

Automatic Solar Panel Cleaning System Based on Arduino for Dust Removal Sover

Abstract—Solar panel is vulnerable to accumulated dust on its surface. The efficiency of the solar panel gradually decreases because of dust accumulation. In this paper, an Arduino based solar panel cleaning system is designed and implemented for dust removal. The proposed solar panel cleaner is waterless, economical and automatic. Two-step mechanism used in this system consists of an exhaust fan which works as an air blower and a wiper to swipe the dust from the panel surface. a dc motor is used to power the wiper. Since, the system does not need water to clean solar panel, it avoids the wastage of water and effective in desert areas. Experimental results show that the proposed cleaning system can operate with an efficiency of 87-96% for different types of sand.

Keywords—*Arduino, Dust removal, Sand removal, Solar panel cleaner, Air blower.*

I. Introduction

To ensure sustainable environment, solar energy can play a vital role because it is an enormous, inexhaustible and green source of energy. Solar energy is directly usable for electrical power generation for a variety of applications which includes residential, commercial and industrial uses. It can provide the necessary amount of electricity without any threat to the environmental and health issues because no harmful gasses are emitted at the time of energy conversion. Moreover, the total sunlight that hits the surface of the earth in an hour and a half, according to the US department of energy, is adequate to manage the yearly energy consumption of the whole world. It is estimated that, the total amount of fossil fuel which is stored in the earth is equivalent to the energy produced from the sunshine on earth of around 18 days [1].

In a solar energy system, photovoltaic (PV) solar panel provides DC electricity from the continuous flow of energy from the sun. MPPT method based on Fuzzy logic controller is presented in [2] to produce maximum energy from PV system. Once the installment of solar panels has been completed, the fuel is free. The operating cost of the system is very low when compared to other energy production methods. However, solar energy is CO₂ free renewable energy source, the routine maintenance of solar panel is required. The particles of dust on the solar panel come mainly from urban and industrial products. SiO₂, Al₂O₃, Fe₂O₃, CaMg(CO₃)₂, Ca(OH)₂, CaO and CaCO₃ are some sorts of dust particles found on the solar panel [3]. Dust Accumulation on the surface of solar panel has serious impact on the system's efficiency. It is estimated that, about 50% of system's efficiency can be reduced and almost 15% power losses can be occurred in dry areas [4]. Therefore, it is essential to keep solar panel's surface clean as much as possible.

Nowadays, different electrostatic cleaning methods and water-based methods are available and widely used as solar

panel cleaner. A semiautomatic wiper control system-based cleaning method is presented in [5]. A maximum efficiency of 86.7% is achievable by this cleaning mechanism. Multiple cleaning systems which include air and water, vibration is presented in [6] for the harsh desert environment. The output power of the system is increased by 27% by using a water jet spray. A self-cleaning method is proposed in [7] which is automatic. To design the system, a 50 W_p solar panel is used which can generate 26-50% more electricity with the proposed cleaning method than a normal solar panel. The whole system is controlled by a microcontroller. Another wiper control method-based two steps cleaning system is developed in [8] where water is first applied on the panel surface and then the wiper is triggered. The system's efficiency becomes 17.55% after cleaning which is quite identical to the average efficiency of the system before dust accumulation.

Electrostatic dust removal is another type of efficient method but it is not suitable for pole mounted PV installations. An electrostatic cleaning equipment is proposed in [9] which is economical and suitable for the mega solar power plants in deserts. The proposed system shows better performance when the dust is less than 5 g/m².

A self-cleaning method based on electrostatic travelling wave is designed in [10] where the system consists of transparent dielectric film and parallel electrodes. With this system, 90% of total dust is cleaned within 2 mins without any water and moving parts. An automatic robotic cleaning system is presented in [11] where a silicon rubber brush is used with an aluminum core to clean the surface of solar panel. On the other hand, Surface acoustic wave is utilized in [12] to remove the spoiling particles from the surface of solar panel. Cleaning effects of surface acoustic wave are also analyzed in this study where spoiled solar panels are used.

Another cleaning technique is developed in [13] which is a transparent super hydrophobic anti-soiling coating on the solar panels. Multifunctional silica nanoparticles and polymeric binders are utilized to develop the coatings. This technique is greatly efficient when the dust particles are less than 200 nm. Though the anti-coating techniques are cheap and easy to apply, water is still a big concern here. An autonomous vacuum cleaning method is designed in [14] with a combination of robot and docking station. The robot works on two-stage cleaning mechanism and can be charged automatically using power from solar panel when needed. An Arduino based robotic arm is designed in [15] which can conceptualize a chess board and has the ability of playing chess.

In this paper, an automatic and economic solar panel cleaning system is proposed for dust removal. The proposed system is waterless and works on two steps cleaning mechanism. Therefore, wastage of water is completely avoided by this system. Exhaust fan works as an air blower

which initially removes the dust from the surface of the solar panel. Then, a wiper is utilized to swipe the remaining dust on the surface.

II. METHODOLOGY AND DESIGN

The proposed solar panel cleaning system uses two-step cleaning techniques. First, an exhaust fan removes dust from the surface of the panel as much as possible. Four different types of sands are used here as dust. Then a wiper made of soft clothes are used to swipe. Therefore, no water is needed for the system for cleaning. This feature keeps the solar panel safe from scratch. The proposed solar panel cleaning system is fabricated with easily accessible components. The prime units are solar panel, microcontroller (Arduino Uno), metallic dc gear motor, buck boost converter and motor drive module. The specifications and motive of some major components used in the proposed cleaning method are presented in Table I.

TABLE I. PROPERTIES OF MAJOR COMPONENTS

| Name | Purpose and Rating |
|----------------------|---|
| Solar panel | A 250W solar panel is used in this system. Its output voltage and current are 30.3V and 8.27A, respectively. |
| DC gear motor | Metallic dc gear motor is connected to the cleaning shaft in order to operate it. The operating voltage, current and speed are 6V dc, 0.4A and 100 rpm. |
| LDR sensor | A light dependent resistor (LDR) is used here to track the sunlight. |
| Wheel | Four wheels are used in this system which moves the cleaning shaft upwards and downwards. |
| Buck boost converter | A dc-dc buck boost converter is used here to supply constant voltage. |

Some other components are used in this system as supporting components. A motor drive module is used to drive the motor and the motor operates with the solar dc power. Push button is also utilized here to set the limit of the movement of the cleaning shaft. Exhaust fan is used to remove the dust from the surface of the solar panel. The complete circuit diagram of the proposed solar panel cleaner is shown in Fig. 1.

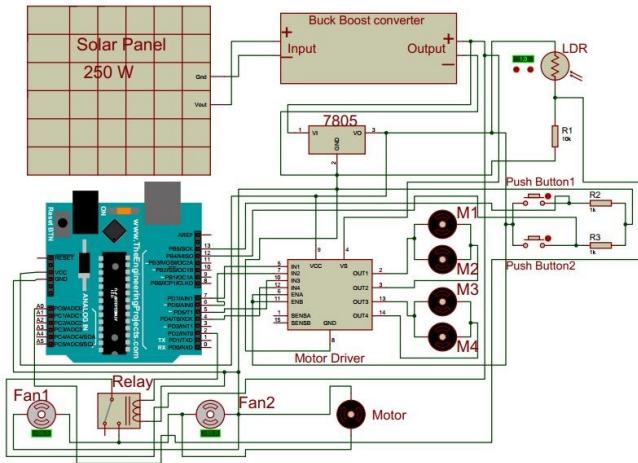


Fig. 1. Complete circuit diagram of the proposed system.

In Fig. 1, a solar panel is placed in the top left corner which produces dc electrical power. A microcontroller is seen just under the solar panel. A buck boost converter is shown in the right side of solar panel which takes input from the solar panel and maintains constant voltage supply. A LDR and 2 push buttons are placed in the right side of the diagram. Four motors

M1, M2, M3 and M4 are shown in the middle of the diagram along with the motor driver, L298N to drive the wheel. A voltage regulator of 7805 is used here to supply the required voltage. the input of 7805 is 12V and it provides 6V as output. Another motor is used to operate the wiper and these are shown in the bottom of the diagram along with the relay switch. Power requirement of the electrical components included in the design is shown in Table II.

TABLE II. POWER REQUIREMENTS OF ELECTRICAL COMPONENTS

| Components | Power (W) |
|----------------------|-----------------|
| Arduino Uno | 0.5 |
| DC gear motor | 2.7 (per motor) |
| Motor driver module | 0.18 |
| Wheels | - |
| LDR sensor | 0.25 |
| Push button | - |
| Fan | 5 (per fan) |
| Buck boost converter | 6 - 70 |
| Solar panel | - |
| 7805 IC | 5 |

III. HARDWARE IMPLEMENTATION AND RESULTS

The proposed solar panel cleaning system is automatic and handmade. Simple architectural design is seen in this system including solar panel, cleaning shaft. A 250W solar panel module is used here which provides an output voltage of 38V (open circuit voltage). the output of the solar panel depends on the sunlight. A buck boost converter is used here to keep the output voltage constant. The output voltage of the converter is set at 12V dc. Therefore, the variation of the sunlight does not have any effect on the output voltage. two reference lines are set for the movement of cleaning shaft/exhaust fan. Each line consists of 2 motors and wheels. When the sunlight comes out, microcontroller and LDR measure the value and the whole system is designed in such a way that the system will start its operation at the beginning of the day typically between 10-11 am. Every morning, the proposed system tracks the sunlight for starting its operation even though there are no dust on the panel surface. Therefore, the proposed system is effective for any types of dust. Fig. 2 shows the full experimental setup of the proposed solar panel cleaner.



Fig. 2. Complete setup of the solar panel cleaning system.

A handmade cleaning shaft is depicted in Fig. 3. Four types of sand are used to justify the efficiency of the proposed system and shown in Fig. 4.

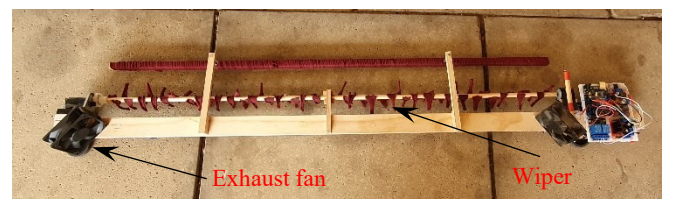


Fig. 3. Cleaning shaft of the proposed solar panel cleaner.

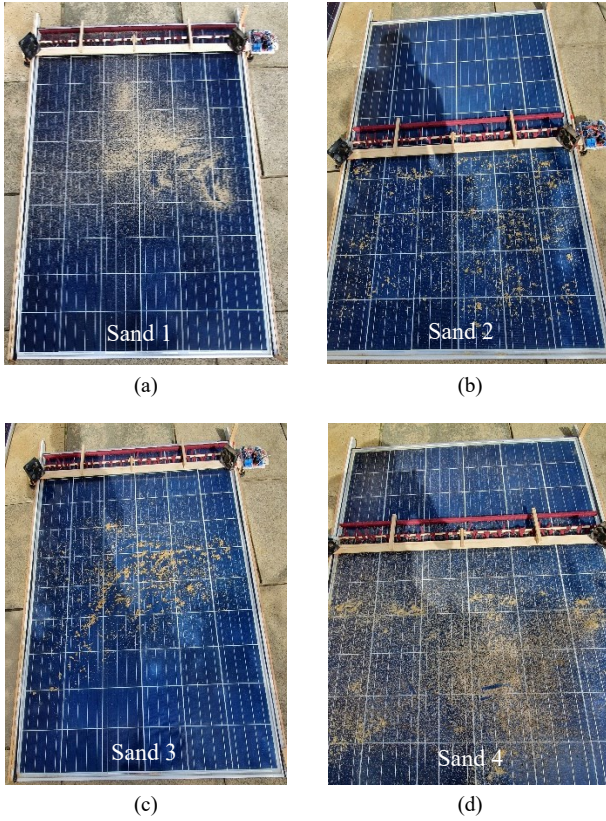


Fig. 4. Different types of sand used for experimental test.

Experimental results validate that the proposed solar panel cleaning system works efficiently at desired level. System efficiency and number of swept vary depending on the type of sands. The efficiency of the proposed system is around 87%, 91%, 92% and 96% for sand 1, sand 2, sand 3 and sand 4, respectively. The number of swept for completing the operation is 3,4,6 and 8, respectively. This proposed system works without water. Therefore, it can be used effectively in the areas which do not have a nearby water source. The proposed system is inexpensive and made with handy components. Performance comparison of the proposed solar panel during normal, dust and dust wiped condition is shown in Table III.

TABLE III. PERFORMANCE EVALUATION OF THE PROPOSED SYSTEM

| Condition | Output voltage (V) |
|-----------------------|--------------------|
| Normal (without dust) | 36.4 |
| Sand 1 | 33.1 |
| Sand 2 | 33.9 |
| Sand 3 | 34.3 |
| Sand 4 | 34.5 |
| After cleaning | 36.2 |

It is evident from Table III that the proposed solar panel cleaning system provides almost same amount of voltage after cleaning. The programming for solar panel cleaning system is visualized with the flow chart as shown in Fig. 5. Cost estimation of the system is given in Table IV.

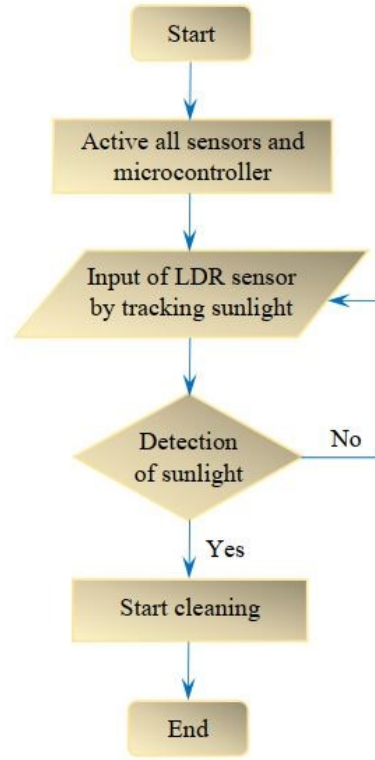


Fig. 5. Flow chart of the program used for solar panel cleaner.

TABLE IV. COST ESTIMATION OF THE PROPOSED SYSTEM

| Components | Price (BDT) |
|----------------------|-------------|
| Arduino Uno | 600 |
| DC gear motor | 1400 |
| Motor driver module | 150 |
| Wheels | 310 |
| LDR sensor | 10 |
| Push button | 10 |
| Fan | 120 |
| Buck boost converter | 100 |
| Solar panel | 3750 |
| 7805 IC | 5 |
| Total cost | 6455 |

The proposed solar panel cleaning system for dust removal shows some advantages over the existing cleaning methods. A comparison is done between the proposed and existing cleaning method and shown in Table V. The characteristics mentioned in the Table below, make the proposed solar panel cleaning system a novel one.

TABLE V. COMPARISON BETWEEN THE PROPOSED AND EXISTING SOLAR PANEL CLEANER

| Proposed solar panel cleaner | Existing methods |
|--|---|
| 1. The proposed cleaning system does not require water for dust removal. | 1. Most of the existing solar panel cleaner is water-based [4]-[6]. |
| 2. LDR sensor is used here which makes it an automatic cleaning system. | 2. No LDR sensor is seen in the cited works in this paper. |
| 3. The proposed robot is made with easily available components. Therefore, it is economical. | 3. Most of the existing cleaner is expensive compared to the proposed system cited in this paper. |

IV. CONCLUSION

In this paper, an automatic solar panel cleaning system is proposed and built with easily available components. The proposed system is inexpensive and does not require any water to do the cleaning operation. Thus, wastage of water is avoided here. And this feature makes this system applicable in the desert areas and where no water source is available. This proposed cleaning system is based on two steps mechanism where exhaust fans do the first part which is remove dust from the surface through air blowing. The second part is done by wiper. This feature ensure the safety of the panel because any type of scratch is not seen during the experimental tests. Experimentally the cleaning system is capable of serving its purpose.

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