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Enhance and Maintain Efficiency of Solar Panel using Auto Cleaning System

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Abstract**—**The conventional sources of energy are depleting rapidly. Which lead the world towards the trend of renewable energy sources. Among renewable energy sources solar PV is one of the major sources of energy. This technology of solar PV faces many challenges. Among these challenges dust accumulation on surface of solar panel is a major problem which leads to sharp decline in solar panel output power and hence efficiency. Different studies suggest that the efficiency of solar panel can be reduced by half of its maximum efficiency if not cleaned for a month. To tackle this problem of dust accumulation, in this thesis an automatic cleaning mechanism has been designed which automatically detects dust accumulation on the surface of solar panel and clean it using a vacuum blower. In this experimental setup a solar panel of 40 watts along with 2 DC motors of 12V supply. The vacuum blower slides over the surface of the solar panel using a cart in backward and forward direction for a few seconds. The supply used for this dc motor and hence the vacuum blower is made from the lead acid battery charged from the same solar panel. The maximum output efficiency of the panel is declined to 70% when dust is accumulated on its surface. Arduino microcontroller is used for triggering the motor and hence the vacuum blower. As vacuum blower is used for cleaning purpose, so this method is free from water wastage. Results showed that the efficiency can be improved to 18-20% after one round of cleaning using this automatic cleaning system.

Keywords**—** Solar Panel, Efficiency maintaining, Cleaning, Hardware, arduuino.

I. INTRODUCTION

In today's world, energy is divided into two forms, renewable energy resources (RES) e.g. Wind, solar, geothermal etc. and nonrenewable also known as conventional energy resources i.e. coal, fuel, gas etc. While back in 19th century, after industrial revolution, fossil fuels (like coal and oil) were commonly used to generate energy. It is a fact, that fossil fuels are depleting quotidian due to profligate use besides that they are proved to be harmful for greenhouse as they release CO_2 which directly effects Ozone layer and it is noted that world's temperature is increased about 0.9 Celsius by 1880 [1]. According to NASA's research an increase of 1 Degree Celsius is enough to warm all oceans, lands and atmosphere [1]. Keeping in mind the environmental impacts and energy crisis of 1973 world needed to change their primitive energy production methods. Thus, the new and better era for search of energy resources started, where environmentally friendly, clean and sustainable energy resources were required which must be competent to completely supplant fossil fuels. As a result of this search RES were tested and accepted by society as they fulfill all the demands and requirements. Solar panels can generate electricity without any waste or pollution, or dependence on the Earth's natural resources once they are constructed. They have no moving parts, so modules are very reliable and have a long-life span. Solar panels are relatively easy to install and are very low maintenance.

A useful characteristic of solar photovoltaic power generation is that it can be installed on any scale as opposed to conventional forms of power generation that require large scale plant and maintenance. Solar panels can be installed to generate power where it is needed, which removes the need to transport and distribute electricity over long distances to remote areas.

A. Background of using Solar Energy.

Sun is the only and powerful gift of nature to humanity due to which live exist but from study material solar energy was used by humans as early as 7th century B.C. when history tells us that humans used sunlight to light fires with magnifying glass materials.

In the late 1700s and 1800s, researchers and scientists had success using sunlight to power ovens for long voyages. They also harnessed the power of the sun to produce solar-powered steamboats. Ultimately, it's clear that even thousands of years before the era of solar panels, the concept of manipulating the power of the sun was a common practice. In 1953, Calvin Fuller, Gerald Pearson, and Daryl Chapin, discovered the silicon solar cell. This cell produced enough electricity and was efficient enough to run small electrical devices. The New York Times stated that this discovery was "the beginning of a new era, leading eventually to the realization of harnessing the almost limitless energy of the sun for the uses of civilization. [2]"

The period from the 1970's to the 1990's saw quite a change in the usage of solar cells. They began showing up on railroad crossings, in remote places to power homes, Australia used solar cells in their microwave towers to expand their telecommunication capabilities. Even desert regions saw solar power bring water to the soil where line fed power was not an option.

Today we see solar cells in a wide variety of places. You may see solar powered cars. There is even a solar powered aircraft that has flown higher than any other aircraft Sun is the only and powerful gift of nature to humanity due to which live exist but from study material solar energy was used by humans as early as 7th century B.C. when history tells us that humans used sunlight to light fires with magnifying glass materials. except for the Blackbird. With the cost of solar cells well within everyone's budget, solar power has never looked so tempting.

The main research question which we want to solve are 1) How to achieve maximum level of output from solar panel? 2) How to maintain efficiency of solar panel at maximum level? 3) Find the best way of cleaning solar panel to maximize its performance.?

B. Organization of paper.

This paper follows standard organization having introduction, literature review, methodology, results and conclusion. Section 1 is Introduction, which delineates a brief background and evaluation of solar energy and solar panel. Section 2 is Literature review about the studies which are been done and what new this work is offering. Section 3 is about methodology. Design parameters and control strategy is delineated. Section 3 is followed by result chapter i.e. Section 4 in this portion results are explained one by one with brief explanations and it is tried to elucidate that how by optimizing fatigue and structural loads power can be maximized. And in Section 5 we concluded the whole project that what we achieved which we planned. And Section 6 and Section 7 are about limitation of a system and future work.

II. LITERATURE REVIEW

As gathering of dust on the solar PV panel lessens its transmittance which brings about the decrease of the power yield, in this manner bringing about loss of energy age. This specific issue is likewise in charge of the short life expectancy of numerous interplanetary investigation missions, for example, Mars Exploration Mission of Curiosity Rover as the power yield from their solar PV panels decreases after some time as a result of the gathering of clean. At a state of time thickness of dust increments to level where control yield decreases to the degree which can't bolster its fundamental capacities. Promote this issue has likewise brought about colossal losses for the solar PV influence plant administrators which experience the ill effects of lessened influence yield considering regular dust accumulation [3].

A. Manual cleaning.

Traditionally cleaning framework was done physically. The manual cleaning has weaknesses like danger of staff mishaps and harm of the boards, development troubles, poor upkeep and so on. The programmed tidy cleaning arrangement of solar PV has taken to defeat the troubles emerge in the conventional cleaning and furthermore creates a viable, non-grating cleaning and keeps away from the inconsistencies in the efficiency due to the affidavit of clean [4].

B. Automated cleaning.

Cleaning development for solar panel exhibit can propel viability of intensity made and secure the solar PV cell. The strategies for dust clearing, for instance, common methods, mechanical cleaning, self-cleaning Nano-film, and electrostatic method are discussed [5] [6]. This is supposed to help scrutinizes with picking up a broad insight of self-cleaning system for sun-based boards and other optical contraptions. The reason for this task is to build up a programmed self-cleaning system for cleaning the sunlight-based board with the goal that the procedure can turn out to be more dependable and quicker, therefore expanding the power yield of the sun powered power plant [7]. Distinctive advancements being made far and wide for self-cleaning of sun-oriented PV are discussed underneath [4] [8].

C. Natural cleaning of dust.

Regular methods are used to oust the cleaning, for instance, wind control, gravitational energy and the scour of the water [9], [10]. The surface of solar panel can be cleaned if its orientation can be swung to upright or sideways in morning, night time and stormy weather. In any case, changing position of the solar panel is incredible. troublesome [9].

Cleaning impact of rainfall is to be viewed as computing yearly losses because of the defilement. In any case, surveying this effect is troublesome. There are two imperative variables to be featured. One is the measure of rain falling on the double, and the other worldly event of rain. The purging impact of rain in two imperative determinants the measure of rain fell on one event, and the recurrence of the rainfall. During raining period, the dust accumulation is negligible because of frequent raining but during summer dry period dust removal by natural means become rare. For this situation, the purging impact of rain is negligible. As the level of radiation and long stretches of daylight in the late spring semester are the greatest, this is path ruining of boards caused the heavy losses in power age amid this time of year. The force of ruining of PV modules is the best on summer dry period. Amid the late spring half-year, the most noteworthy power age, and consequently the soil amid this period causes critical losses [4] [11].

D. Mechanical evacuation of residue.

The mechanical systems [15] empty the residue through scrubbing, vibration and ultrasonic drive. The scrubbing procedures unsoiled the sun-controlled cell with the help of a

sweeper or brush which was driven by a motor, construction wise like windscreen-wiper of a car. In any case, immediately, owing to the little dimensions and the sturdy adhesively of the residue, this technique for dust removal is wasteful. Likewise, the loathsome working conditions of the sun powered PV makes the upkeep of the machine troublesome. By then, because of significant zone of the sun based solar panel show, that the machine used for cleaning is competent. Taking everything into account, the glass surface of the solar panel potentially was hurt by the brush while rubbing Expelling the cleans using vibration and other methods using ultrasonic is furthermore a generous mechanical cleaning [14]. The main consideration of this method is the methodology used for driving, the repeat and the eventfulness of the sun-controlled cell. [13] Williams R. Brett and his gathering considered the shuddering depiction of oneself cleaning sun powered boards with piezoceramic incitation. Their examination is still at the basic period of examination [9].

E. Self-Cleaning Nano-film.

When exterior of the sun-controlled panel display is anchored with a pellucid layer of Nano-film, it will remain tidy [13]. The composition of self-cleaning Nano-film is super hydrophilic material or super hydrophobicity material. It suggests oneself cleaning segment of the Nano-film incorporate two approaches [9].

TiO_2 is a champion among the most well-known super Hydrophilic material which has both hydrophilic and moreover photocatalytic characters. There are two stages in this cleaning strategy. Foremost is the is the photocatalytic methodology, the splendid radiance descends on the surface of TiO_2 film, both reacts and the dirt ruptures apart [14]. After that as a result of the hydrophilic thought of TiO_2 disseminates the water on to the surface of the sun-oriented board and flush the clean. Regardless, the above-mentioned technique isn't such outstanding in light of the way that sun powered power plants are generally arranged in the dry locale where precipitation is uncommon and unusual in nature [8].

Super-hydrophobic are those materials which indicate abnormal state of aversion to the water atoms. For instance, leaves of lotus plant which are have less wettability. As of late parcel of studies have been directed to recreate the hydro-phobic nature by framing small scale structures or Nano-structures [15]. These structures are outlined with the end goal that they make a contact edge of more than 150. Subsequently, the water beads that fall on these sorts of surface move off the surface, conveying natural and inorganic clean particles with them. In this manner cleaning the surface. Be that as it may, there is still a great deal of suspicion in the utilization of super hydrophobic material in self-cleaning application [16]. It is proposed that future examinations ought to be led to check the attainability of these kinds of materials in genuine world [8] [17].

F. Electrostatic removal of dust.

Electrostatic dust removal is a model electric system. After conducting research Clark P E, MiNET to F an and Keller J prescribed there might be two probable instruments of elements charging on surface of the moon. 1) Triboelectric charging, 2) Photoelectric effect using UV light. Consequently, assuming there is a high gradient on the exterior of the solar panel, the charged and uncharged dust particles will be pulled to the sheets in light of the electrostatic forces. At the end the solar panel will charge the particles and they will have comparative electric charge and electrostatic force of abhorrence. Ultimately, the perfect elements will drift apart the solar panel. Regardless, this strategy can't be used as a piece of PV structure, in perspective of the influencing of rainfall on earth. The well known the electric powered dust cleaning advancement relies upon the electric window adornment thought made by F.B. Tatum and associates at NASA in 1967 and also made by Masuda at the University of Tokyo in the 1970s[18]. The mentioned approach is seemed to elevate, and transfer charged and uncharged dust elements by means of electrostatic and dielectrophoretic powers [11]. Starting late, various investigators have engrossed the ways in which this development been associated for astronomical applications on the moon and Mars. Electrify window trimmings contain a movement of identical terminals introduced in a dielectric surface, transversely over which these movements are conveyed in the anode potential outcomes figure 1 [9]. At instant when the terminals interface with a multiple-stage AC voltage, a voyaging ripple galvanic shade be energized (appeared as figure 2 [19]. With the appropriate repeat and adequacy circumstances, the excited elements won't be permitted to store, anyway will be assigned to pass aside the outward after the electric field. Thusly, the exterior will remain free of particle oath [4].

G. Electrodynamic screens method.

In this paper author proposed for Electrodynamic Screens (EDS) process for cleaning of solar PV panels. Straightforward Electrodynamic Screens (EDS), comprising of lines of straightforward parallel cathodes inserted inside straight- forward dielectric film can be utilized for clean expulsion [14]. At the point when the anodes are stimulated by staged potential, the tidy elements on the SPV exterior of the film turn out to be electrostatically charged and are evacuated by the voyaging wave created by connected electric field [19]. More than 90% of stored tidy is evacuated inside two minutes, utilizing a little portion of the vitality delivered by the boards. Method proposed in this paper is useful for dry climatic, yet it has requirements in muggy conditions [20].

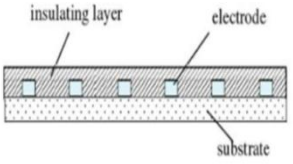

Figure.1

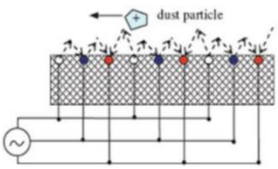

Figure.2

Clean isn't the main factor, different variables like flying birds dropping, water stains and so on comes into picture which diminishes the proficiency of the PV boards, where the previously mentioned procedure would not be effective [9][21]. All the methods discussed have certain merits and demerits. Therefore, in this thesis a different method is proposed for design of automatic cleaning system for solar panel using vacuum blower. The vacuum blower used will be power efficient and, in this way, we can avoid huge wastage of water used in other cleaning methods.

III. METHODOLOGY

Several methods for cleaning of solar panels are discussed in the previous section. Each method has its own merits and also some demerits due to which they are not feasible enough to be used. In this project an auto-cleaning system for solar panels is designed using vacuum blower to cope the problem of dust accumulation on solar panel in an efficient way. In this section detailed design of the prototype is discussed.

A. Block diagram.

According to block diagram a detection device is used to detect dust accumulation on surface of solar panel. Light sensors are mostly used. This light sensor is further connected to a microcontroller. Microcontroller is programmed in such a way that a predetermined threshold value is set. Whenever this threshold value is exceeded it activates the cleaning mechanism, vacuum blower in this case which cleans the surface of solar panel.

B. System components.

The components used in design of this prototype is 1) Light detection Sensor: for detecting sun light. 2) Solar panel. 3) Arduino. 4) DC motor drive: L293D IC package of 12V is used. 5) Cleaning mechanism: Vacuum blower with dc motor drive. 6) Cart: for sliding the vacuum blower over the solar panel. 7) Software proteus: For simulations.

C. Light detection sensor.

There is no built-in sensor in proteus, so a light sensor is designed with the help of components in proteus library. A sunlight detection sensor is used to find either there is sunlight around the solar panel or not. If there is solar radiation but efficiency of solar panel(voltage) is below a specific value, the threshold then it means that there is dust accumulation on solar panel. Microcontroller will trigger the vacuum blower for cleaning the solar panel. But if there is no sunlight that is output of the light sensor is below a specific threshold value, then it will indicate that its cloudy weather or night time so, it means this is not the case of dust accumulation and no triggering of vacuum blower. Output of light intensity sensor is also taken in volts.

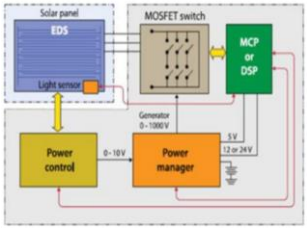

Figure 3. Block Diagram of EDS/PV array system [4].

Figure 4. Block diagram of Auto Cleaning Mechanism

There are two circuit components of light detection sensor. 1) LDR: Light dependent resistor is used for irradiance strength estimation. LDR is a light dependent resistor, its resistance varies as irradiance strength changes. Due to resistance variation output voltage will vary and in this way changes in solar radiations can be measured 2) RESISTOR: A 10K ohm resistor is used with LDR and output voltage is taken across this resistor. 3) VOLTAGE SOURCE: A voltage source B1 of 12V is used, which gives a maximum output of 11V with 10K ohm resistor.

D. Solar panel.

A solar panel is also modeled in proteus as there is no built-in solar panel in proteus library. It is only a logical model for implementation of basic idea, for detail and accurate measurements the above system can be implemented in hardware.

E. Arduino microcontroller.

Arduino UNO R3 is used as microcontroller for triggering the cleaning mechanism. The Arduino Uno R3 is a microcontroller board in view of a remount able, double inline-bundle (DIP) ATmega328 AVR microcontroller. It consists of 20 hi-tech input/yield pins (of which 6 pins can be used as PWM output and 6 can be utilized as simple sources of info [22].

F. L293D H-Bridge IC drive.

L293D is a dual H-connect engine motorist coordinated loop (IC). Engine drivers go about as current and flow speakers since they take a low-ebb and flow control flag and give a higher-ebb and flow flag. This high current pulse is used to operate the machines [23]. L293D composed of two inherent H-connect source circuits. In the genuine procedure of working, both the DC machines can be operated all the time, both in advancing and backward movement. The machine activities of two motors can be managed through input at pins logic 2 and 7 and 10 and 15. Information logic 00 or 11 will seize the comparing machine logic 01 and 10 will turn it in clockwise and anticlockwise directions individually. Empower pins 1 and 9 (comparing to the two engines) must be high for motor to start operating. At the extremity when an empower input is high, the interconnected machine will start operation. Afterward, the output stops self-motivated and work in phase with their data sources. Also, when the source input is low, that driver is debilitated, and their outputs are low and in the high-impedance state.

We are using small machines which could be handle by L293D IC which have its own optocoupler with H-Bridge connection for driving and isolating motor from Arduino microcontroller.

G. Vacuum blower.

A vacuum blower with simple dc motor-driver of 12V is used for cleaning purpose. Actual ratings of dc motor to be energy efficient, will depend on practical scenario of solar panel and its output voltage. For simulation purpose motor drive of 12V DC is used. It is connected to two output pins of L293D, pin no 3 and 6.

H. Cart.

Vacuum blower is mounted on a cart which can move forward and backward on the solar panel surface, the cart is also connected to the two output pins of L293D that is pin no 11 and 14. Dimensions of cart depends on actual size of solar panel used for observation purpose.

I. Proteus.

The Proteus Design Suite is an exclusive programming device software applied primarily for electronic outline robotization. The invention is employed principally by electronic plan engineers and professionals to make representations and electronic designs for buildup printed circuit sheets. Proteus design environment is a developer application used for simulations and design implementation in soft-ware. It tends to be bought in several combinations, depending upon the extent of plans to be developed and the provisions for microcontroller modernization. All PCB Project objects integrate an auto switch and essential combined mode SPICE reenactment potentials of plans and as the outline duration of a PCB set-up venture. It is in this manner a focus part and is merged with all element designs. The previously mentioned venture is reproduced in Proteus8.TIMER. In addition to the light detection sensor a timer is also inserted in the project model to enhance the efficiency and reliability of the dust cleaning system of the solar panel.

J. Detail chart flow.

Figure 5 is given the detailed flow chart of the working sequence of the simulation model. According to the flow chart there is cleaning mechanism, which depends on light intensity and hence the dust accumulated on surface of solar panel. The sunlight intensity sensor will monitor the intensity of sunlight continuously. Arbitrary values are chosen for Lux and voltage of 70 for the solar panel under observation. If the output of light sensor is less than 70, then there will be no triggering of cleaning mechanism and cycle will go to an end. Because it means there is no sunlight and efficiency are declined because of shading or cloudy weather and there is no dust accumulation impact. If this output of light sensor is greater than 70 and output voltage of solar panel is less than 70, then it means there is sunlight, but dust is accumulated on the surface of solar panel so output voltage and hence efficiency of solar panel is declined. Microcontroller will trigger the cleaning mechanism and it will operate until efficiency(voltage) of solar panel goes to its nominal values. The blower is mounted on the cart and will move backward and forward with a specific time delay of 2sec and 3 sec respectively. This cart movement delay will depend on solar panel size and dimensions in practical real word application. If the solar panel is lengthy and wide then this time delay will increase and vice-versa.

K. System simulation model in proteus:

All the circuit is divided into four main blocks as shown in figure 6 the first block (left-top in 3.9) is LDR as light sensor for reference voltage and to find either it is sunny day or not. and second block is solar panel, if there is sunny day but output of solar panel is less than Light sensor so it's mean that the panel want to be clean which is what decide by Arduino module and all the cleaning algorithm is program in third block (second and third block is shown right-top and left bottom section of 3.9.) and the last block are output module when panel need to be clean then Arduino activate blower

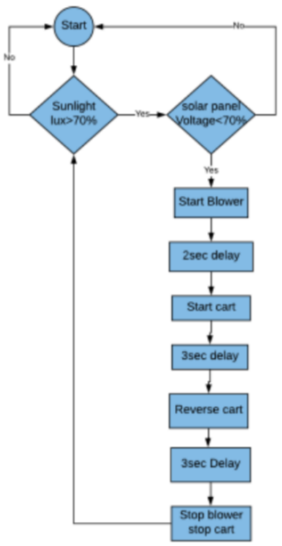

Figure 5. Block diagram of Auto Cleaning Mechanism

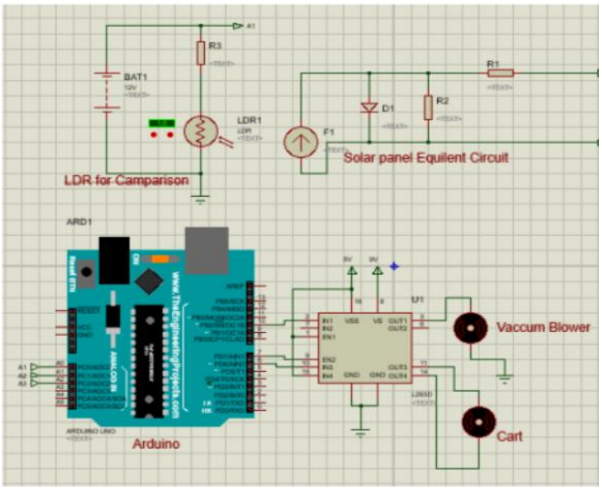

Figure 6. System Simulation Model in Proteus

IV. RESULTS AND DISCUSSION

A. *Effects of dust accumulation on different electrical parameters of solar panel.*

An indoor experimentation was steered to find the effects of dust accrual on surface of solar panel.

The above figure 7 show voltage characteristics of the solar panel under observation. First the data of clear surface of solar panel is taken which gives a maximum voltage of 18.86 volts for a maximum luminous intensity of 21500 W/m2. The table given below shows the data collected during experiment using clear solar panel.

Power generated by the solar panel is given by P=VI. At clear surface maximum yield was obtained from the solar panel. But as layers of dust started to accumulate on surface of solar panel the area under the curve gets smaller and smaller. Hence power generated gets lessen and lessen. Figure 8 shows the data of dusty panel.

Figure 8 show us that due to dust accumulation there is a slight reduction in panel's voltage and hence power. The maximum voltage obtained in this case is 18.32 volts at maximum lux of 21500 W/m2. The table given below illustrate the data for dusty panel collected during experiment.

B. *Effects of dust on voltage of solar panel.*

Accrual of dirt on exterior of PV panel also leads to a decline of efficiency of the solar PV. Efficiency of PV array is observed on the basis of voltage variation of clear and dusty panel.

$$n = \frac{V_p x I_P}{P_s x A}$$

Vp and Ip are voltage and current of solar panel, whereas Ps is the power generated and A is the surface area of the solar panel. A comparison is made between clean and dusty panel voltage on the basis of experimental data collected during performance. The graph below shows that there is a slight reduction in panels voltage due to dust accumulation on surface of solar panel.

This reduction in panel voltage can lead to a decline of panel's efficiency up to 40-50% in worst cases. This can lead to loss of power which is an enormous amount. The table below shows data collected during experiment for clear and dusty panel.

The maximum efficiency can be achieved that is of 90% for improving that efficiency from 71% reduced by dust on maximum luminous intensity i-e on sunny day.

C. *Prototype analysis.*

The prototype designed in this thesis can be used to clean surface of solar panel and efficiency of solar panel can be enhanced up to 18%. A solar panel of 40 watts (20 volts) is used which can give maximum output of 36 watts as efficiency of most panels is 18-16%. If the power of solar panel is declined from 20 watts to 18 watts there is 10% decrement in output power of the solar panel.

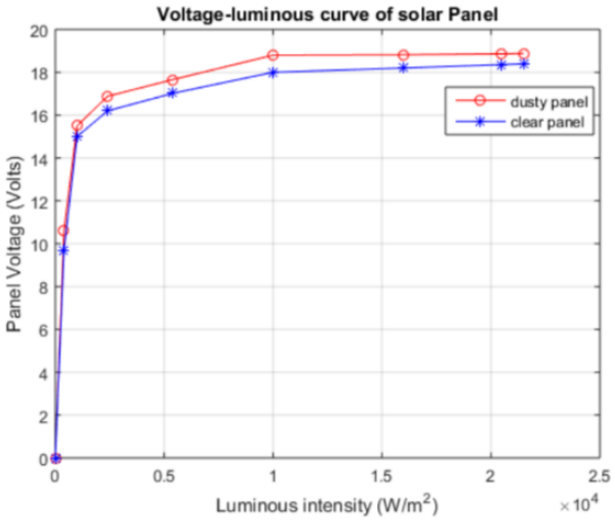

Figure 7. Voltage-Luminosity Graph of PV

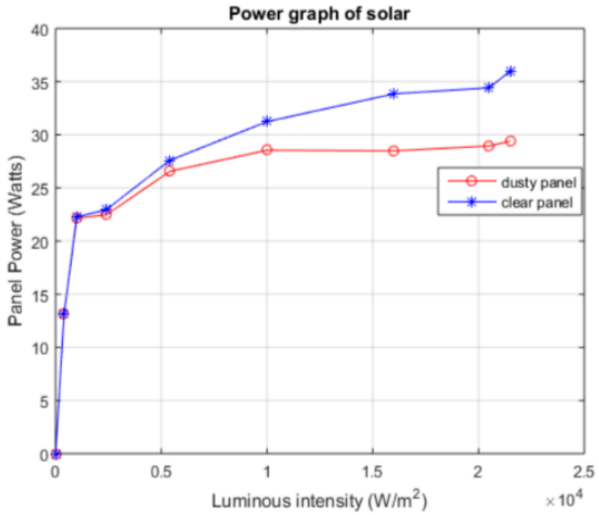

Figure 8. Power-Luminosity Graph of PV

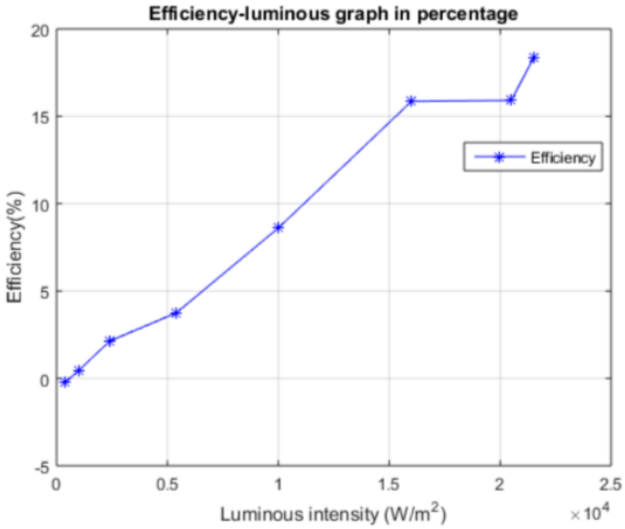

Figure 9. Efficiency-Luminosity Graph of PV

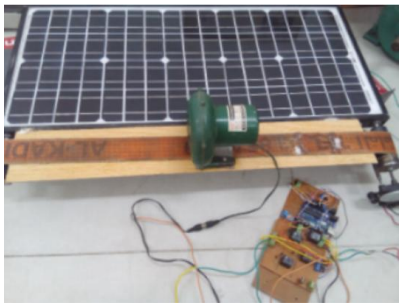

Figure 10. Prototype Analysis

But due to dust this reduction is decline to 30%. With the help of this prototype the 30% loss in output power of the solar panel can be avoided or can be reduced to a small value. Motor of cart and blower combinedly consumes 35 watts, but the duration of its operation is very small i-e 6 seconds. Length of the solar panel and the belt used for sliding the blower is 1m. As mentioned above the time of operation for the blower and cart is 6 seconds so power consumed during this short duration of time is negligible. Therefore, the power required from the solar panel to operate this prototype is not a problem.

CONCUSLION

It was shown during experimental analysis of this thesis that soiling has a negative impact on overall performance of the solar panel under examination. Graphical data collected during observation shows that output power of the PV panel can be declined up to 70% in the absence of the auto cleaning system designed specifically in this thesis for cleaning the solar PV. By practicing the auto cleaning system, which will detect if there is dust accumulation on the surface of solar panel and clean automatically the soiling effect, the overall output power and hence efficiency of the solar panel can be improved up to 18-20%. Beside improvement in output power and efficiency of the solar panel, there are certain other advantages of using auto cleaning system for the solar panels. Firstly, this mechanism of cleaning the solar PV is economical as no money has to be paid to companies or no labor force is required. Secondly in this method a vacuum blower is used for cleaning the solar panel so there is no wastage of water and this method can be very useful in arid zones where there is scarcity of water. Another advantage is that it is an automatic system so it is time efficient, there is no wastage of time. As soon as dust accumulation is detected on the surface of solar PV, the cleaning mechanism will start to operate until efficiency of the solar panel is restored to its nominal value. Besides the periodic cleaning of solar panel will results in good transmittance and full utilization of solar energy during peak sun shine hours. As no brushing and rubbing is used in this cleaning method so no deterioration of the solar panel surface. Finally, this method of cleaning the solar panel using vacuum blower is environmentally friendly and will prolong the lifespan of solar panel by preventing shading impact of solar panel. Note that the motor used for operating the vacuum blower is energy efficient as the kwh ratting of this motor is with cart is 5.82x10−5 KWh (as they operate only for 6 seconds) is very less as compare to solar panel i-e 3.6x10−2KWh. It is clear that the financial profit of improved production and protecting the lifetime of the panels significantly compensates the cost of regular maintenance of the PV modules surface.

LIMITATION

Limitation of our project are as follow;

- It is not so helpful for mud removal because of we used vacuum blower but if we use water spray along with brushes this limitation can be overcome.
- For more dusty areas the dust accumulation on panel is high so dust accumulation is directly related to cleaning mechanism due to which power consume by cleaning mechanism is more but this is probabilistic and operating only for 6seconds as per time so the power consumption is not so high to make panel overloaded.
- This project is only feasible for large scale solar parks.

FUTURE WORK

The prototype designed in this thesis is the basic design for solving the problem of dust accumulation on solar panel. Further changes can be made to this prototype to rectify it further and hence to improve its efficiency. Following work can be done in future to enhance efficiency of the above-mentioned prototype.

- Vacuum blower of low ratting can be designed to lower the power consumption from the solar panel.
- Additional development will optimize the system to be smaller, lighter, easier to assemble in higher volume and more user-friendly.

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