Proceedings of the
International Conference on Mechanical Engineering and Renewable Energy 2019
(ICMERE2019) 11 – 13 December, 2019, Chittagong, Bangladesh

ICMERE2019-PI-202

DESIGN AND FABRICATION OF AN AUTOMATIC SOLAR PANEL CLEANING SYSTEM

Md. Omar Faruque[1], Dr. Muhammad Mostafa Kamal Bhuiya[2], Salman Ahmed[3], Fahad Munshe[4]

Department Of Mechanical Engineering, Chittagong University Of Engineering And Technology
Chattogram-4349, Bangladesh
omar.faruque2312@gmail.com[1,*], mkamalcuet@gmail.com[2], salmancuet5630@gmail.com[3],
mdfahad2301@gmail.com[4]

Abstract- *An experimental investigation was carried out to design and develop an experimental setup for removing the dust particles of the solar panel applying an automatic cleaning system. The cleaning system was developed using the dust sensor and arduino microcontroller. The performance evaluation of the cleaning systems was carried out. It was observed that the solar panel efficiency level reduced about 2% if the modules would not be cleaned about five successive days. But using the automatic cleaning system the maximum efficiency fluctuates only from 13.99% to 14.07% which implies it helped to maintain the efficiency. The efficiency reduction was mitigated using the cleaning systems.*

Keywords: Dust Particles, Cleaning System, Arduino, Performance Assessment

1.INTRODUCTION

Solar energy is the cleanest, inexhaustible, easily available and an abundant energy resource available on the earth. Solar energy is one of the most sustainable energies in the world. The world is becoming increasingly dependent on renewable energies as well as on solar power because of the global warming. The sun has been burning for more than 4 billion years. The power of sunlight we get on the earth is about 125,000 TW [1], which is over 6,000 times more than the current demand consume in 27 years. The amount of solar reaction incident on the earth every 72 hours is equivalent to all energy stored in the Earth such as coal, oil, natural gas reservoirs. Solar energy can suffice the present and future energy demands of the world. The energy industry is also keen on moving towards providing the electricity in green and sustainable manner. Photovoltaic array installations are becoming more prevalent around the world. Each of these solar parks has an expected lifetime of 20 – 25 years, and it is vital to maximize the power generating potential during daily service. A semi-conductor is used in PV cell and most commonly it is silicon. In all PV cells, there are at least two layers of semi-conductors, in which one positively charged and one is negatively charged. Light incidents on the semi-conductor and the electric field across the junction between the two layers of silicon causes electricity to flow by releasing electrons and generates DC current. The more the intensity of the light, the more the flow of electricity. An operational diagram of PV cells is shown in Fig. 1. Countries like Bangladesh those have dusty environment, dust on the PV cells leads to reduction of the convertibility of electricity. Wind carries dust particles and deposit on the glazing materials and thus, it reduces their efficiency. The accumulation of dust particles on the surface of photovoltaic (PV) panels negatively affects the performance the same way as if on a cloudy day.

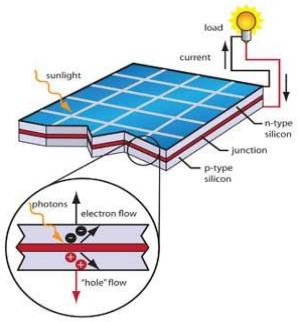


Fig. 1: Solar cell or PV cell operation Diagram [2]

In order for the PV cells to operate at maximum efficiency without energy loss, the panels' surfaces need to be clean and allow free entrance of photons. Both dirt and clouds block out the sun and have the same effect on reducing energy generated. Frequent objective inspections and spraying water on PV cell can help to reduce this problem. Cleaning regular will increase 10%-60% in efficiency. Many researchers studied at the effect of a dust and other impurities on the solar panel and much experiments have been carried out to clear up this trouble. Under are a few theories and researches which can be related to this mission. Previously, many works have been done for cleaning the dust on the solar cell. Many processes have been applied, some are manual and some are automatic. Sabah et al. [3] in this study, dust accumulation for solar panels was explored for roughly one year for a lengthy period of time. The findings were a decrease in the transmittance of the solar

cells, which emphasizes the impact of accumulated dust, despite the change in the tilt angel that is in competition with the deposition of dust on the panels. Casanova et al. [4] the accumulation of dust on the surface of the PV module reduces the radiation in the solar panel and then losses in the energy generated. Dust particles not only decreases the radiation on the solar cell, but also shifts the reliance on the incidence angle of such radiation. Elhady et al. [5] researches on influence of cleaning with water and surfactants on the performance of PV panels. Surfactants are used to remove the anionic and cationic dust. This methodology is implemented using a non-pressurized water system in order to study its applicability as a step to develop a cleaning system that can clean the PV panels with the minimum amount of water and energy. Mondal et al. [6] discuss about future aspects of automatic cleaning systems for solar PV panels. This paper discusses a comprehensive overview of dust problem and the recent developments made on automated cleaning system for solar photovoltaic modules which give brief overview on techniques like electrical, mechanical, chemical and electrostatic.

Mavroidis et al. [7] designed a robotic device for cleaning photovoltaic panel arrays using water spray. They found that the water being sprayed by the robot cools the panels while cleaning which can further increase efficiency of the array by up to 15%. Burke et.al [8] suggested a design without using water. This will assist solar panel arrays reach manufacturing output closer to their full capacity and can save companies on energy generation related expenses. Project SPACE's objective is to produce an automated solar panel cleaner that addresses the adverse effects of soiling on commercial photovoltaic cells. The analytical findings indicate a peak deflection at 4.41 degrees on the drive shaft. This deflection will take place at the farthest end of the motor. The peak deflection before plastic deformation of the beam was estimated to be approximately 62 degrees. Manju et al. [9] designed automatic Solar Panel Cleaning System It includes that the cleaning system designed cleans the module by controlling the Arduino programming. To remove the dust in the PV modules to improving the power efficiency.

The overall aim of this study is to design and establish an experimental setup for removing the dust particles of the solar panel using an automatic cleaning system. The specific objectives of this study are:

- To design and fabricate a single axis and a dual axis automatic solar panel cleaning system to remove the accumulated dust particles.
- To observe the cleaning effect of the single axis and dual axis cleaning system.
- To compare the performance of both automatic cleaning systems.

2. FABRICATION PROCESS

Two models are developed and fabricated which will automatically remove the accumulated dust on the solar panel for which the efficiency of PV cell decreases. A water jet strikes on the PV cell and a cleaning brush rolls on the surface on the forward-backward and also left-right direction. The main objective of this study is to reduce the decrement of efficiency due to the accumulated dust.

2.1 CLEANING SYSTEM MECHANISM

A dust sensor is used in leaning system. It checks if the density of dust has reached the threshold or not. If the dust level has passed, Arduino sends a signal to the motor and the motor starts running. The motor provides rotating movement to the belt drive and this rotary motion is transformed into linear motion, moving the cleaning device forward. At this point, the pump is started concurrently by the Arduino command. It provides water to the nozzles from the reservoir. And then the nozzles commence to splash water on the surface of the solar panel.

There is a limiting switch at the end of the stationary frame. The touch of the cleaning machine activates the switch and the rear movement begins at home. At home, there is another limiting switch. The limit switch essentially changes the direction of the motor rotation. This forward-backward movement continues like this. It continues 3 times after this whole process is repeated. When the dust passes the certain level again, the complete method continues again. The main benefit of the entire scheme is that it works with heavy duty rechargeable batteries on a dc supply. And it is possible to reuse the energy produced by the solar module to charge the battery. This system therefore offers energy recycling without any internal energy source being used. The flow chart of the cleaning mechanism working system is shown in the Fig.2:

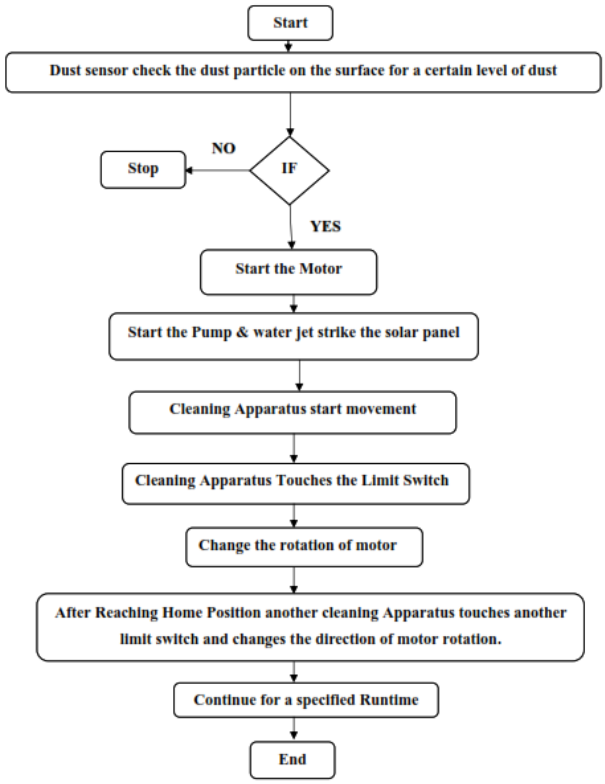


Fig. 2: Flow Chart of Cleaning System

2.2 EXPERIMENTAL SETUP

Both the cleaning system used the same microcontroller and the sensors. The moving frame of the single axis cleaning system was powered by a mechanism of motor belt drive where the moving frame of the dual axis and the moving body were powered by the mechanism of the gear motor wheel.

2.2.1 Equipment

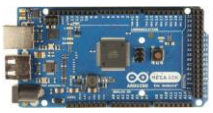
Various equipment had been used in the automatic cleaning system. In Fig. 3(a) a solar panel is shown Here it is the main element and for removing the dirt from this and observe the efficiency before cleaning and after cleaning. The rolling brush will clean its surface after the slash of water by nozzles. In This experiment two solar panel had been used. One is 20W another one is 5W. In Fig.3 (b) A 1-inch dia PVC pipe was used for the single axis cleaning system and a 0.75-inch dia PVC pipe was used for the dual axis cleaning system. For the complete cleaning of the solar panel, the belt drive shown in Fig. 3(c) is used to push the brush with the wiper forward and backwards. Two A75 belt was used in the Single Axis Automatic Solar Panel Cleaning system as it fulfilled the requirement and was easily available in the market. The Mega 2560 is an ATmega2560-based microcontroller board, as shown in Fig. 3(d) was used. A submersible water pump shown in Fig. 3(e) was used for both cleaning system. 12V DC wiper motor) was used in a single axis cleaning system and four 12V 100 rpm DC motor and four 12V 50 rpm DC motor were used in the dual Axis cleaning system. In Fig.3 (f) the 12V DC motor is shown. Shown in Fig.3 (g), the flat fan nozzle will flow water spray water jet on the solar panel. In Fig.3 (h) a limit switch has been shown. It is basically used to change to direction of motor rotation. A motor driver is an electronic circuit that allows a voltage in either direction to be applied across a load. L298N Motor Driver was used shown in Fig.3(i). A relay is an electrically operated switch that can be switched on or off, allowing the current to pass through or not, and can be regulated with small voltages such as the Arduino pins ' 5V. in Fig. 3(j) a relay module is shown. It is used to control the pump. Sharp's GP2Y1010AU0F is an optical air quality sensor was used to measure the dust. In Fig. 3(k) the dust detector sensor has been shown.

.

(a)Solar Panel

(b)Pipe

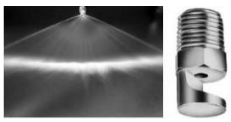
(c)Belt



(d) Arduino Mega

(e)Pump

(f) 12V DC Motor



(g) Nozzle

(h) Limit Switch

(i) Motor Driver

(j) Relay

(k)Dust Sensor

Fig. 3.: Experimental Equipment

The Single Axis Cleaning System 3D model has shown in the Fig. 4 .It cleans the solar panel with splash of water and a rotating brush moves forward and backward direction

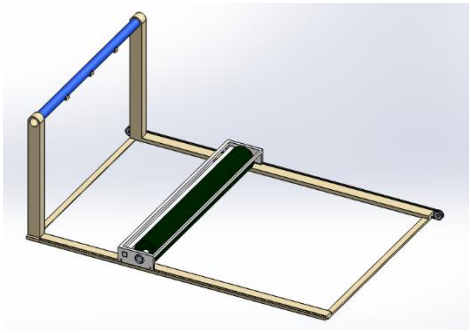


Fig. 4: 3D Model of Single Axis Cleaning System

The single axis cleaning system consists of two frames. One is stationary and another one is moving frame. In Fig. 5 the 3D model and the fabricated model of the moving frame with the cleaning brush has been shown.

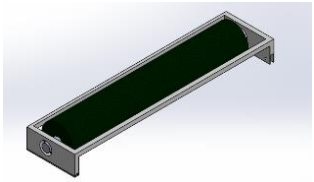


Fig. 5: 3D Model and Fabricated Model of Moving Frame with Cleaning Brush

The stationary frame on which the solar panel is placed and which also carries the pipe and nozzle setup has been shown in Fig. 6.

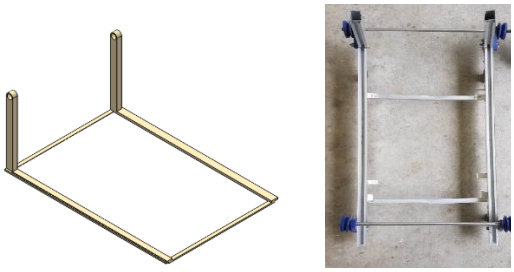


Fig. 6: 3D Model and Fabricated Model of Stationary Frame

Fig. 7 depicts the fabricated model of the single axis automatic cleaning system. It cleans the solar panel by one axis movement.

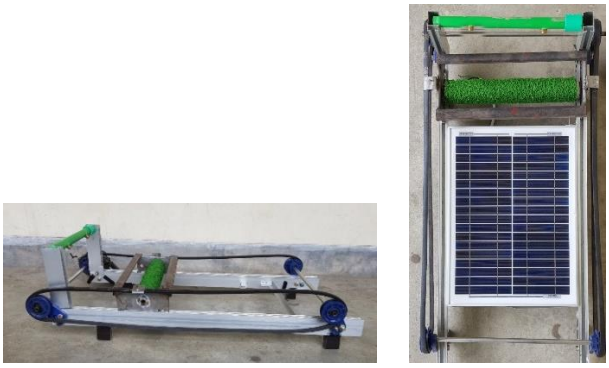


Fig. 7: Fabricated Model of Single Axis Cleaning System

4. RESULTS AND DISCUSSION

As outlined in the problem, how dust decreases the efficiency of the solar power plant and how it is easier to compare the effective automatic cleaning system with other techniques. The data below shows how effectively the cleaning system works. Solar panel efficiency was found from Eq. (1).

$$\eta = \frac{P}{IP \times A} \times 100 \quad (1)$$

$$P = V \times I \quad (2)$$

IP = 1000 w/m^2, A = 0.1364 m^2

A circuit was built with four 1k Ω and two 10Ω resistor whose equivalent resistant was 18.5Ω. The circuit diagram is shown in figure 4.1The output wire from the solar panel were connected with circuit terminal and using multimeter the voltage was measured. Dividing the measured voltage with equivalent resistance 18.5 Ω calculated the Current in Amp units. The power and efficiency were calculated by using above equations. At different hours of the day solar panel voltage, current, power and efficiency have been measured. The findings obtained are as follows:

Fig. 8 demonstrate the Efficiency vs. Time graphical representation of 20W solar panel for the time period of five days at distinct hours. It is visual from the graph that the efficiency decreased to a certain point with the passing day time as more dirt and dust were accumulated on the solar panel over the past days. And the increasing trend following the decreasing trend of the graph for each day is due to the day-round shift in solar insolation.

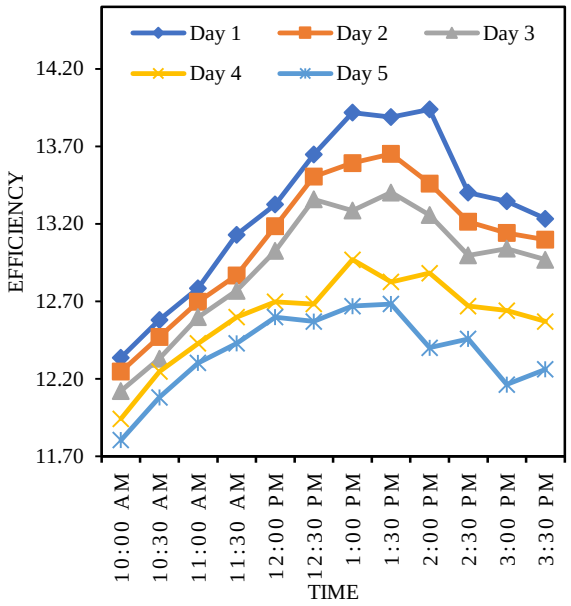


Fig. 8: Efficiency vs. time without any cleaning system for 20W solar Panel

Highest efficiency was reported for Day 1 at 13.94% where, owing to the accumulated dust, the maximum efficiency was 12.68% Watt after five days without any cleaning.

Fig. 9 shows the Efficiency vs. Time graphic illustration of 20W solar panel equipped with Single Axis Automatic Cleaning System at distinct hours for a period of five days. With the passing day time, the efficiency remains nearly the same region over the five-day period. As when the dust accumulates on the solar panel, it is sensed by the dust sensor and the cleaning system begins to work

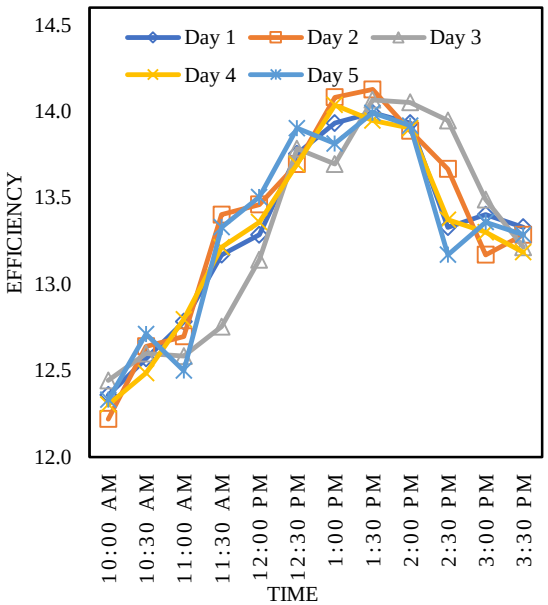


Fig. 9: Efficiency vs. time with single axis automatic solar panel cleaning system for 20w solar panel

The graph in Fig.10 compares the efficiency values of 20W solar panel with the installed single axis solar panel cleaning system and without the cleaning scheme. It is clear that uncleaned dust solar panel has less efficiency than the cleaned solar panel with automatic solar installation of the single axis. This is a gap of 1.31% solar panel efficiency with and without the automatic solar panel cleaning system installed

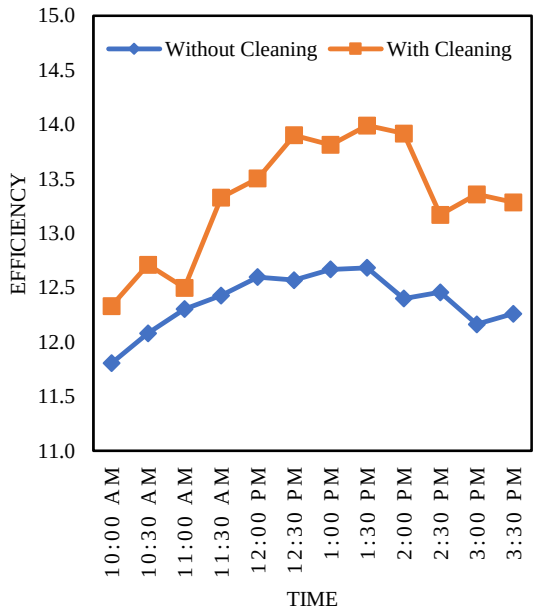


Fig. 10: Comparison of efficiency with single axis cleaning system installed and without cleaning system for 20w solar panel

5. CONCLUSION

The setup developed in this work focuses primarily on solar PV collector's better cleaning system to reduce the losses from dust. The fundamental cleaning model was intended, built practically and assessed the efficiency. For the cleaning system, data were collected for five days. Two solar panels were used concurrently for. One solar panel was kept without a cleaning scheme and the other solar panel was kept on the automatic cleaning system developed. The followings are the concluding remarks:

- It was noted that the project objective was achieved. The efficiency of the solar panel reduced over the passing days without cleaning, the panels were cleaner with the cleaning system, so over the five days the power and efficiency were nearly in the same range.
- The highest efficiency for day 1 was recorded 13.94% for 20W solar panel without any cleaning system and at day 5 it reduced 12.68%. The maximum efficiency fluctuates only from 13.99 to 14.07% by using cleaning system over the five days, which implies it helped to maintain the efficiency.
- However, the cleaning system should be used for solar panels which are small in width
- In this cleaning system, less machinery was used, therefore cleaning scheme is feasible due to lower power consumption and lower likelihood of failure.

6. REFERENCES

[1] C. Hutchinson, S. Herrmann, and S. M. Herrmann, "The Future of Arid Lands - Revisited A Review of 50 Years of," no. January 2007, 2016.

[2] "From light to heat to electricity," 2019. [Online]. Available: https://climatekids.nasa.gov/sun-people/. [Accessed: 07-Nov-2019].

[3] K. Sabah and S. N. Faraj, "Self-Cleaning Solar Panels to Avoid the Effects of Accumulated Dust on Solar Panels Transmittance," vol. 2, no. 9, pp. 246–248, 2013.

[4] M. Piliougine, J. Carretero, P. Bernaola, and P. Carpena, "Analysis of dust losses in photovoltaic modules," pp. 2985–2992.

[5] K. A. Moharram, M. S. Abd-elhady, H. A. Kandil, and H. El-sherif, "Influence of cleaning using water and surfactants on the performance of photovoltaic panels," *Energy Convers. Manag.*, vol. 68, pp. 266–272, 2013.

[6] P. Taylor, A. K. Mondal, and K. Bansal, "A brief history and future aspects in automatic cleaning systems for solar photovoltaic panels," no. May, pp. 37–41, 2015.

[7] M. Anderson, A. Grandy, and J. Hastie, "ROBOTIC DEVICE FOR CLEANING PHOTOVOLTAIC PANEL ARRAYS," pp. 1–11.

[8] R. Greenough, D. Jensen, and E. Voss, "Project SPACE : Solar Panel Automated Cleaning Environment," 2016.

[9] M. B. A. Bari and C. M. Pavan, "Automatic Solar Panel Cleaning System," vol. 4, no. 7, pp. 26–31, 2018.

7. NOMENCLATURE

Symbol	Meaning	Unit
η	Efficiency	Dimensionless
P	Power	Watt
IP	Input Power	Watt/m^2
A	Area	m^2
V	Voltage	V
I	Current	Amp