A Low Cost Automated Cleaning System for Photo-voltaic Panels

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***Abstract*— Accumulation of dust on the surface of solar panels distract the light from reaching solar cells. This leads to significant degradation in the performance of solar panels in terms of output power. In this paper, we present a simple and low cost cleaning system to mitigate the effect of dust on the performance of solar panels. The mechanical as well as the electrical subsystems are described, an algorithm for controlling the cleaning mechanism is proposed. Results show that the cleaning system allows the solar panel to provide regular power output.**

Keywords*— Photo-voltaic, auto-cleaning; dust effect; temperature effect;

I. INTRODUCTION

In the last decades, a lot of attention is given to the development and implementation of solar energy, as it is playing a fundamental role in generating clean and sustainable energy [1]. Solar energy, provided by the sun, comes in the form of solar irradiance, which can be converted into electricity by using photovoltaic (PV) panels. The power generated from a PV module depends on the amount of solar irradiance that reaches the solar cells [2]. Thus many factors affect the output of the module. These factors can be classified into two types: The first type is the factors that cannot be controlled, such as the frequency and the concentration of the clouds. The second type is the factors that can be controlled such as the direction and the cleanness of the panel. The latter is of great importance as it can significantly affect the output of the PV module. Accumulation of dirt or particles like dust, water, sand and moss on the surface of solar PV panel distracts light from reaching the solar cells. This is a major problem since the light obstruction materials pose as external resistances that reduce solar photovoltaic performance [3].

Manual Cleaning is usually used in order to overcome this problem. However, this process is not practical when considering large implantation of highly distributed PV modules. Moreover, the safety of workers is critical in such environment. To overcome this challenge, automatic systems are used to clean the PV when required. This paper presents the designing and implementation of an automatic cleaning that solves the problem of dust or dirt accumulation over the installed PV modules. The rest of the paper is structured as follows. Section II presents some of the existing work. Section III presents the system design and describes the mechanical and electrical subsystems. Section IV presents the results before concluding in section V.

II. RELATED WORK

Power output from PV systems is highly dependent on the amount of irradiance that reaches the solar cells, which itself depends on several factors such as the accumulation of dust and dirt. The authors of [3] analyze the effects of accumulation of dirt on the performance of solar panels. It was found that such conditions can degrade the PV systems performance up to 85%. In [2], the authors explain the process of dirt accumulation on solar panels and its effect on the power output as well as possible solutions. The authors classify the possible solutions into natural, such as rainfall, manual and mobile cleaners. In [4], a new cleaning system based on electrostatic forces to remove dust from the surface of solar panels is proposed. A two-phase high voltage is applied to electrodes embedded in the glass plate of a solar panel. This system suits mega solar power plants and is not applicable in case of distributed solar panels.

In [5], a new robotic cleaner for PV modules is presented. The robot consists of ducted fan, roller brush and blower fan to offer slippage-free motion and cleaning on a glassy surface. In [6], a new cleaning system for solar panels is proposed. The

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system drives water from sea level, purify it and use it in cleaning the PV system. The cleaning system is applied each day at 8 am in the morning. The system also use wiper during day and flashing LED during night to scare the birds away. This system needs to be implemented near the sea. Moreover, the mechanism may lead to wasting of water and consuming more energy as cleaning is done each day even if the panels are functioning normally.

In this paper, we present the design and implementation of an automated stand-alone cleaning system that aims at cleaning PV modules. The system is designed for relatively small size PV modules that does not require human interference. An algorithm is proposed to reduce the unnecessary use of water by triggering the cleaning mechanism only when needed. Preliminary experiments are done to verify the effectiveness of the proposed system.

III. System Design

Our cleaning system is design for solar panels that are found on buildings (e.g. residential). Designing such system should take into consideration several requirements. The system should not consume a lot of resources such as water, power and space. The cleaning system is applied on a 100 W M36PCS Mono crystalline solar panel, for which its specifications are presented in Table I. The cleaning system consists of a mechanical subsystem and an electrical subsystem.

TABLE I. Summary of Solar Panel Specifications

Peak Power	100 W
Mass	8 kg
Dimensions (mm)	1020*670*35
Open circuit voltage	22.4 V
Short circuit current	5.8 A
Cell efficiency	17.3%

A. Mechanical Subsystem

The mechanical subsystem deals with the water source and cleaning mechanism. In order to reduce the space occupation, the mechanical subsystem is integrated within the area of solar panel. The water is reserved in a tank near the solar panel. The tank can be the same as the one used by the residents/ workers. A pump is used to drain the water to the sprinklers. Two sprinklers are used in our system to ensure spreading water all over the solar panel. The design of the sprinkler is presented in Fig. 1.

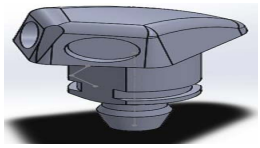

Fig. 1. Water Sprinkler.

The cleaning is done by the use of a wiper. Indeed, DC motor is used to move the wiper. The design of the cleaning subsystem that hold the wiper is presented in Fig. 2.

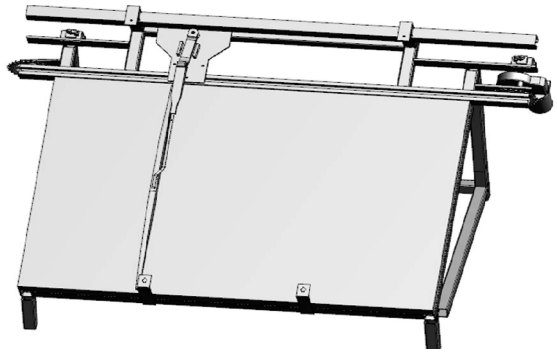

Fig. 2. Cleaning subsystem.

The system consists of the stand, wiper holder, wiper, motor, two micro switches, two rails, two water sprinklers, water sprinklers holder, wheel, gear and ball bearing. The stand is used to ensure fixed positioning of the system. The wiper should be correctly placed to ensure cleaning of the panels. This is done by the help of the wiper holder that can be regulated. The micro switches are used to help stopping the motor without exceeding the limits of the rails. Fig. 3 presents several components used in the design and implementation of the mechanical subsystem.

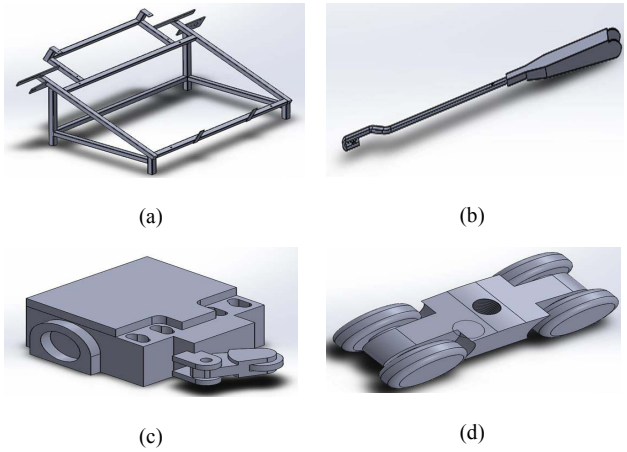

Fig. 3. Some of the mechanical components used in the cleaning subsystem: a) Stand, b) Wiper holder, c) Micro switch d) Rail wheels.

B. Electrical Subsystem

The electrical system aims at powering and controlling the mechanical components of the cleaning subsystem. There are several options that can be selected. However, to make it simple, we use the current output of the panel as the main parameter in taking the decision. In addition, several controllers can be used in taking the decision. We use Arduino controller (e.g. Arduino Uno) in order to control the wiper and sprinklers. Arduino controllers are available with relatively low price. Arduino current sensor is used in order to measure the current output of the PV panel. The movement of the motor is controlled using motor driver. H-bridge is used to allow the motor to move in both directions based on the signal provided by the Arduino controller. Figure 4 shows the simplified block diagram of the control system.

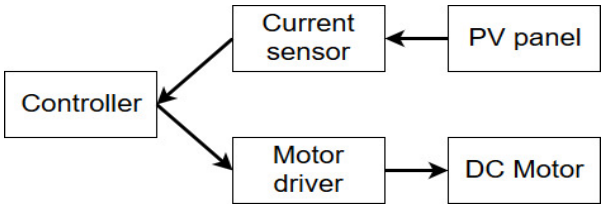

Fig. 4. Simplified Block Diagram

Fig. 5. Panel with dust.

C. *Proposed Algorithm*

It is important to design an efficient algorithm for initiating the cleaning mechanism. On the one hand, cleaning is important to ensure normal functioning (normal power output) of the solar panel. On the other hand, the cleaning mechanism should not be aggressively used in order not waste power and water. In addition, the proposed algorithm should have low complexity and should be able to work with local information only.

The algorithm takes into consideration the power output of the solar panel and the time of year. The power output will be measured two times a day. In principle, a threshold for power output is fixed, where the cleaning mechanism will be initiated when the output power drops below this threshold. However, factors other than dust can affect the power output such as clouds. Thus, the algorithm initiates the cleaning mechanism after noticing the power drop for a certain duration, which changes depending on the time of the year, as this will affect the existence and duration of clouds.

IV. Experiments and Results

In the following we present the results of the experiments that are done on the described system. The solar panel is tilted to have an angle of 60 degrees with the vertical. Experiments are done during the months of June and July. The value of the measured current is used to evaluate the performance of the panel (fixed voltage).

A. *Effect of dust on the solar panel*

In order to study effect of dust on the output of solar panel, we measure the current output (fixed voltage) of the solar panel in case of existence of dust and after cleaning the solar panel. Figure 5 shows the panel with dust. Measurements are done several times and the results are presented in Table II. Indeed, the output current in case of dust depends on the thickness of the dust and time of day, and the presented results are average of all the experiments. As shown in Table II, the results confirm the fact that dust can significantly degrade the performance of solar panel where the power output drops by around 44% in average.

TABLE II. Current output of solar panel in case of dust and after cleaning

	Current (A)
With dust	3.13
After cleaning	5.6

B. *Manual vs Automatic cleaning*

In order to verify the effectiveness of the cleaning system, we measure the current output of the panel after cleaning by hand (manual) and using the cleaning system. The measured current shows negligible difference (less than 1%) between the two cases, which can be caused by many other factors. The result verifies that the automatic cleaning system is effective in enhancing the performance of the system.

C. *Power and water consumption*

In order to ensure cleaning of the panel, water should be spread and the wiper should move forward and backward several times. Based on our experiment, each time the panel is cleaned requires in average 0.4 Wh.

D. *Algorithm Testing*

The device is currently under testing for several months to ensure efficient performance. The output of the PV panel is monitored and data is being collected in order to refine the thresholds of the algorithm.

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