverse operation as per the time period shown in the Table 3.

3. Conclusion

Even though so many methods are discussed in this review, our method consists of very less components and no sensing devices, simple operating mechanism. Due to regular cleaning with proper interval, it will give better performance and improves the system efficiency by 15–20%. The maintenance cost also is less because of no usage of water and it will not create any electric short circuit and damage in structure of the PV panel. The cost of the total system is very less compared with all other systems. The overall degree of deterioration decreased, and efficiency of the PV panel increased.

CRedit authorship contribution statement

K. Jaiganesh: Investigation, Writing - original draft. **K. Bharath Simha Reddy:** Conceptualization, Writing - review & editing, Supervision. **B.K.D. Shobhitha:** Formal analysis, Data curation. **B. Dhanush Goud:** Writing - original draft.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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