Weeper Control Design based on Microcontroller for Photovoltaic Panel Cleaning System

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Abstract—This paper presents the design of a cleaning system for the surface of a photovoltaic panel using a weeper control mechanism. We have experimentally designed the cleaning system for single (Photovoltaic) PV panel. The weeper cleaning system is controlled using a microcontroller. The cleaning system operates by spraying an amount of water on the PV panel surface, and then actuating the weeper using a DC motor. Two limit switches are used to sense the weeper position at the edge of the PV panel. In the experimental test, an amount of dust is deployed on the PV panel surface to test its power performance. The experimental results have shown that the weeper can improve the efficiency of the PV panel of about 47% over the efficiency before the PV panel is cleaned. The weeper can be managed to work periodically for example five times in a day, or can be manually activated using remote control mechanism. The power performance of the weeper system is also tested. The percentage of the power consumption over total PV system power during standby condition of the weeper is about 0.79%. While during water spray and weeper operations, it consumes respectively about 8.94% and 4.49%. This low power consumption make this cleaning system feasible for further product development. (Abstract)

Index Terms—Component, formatting, style, styling, insert. (key words)

I. INTRODUCTION

Photovoltaic panels are always located in an open environment. This is done surely because of the need for solar penetration into the panel surface. Therfore, the surface of the solar panels will always be covered by any disposals including dust. The existence of dust on the surface of the panels will reduce the conversion efficiency upto 18%. Hence, a cleaning mechanism to maintain the power performance by removing the dust from the solar panel surfaces is required [1, 2, 3]. The Moreover, disposals which cover continuously solar panel surfaces can damage any cell in a solar module [4]. Other pollutants such as ash can also reduce the power performance of a solar panels [5].

In order to implement the mechanism, we can use for example weepers to remove dust n the panel surface [6]. The weeper can be actuated by DC motor and activated daily or even per hour, or accidentally when the panel surfaces are dusty. The DC motor is then controlled by an electronic control unit with a few number of sensors or limit switches to adjust its forward and reverse rotations.

In any circumstance, we can also use a robot to clean the surface of solar panels. However, the existing robot is still very costly [7] of about $50,000 and should be operated by at least two human operators.

This paper presents an experimental result of a cleaning system powered by weeper. The design steps consists of design phase and testing phase. The design phase includes weeper mechanical setup on the PV panel, electronic hardware design and embedded software development. The testing phase includes testing, measurement and data analysis. Measuring and testing were conducted by spreading dust over the surface of the photovoltaic with different mass volume. Data analysis is made to analyze the output power of photovoltaic during normal day light conditions, dusty conditions and conditions after cleaning with the proposed windshield weeper system.

II. PROBLEM STATEMENT AND DESIGN OBJECTIVE

Electric energy generated by the photovoltaic is very susceptible to the influence of a layer of dust on the surface of the photovoltaic. Dust layer on the photovoltaic surface can reduce the level of solar radiation accepted by photovoltaic. Thus, it will decrease the energy produced and efficiency of the photovoltaic.

The aims of this research are designing and constructing a wiper system which is capable to clean the surface of photovoltaic that littered and covered with dust layer. This study also aims to analyze the power generated and efficiencies by photovoltaic during normal day light and dusty conditions. The power performance of the photovoltaic panel is also measured and analyzed after it was cleaned by the wiper system for different amount of dust deployed on the PV panel surface.

III. DESIGN OF THE MECHANICS AND CONTROL SYSTEMS

In our research work, we use a photovoltaic module/panel with poly-crystallin technology. The specification of the poly-crystallin photovoltaic panel is as follows:

a) Peak output power is 100W (100Wp)
A. Mechanical Setup

Fig. 1 shows the perspective view of the system designed. On the right side of the figure, we can see a box (a) containing a DC motor and its electronic control unit, the weeper (b), lower limit switch (c), upper limit switch (h), and water sprayer (i).

b) Maximum output voltage ($V_{MAX}$) is 17.5 V
c) Maximum output current ($I_{MAX}$) is 5.71 A
d) Open-Circuit Voltage ($V_{OC}$) is 21.5 V
e) Short-Circuit Current ($I_{SC}$) is 7.02 A

Fig. 1. The real perspective view of the photovoltaic panel with weeper control system.

Fig. 2 presents the right side view of the photovoltaic (PV) panel with weeper control system. In this experiments, we rise up the PV panel top position about 83° relative to the gravity axis as shown in the figure. The drawing unit shown in the figure is in millimeter.

Fig. 2. Right side view of the photovoltaic panel with weeper control system.

Fig. 3 presents the leg side view the PV panel setup with the weeper system. The following items present the dimensional specification of the system mechanics.

- The height of the back frame: 655 mm
- The height of the front frame: 451 mm
- The slope of the frame: 83°

B. Control System Design

Fig. 4 presents the control system model of the cleaning system in a block diagram. The block $C(s)$ shown in the figure is a multi-input multi-output (MIMO) transfer function model. The microcontroller $C(s)$ is the main electronic control unit, which start operating cleaning mechanism based on an activation signal set by a Real-Time Clock (RTC) module or from an activation signal from a remote control. When an activation signal is received by the microcontroller, then the microcontroller will start activating the water spraying mechanism for about 10 seconds. Afterwards, the weeper start moving to clean the surface of the solar panel until it reach the lower limit switch, and it moves back to its initial position. The lower and upper limit switches are normally closed. Thus, when the weeper touches the limit switches, then they will send 5V signal to the microcontroller.

Fig. 5(a) presents the system configuration of the microcontroller-based weeper system. The actuators (pump or water sprayer and weeper motors) and the microcontroller is supplied with electric power from the solar panel. The microcontroller is supplied with 5V voltage, the pump motor for water sprayer is with 12V and the DC motor for the weeper is with 6V voltage supply.

The distance of the weeper movement for one direction is 151.2cm or 1.512m. For a single motor rotation, the weeper movement reaches 12cm, since the motor shaft radial is about 1.91cm. Table I presents the operating conditions of the weeper motor for different voltage level. The Voltage and current supplied to the weeper motor, in order to make a single-direct 151.2-cm-linear movement, are measured to obtain the power consumption. The time required to move
151.2cm linearly \((T_w)\) is also measured to achieve the total energy requirement in Joule \((J)\) or Watt-Second. The \(x(t)\) is the linear movement equation of the wiper, where each constant represents the movement speed.

### TABLE I. Energy and Power Measurements for Different Operation Voltage Levels of the Wiper Motor.

| Voltage | Current | Power | \(T_w\) | Energy | \(x(t)\) |
|---------|---------|-------|---------|--------|---------|
| 4.9 V   | 0.48 A  | 2.35 W| 5.9 s   | 13.865 J | 25.6t   |
| 5.6 V   | 0.58 A  | 3.25 W| 4.8 s   | 15.6 J  | 31.5t   |

From Table I, we can see that the optimum energy consumption to operate the wiper motor is by supplying the motor with 4.9V. Operating the wiper motor below 4.9V cannot actuate motor to work normally.

Fig. 5(b) shows the photograph of the real electronic control unit using the microcontroller.
IV. TESTING

We have made some experiments by deploying a few gram of dust averagely on the surface of the photovoltaic panel. The mass volumes of the dust used to test the system are 12.82g, 25.64g, 38.45g, 51.29g and 64.11g. The dust deployment on the panel surface is made to check the capability of the weeper/cleaning system to improve the PV efficiency. Table II presents the measurement results, and calculations of power and efficiency, when we use an amount of 12.82g dust. It seems that the weeper action can improve the PV panel efficiency from about 15.29/% up to 17.56% for single weeper repetition, up to 17.59% for twice weeper repetition and up to 17.60% for three times weeper repetition.

| No. | Mass of Dust (gr) | G_L (Lux) | V_OC (V) | I_SC (A) | Weeper Repetition | G_W (Watt/m^2) | Power Radiation P_R (Watt) | Fill Factor FF | Power P_e (Watt) | Efficiency η (%) | Averg. Efficiency η (%) |
|-----|------------------|-----------|----------|---------|--------------------|---------------|---------------------------|---------------|-----------------|-----------------|------------------------|
| 1   | 0                | 78200     | 19.64    | 5.15    | 0                  | 617.78        | 462.16                    | 0.81          | 81.48           | 17.63           | 17.61                  |
| 2   | 12.82            | 78100     | 19.62    | 5.14    | 0                  | 616.99        | 461.57                    | 0.81          | 81.22           | 17.60           | 15.29                  |
| 3   | 77100            | 19.55     | 4.43     | 0       | 0                  | 609.09        | 455.66                    | 0.80          | 69.71           | 15.30           | 17.56                  |
| 4   | 77600            | 19.57     | 4.45     | 1       | 0                  | 613.04        | 456.62                    | 0.81          | 70.11           | 15.29           | 17.59                  |
| 5   | 78400            | 19.63     | 5.14     | 1       | 0                  | 619.36        | 463.34                    | 0.81          | 81.27           | 17.54           | 17.59                  |
| 6   | 78300            | 19.62     | 5.15     | 1       | 1                  | 618.57        | 462.75                    | 0.81          | 81.38           | 17.59           | 17.60                  |
| 7   | 79300            | 19.63     | 5.21     | 2       | 0                  | 626.47        | 468.66                    | 0.81          | 82.38           | 17.58           | 17.59                  |
| 8   | 81100            | 19.65     | 5.33     | 3       | 0                  | 640.49        | 479.30                    | 0.81          | 84.38           | 17.60           | 17.60                  |
| 9   | 81200            | 19.64     | 5.34     | 3       | 0                  | 641.48        | 479.89                    | 0.81          | 84.43           | 17.59           | 17.60                  |
| 10  | 81200            | 19.63     | 5.34     | 3       | 0                  | 641.48        | 479.89                    | 0.81          | 84.43           | 17.59           | 17.60                  |

V. CONCLUSIONS AND OUTLOOKS

This paper has presented a weeper equipment used to clean the surface of a photovoltaic panel. Based on the experimental results, we conclude some points as explained in the following.

1. The system test results showed that the average efficiency of photovoltaic on the initial condition is 17.51%. However, under dusty condition with the mass of dust 12.82g, 25.64g, 38.45g, 51.29g and 64.11g, the efficiency were decreased by 15.29%, 11.82%, 11.35%, 10.86% and 10.06%, respectively. Therefore, the average decrement in efficiency with dusty condition was 11.88%. After cleaning operation was turned on with one wiper movement, the average efficiency increased by 17.44%. Moreover, when the cleaning is made with twice wiper movement, then the average efficiency was 17.48%. Finally, after the cleaning is made three times, the average efficiency was 17.50%.

2. The percentage of the power consumption of system during standby condition was 0.79%, during spraying operation was 8.94%, and during the weeper operation was 4.49%. This low power consumption make this proposed cleaning system feasible for further product development.

3. The weeper can be managed to work periodically, or can be manually activated using remote control mechanism. The periodical cleaning service is enabled by using a real time clock (RTC) embedded on the system. We can activate periodically the weeper system for example by five time in a day with a specified schedule. The weeper can also be activated manually using wireless device. Using the standard device, the weeper can be remotely operated in the distance of maximum 27m.

In the future, we would improve our system by addressing the following subjects:

1. We could use extended or extra rechargeable battery to power the cleaning system. The electric energy from the PV panel can be used to charge the battery.
2. The system testing could be made with real-time data logging to achieve better performance analysis.
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