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Automated dust detection and cleaning system of PV module

Kelebaone Tsamaase[1], Tapologo Ramasesane[2], Ishmael Zibani[3],
Edwin Matlotse[4], Kagiso Motshidisi[5]
[1,2,3,4,5](Electrical Department, University of Botswana, Botswana)

Abstract: *This paper describes the development of an automated dust detection and cleaning system which could be used to clean photovoltaic (PV) modules. Dust accumulation is one of the factors which negatively impact of the PV module output because it obstructs solar radiation to incident on the module surface hence reducing the overall performance of the system. The system was designed by writing a C program and compiled with Arduino IDE to read voltage and sense current from the PV and calculate power output. The circuit was built with proteus 8 professional. Simulation results show that the system was able to detector power loss due to dust accumulation on module surface and as a results the motor drive for the cleaning mechanism responded accordingly to operate cleaning mechanism. The work is still ongoing whereby a prototype will be built to demonstrate the practicality of the system.*

Key words: *Dust, photovoltaic module, automated cleaning system*

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I. Introduction

The global increase in energy demand and exponential exhaustion of fossil recourses has favoured the development of new systems of electricity production and solar energy has undoubtedly been one that has the highest application in housings, due to its simplicity and easy implementation through the utilization of photovoltaic panels. PV cells are made of a material known as semiconductors, the most common being used is silicon. Essentially, when the light strikes the cell, some of this is absorbed within the semiconductor material. and knocks the electrons loose, allowing them to flow freely hence generating flow of electrons or current as shown in figure 1[1, 2]. However, performance of the PV panels due to accumulation of dust has always been a concern. Dust accumulation such as bird's droppings, soil, leaves as shown in figure 2 are one of the factors that affect PV panel performance as they reduce amount of irradiation in the PV modules making the PV panel to experience low optimal efficiencies [3, 8]. Other factors which also impact of the performance of PV panel include but not limited to the following, panel cracking which is common during production (manufacturing) and heavy winds, discoloration which reduces penetration of the sunlight to the panel hence reducing efficiency, soiling which is most prominent in dusty environment, hot spots due to high temperatures which decrease output power[4, 7]. This paper is however limited itself to effect of dust accumulation only.

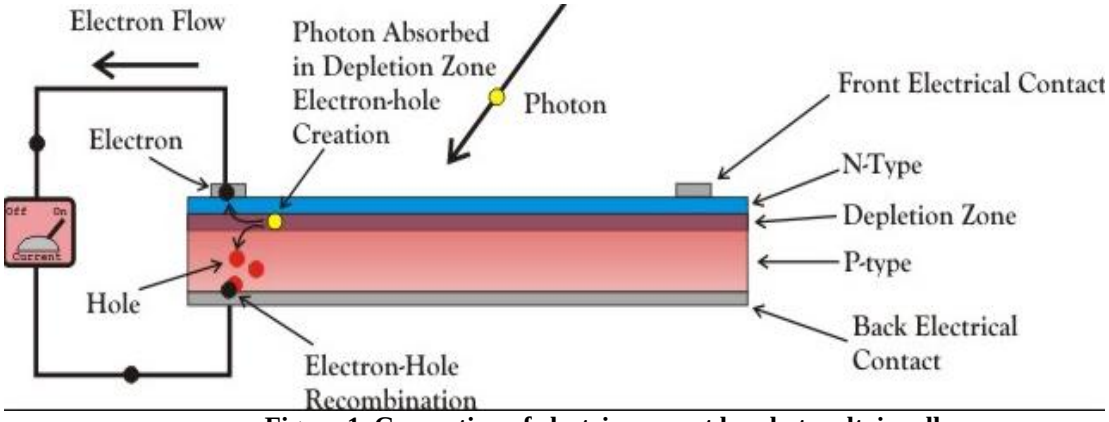

Figure 1. Generation of electric current by photovoltaic cell

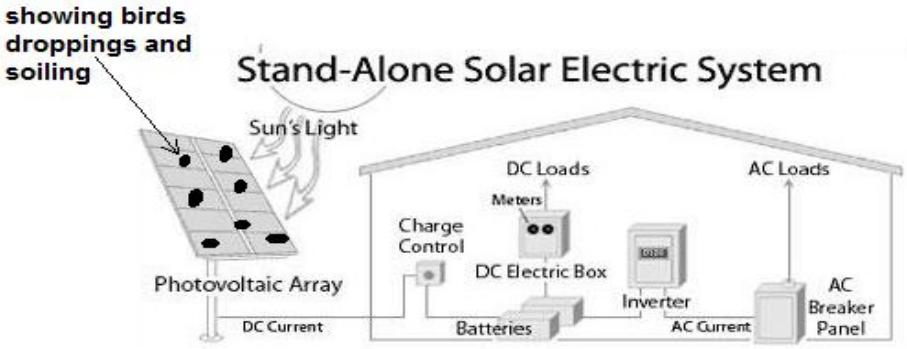

Figure 2. Showing soiling of PV module

The energy and the efficiency produced by photovoltaic modules is related with solar's available irradiance and spectral content therefore care and maintenance through cleaning of PV modules is essential in improving performance and irradiance. The cleaning of PV panels helps PV system users attain maximum power output as the PV cells surface area become fully exposed to maximum light intensity. The settled dust, if not cleaned, affects the performance of the solar PV module by shading the front surface thus obstructing solar radiation incident onto the PV panel surface. It is therefore necessary to keep PV panels clean so as to harvest as much solar radiation as possible. Monitoring of the performance of the PV panel can be done by measuring the output power of the panel and determine the efficiency of the panel and automatically clean the panel when a set amount is reached [5].

This paper is arranged according to the following sections: Section II deals with various cleaning techniques which can be employed in PV panel cleaning. Section III gives the details of operation proposed automated cleaning system. Section IV gives the results and analysis while Section V gives conclusion and future work.

II. Cleaning Techniques

There are different techniques of cleaning accumulated dust, example, dry cleaning technique which consists of sliding brushes on PV panel surface [3]. Also electrostatic cleaning is used where the dust is shaken off the PV panel when an electrically charged wave breaks over the surface of the PV panel. Another technique IS wet cleaning. One of the wet cleaning examples include Heliotex, which is an automatic cleaning system that washes and rinses solar panel surfaces [6]. The Heliotex system sources the water from the residence via a hose pipe connected to the pump and attached to nozzles on the solar panel surface without causing rubbing. The advantage of wet cleaning is that effectiveness of the PV panels is improved. Disadvantages of the system are that plenty of water and equipment such as pumps are required.

III. Automated Cleaning System Operation

For this research the dry cleaning method was used. The automated cleaning system for PV modules was developed considering the type of dust detection or monitoring technique, method of cleaning and the cleaning mechanism. Therefore, the cleaning software was modelled to work hand-in-hand with the amount of irradiance produced from the sun and the software operation as illustrated by the flowchart below. According to the developed algorithm the software development for monitoring the efficiency and cleaning is operational during the day only when it is sunny. The software implementation was written in C and uploaded to a microcontroller using an IDE provided by Arduino and the simulation was carried out.

The system consisted of the two DC motors connected to the Arduino UNO via control circuit of the L293D motor driver. The monitoring circuit and the light sensor were also connected to the Arduino UNO board. The sensor was used to detect the presence of the light and the microcontroller will respond to this by measuring output power from the panel if it is clear day or the output is "HIGH". The cleaning mechanism will be active only when the efficiency or the output power is low (20% below average value.).

As per the flow chart below, the sensor detects presence of solar radiation and if it is not available it remains in idle or standby mode. When it detects the solar radiation the system measures power PV module power output resulting from that radiation and compares it with the average power. If the output power is less than 20% below average the system interprets that as normal and does not activate the cleaning mechanism. When the output power is 20% or more below the average the system activates cleaning mechanism with motor making forward rotation hence moving cleaning arm along the panel surface. The cleaning arm moves until reaching limit switch which then activates reverse rotation of the motor. The reverse rotation moves the cleaning arm back to its original position where it is stopped by another limit switch. The cyclic process will continue until the measured output power is within the limit of not more than 20% below average value.

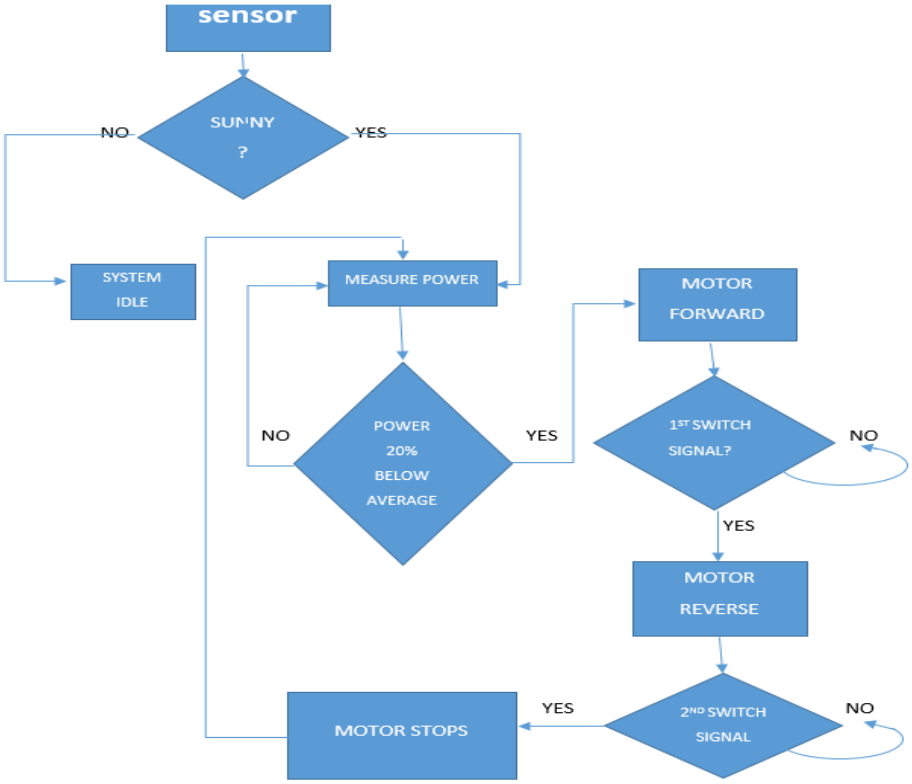

Figure 3. Flow diagram of automated dust detection and cleaning system

IV. Methods

a) The following equipment and instruments are utilized in the experimental setup

- Arduino UNO - (0 V- 5V input) micro-controller board which is based on the ATmega328.
- PV panel, rated 18V, 0.83A, 15W.
- Hall-Effect linear current sensor
- Voltage measurement unit: 18 V/ 5V voltage divider
- Motor drive to provide the control of the two DC motors used for cleaning mechanism.
- DC motors: two dc motors rated at 12V-100r.p.m.
- Photodiode to generate a current signal proportional to the light intensity

The output voltage of the micro-controller was calculated as follows:

$$V_{out} = \frac{R_2}{R_1 + R_2} V_{in} \quad \textbf{(1)}$$

$$R_1 = \frac{R_2 V_{in}}{V_{out}} - R_2 \quad \textbf{(2)}$$

$$R_2 = R_1 \frac{V_{in}}{V_{out}} \quad \textbf{(3)}$$

b) Simulation circuit of the system

The system consisted of the two DC motors connected to the Arduino UNO via control circuit of the L293D motor driver. The monitoring circuit and the light sensor were also connected to the Arduino UNO board. The sensor was used to detect the presence of light and microcontroller responds to this by measuring output power from the panel if it is clear day or the output is "HIGH". The cleaning mechanism becomes active only when the efficiency or the output power is low. The whole circuit was built by proteus 8 professional software as shown in the figure 4 below. In figure 6, circuit was incorporated with limit switches stop and change direction of rotation of the motor.

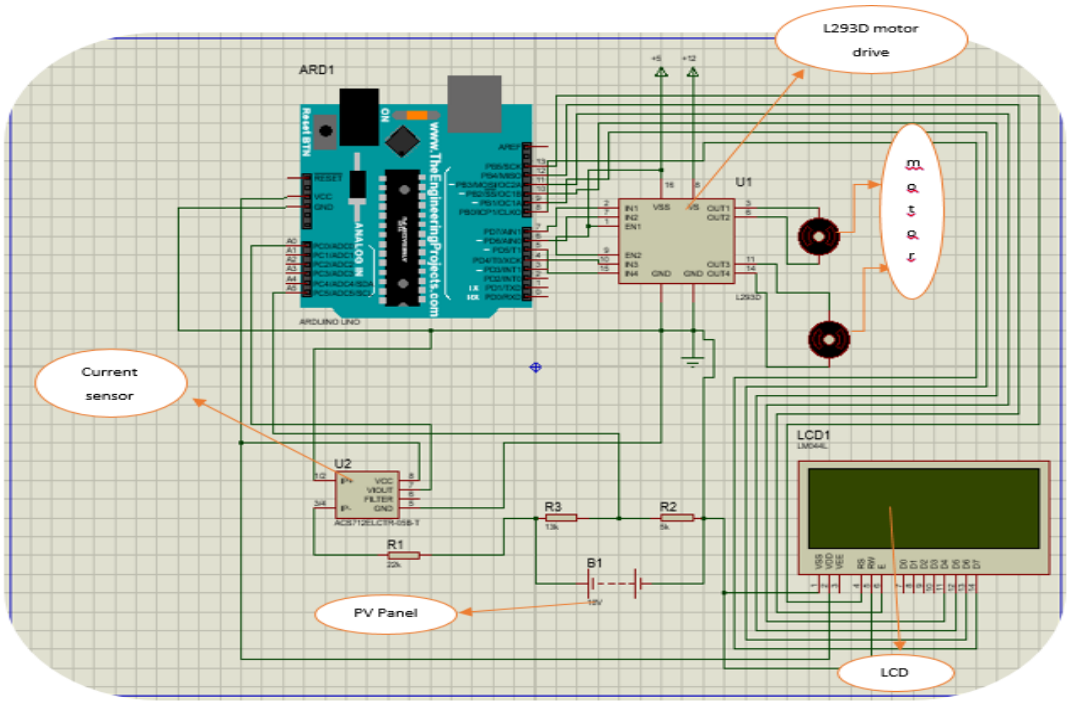

Figure 4. Simulation circuit of the system

V. Analysis And Discussion Of The Results

a) Clean PV panel

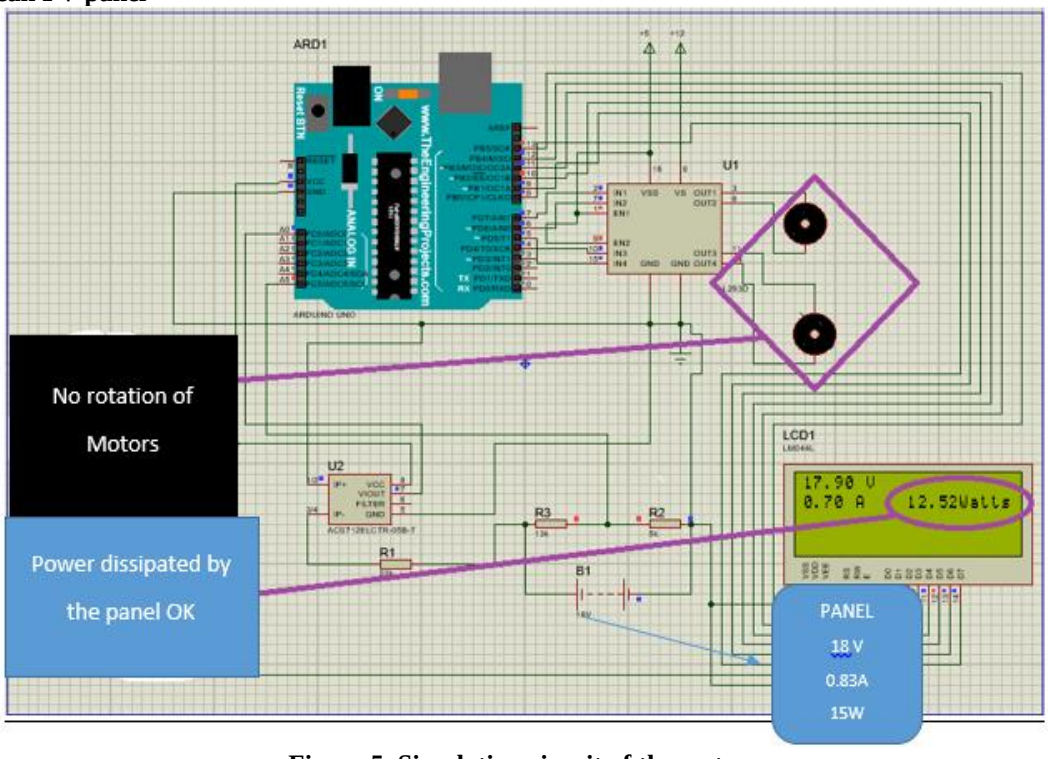

Figure 5. Simulation circuit of the system

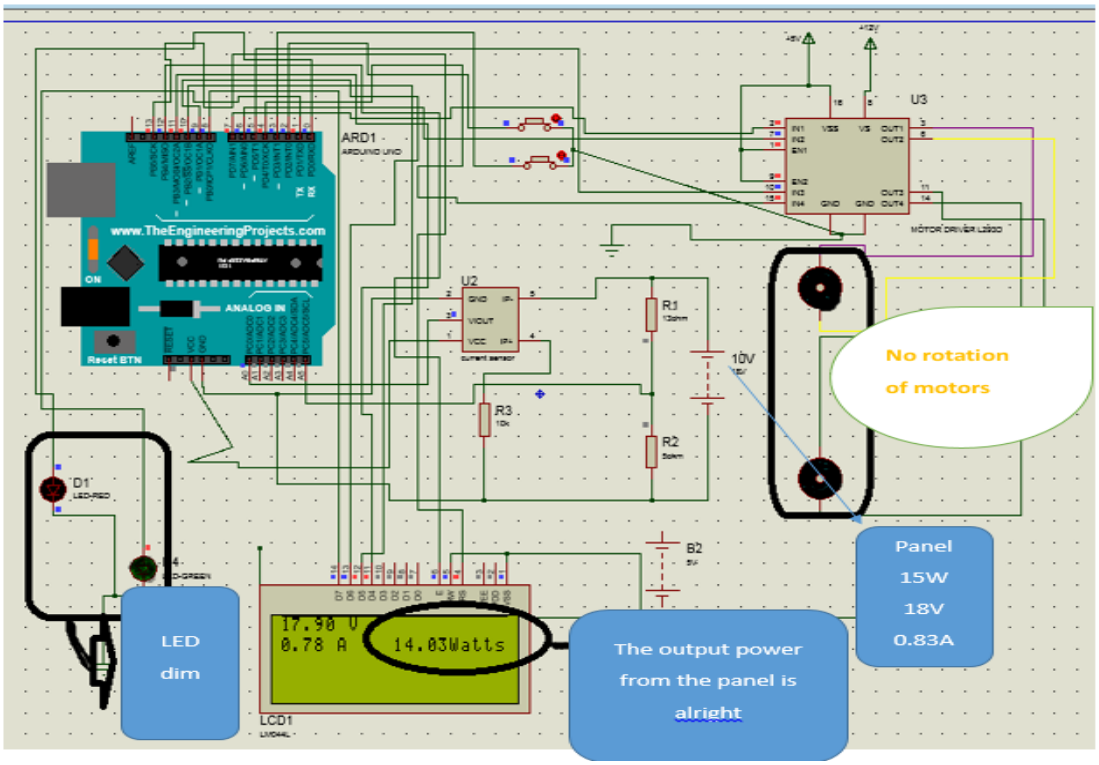

Figure 6: shows high performance of the PV module producing high power

b) Soiled PV panel

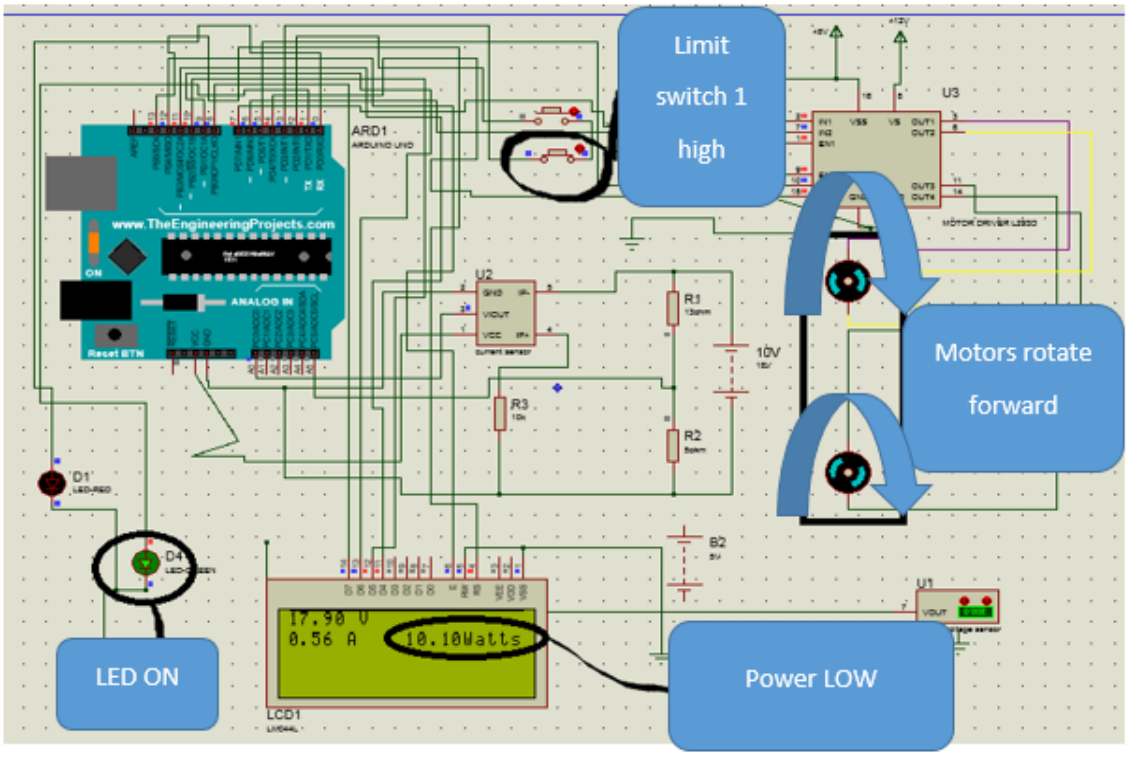

Figure 7. Simulation circuit of the system

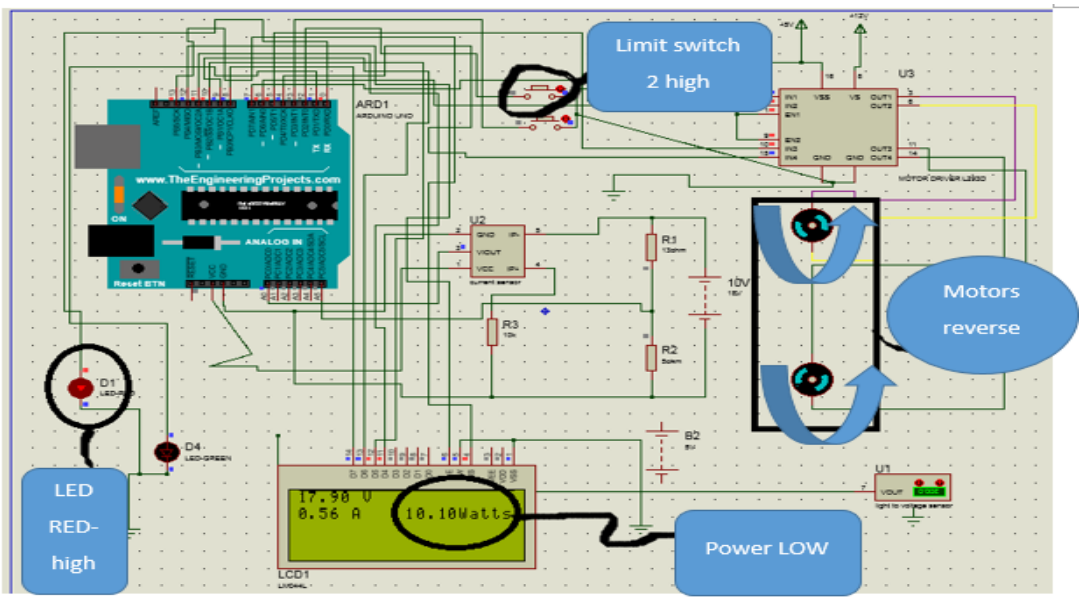

Figure 8. Simulation circuit of the system

a) Clean panel

During the simulation the sensor pin was" HIGH", that is, it was assumed to be sunny. The results in figure 5 shows the out power displayed in the LCD, 12.52 W, which was an indication than the output power of the PV module was being monitored by the measurement unit. In figure 6, an assumption was made and conditions set to represent the panel operating at its maximum efficiency. The power displayed by the LCD was high, 14.03 W, hence two motors did not rotate and the LED's were DIM. The non-activation of cleaning mechanism shows that there was no dust on the panel.

b) Dirty panel

The panel was assumed to be dirty or soiled. This condition was achieved by varying the output voltage from the source rand the current becoming less, 0.56 A as shown in figures 7 and 8. This reduced the output power to a lower value, 10.10 W, and the reduction of output power triggered operation of cleaning mechanism by activating two DC motors to rotate.

VI. Conclusion And Future Work

The proposed system successfully detected presence of soiling or dust on the PV panel by measuring the output power as shown in figures 5, 6, 7 and 8, and was able to operate the cleaning mechanism. The cleaning mechanism also responded successfully as shown by two limit switches which were able to change direction of rotation of motors. The work is still ongoing whereby the next stage would be to build a prototype to demonstrate the practicality of the system. It is also intended to expand the work further at a later date to include other variables such as tilt angle of the module to determine how it can be used to enhance dust cleaning by rolling down dust particles thus minimizing the frequency of operation of the cleaning mechanism.

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