IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 13, Issue 5 Ver. II (Sep. – Oct. 2018), PP 26-33
www.iosrjournals.org

Dust-cleaning system for improved PV Module Output

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

Abstract: *This paper describes the system which was designed and a developed prototype to clean off the dust from a PV module. Dust settlement on the PV module surface is one of the factors affecting the performance of PV module by obstructing solar irradiation incident on the module surface. By cleaning off the dust from muddle surface therefore improves the module output and ultimately improving even the overall performance of the PV system. The results show that with the system was able to respond to the low output level by wiping the surface of the PV module. The prototype assembly comprise of a programmed Arduino micro controller, a PV panel, wipers, battery and motors and artificial light simulating the sun. Further work will focus on developing real system since the prototype has proven that the system is viable. 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*

Date of Submission: 17-11-2018 Date of acceptance: 04-12-2018

I. Introduction

Increasing demand of energy, depletion of nonrenewable energy, effects of climate change, has increased the interest in investing on renewable energies. Renewable energy sources such as wind and solar have already been widely tapped around the globe. Solar energy due to its abundance has seen the development of photovoltaic energy generator of varying capacities from few kilowatts to megawatts. The systems appear in different configurations such as stand-alone, grid-connected, micro-grids and so forth. However, solar photovoltaic energy systems, like any other generator, is not without its own challenges varying from technical, environmental such as temperature, location specific and so forth. One of the challenges is the deposition of dust on PV module surface [1-7]. The deposited dust obstruction incident solar radiation from the module surface and not all the radiation which was supposed to incident the module surface does so because of the layer of dust deposited on the surface. This ultimately has a bearing on the voltage, current and power output of the PV module because they are dependent amongst others, the amount of solar radiation incident on the module surface. Any reduction of incident radiation leads to a reduction of the mentioned module output parameters [8, 9]. This has prompted research on how best the dust could be cleaned from the module surface [10]. Various researches were done some possible solutions proposed. However, the research is still on going to come up with optimal mechanism which could do dust cleaning. In this regard, this paper present prototype of the PV module surface dust cleaning system was proposed, designed and simulated [9]. This paper presents a dust-cleaning mechanism which was built following the designs and simulations [9]. The results showed that the system was successful on its intended purpose.

This paper is arranged according to the following sections: Section II deals with list of equipment used. Section III gives the procedure used on the building up or assembly of the prototype. Section IV deals results, analysis and discussions while Section V deals with discussions and further work.

I. LIST OF EQUIPMENT USED

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 (ACS 712)
- 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

(a) Arduino UNO:

Arduino with its easy to use characteristics, was considered for successful implementation of this microprocessor-based project. Arduino normally functions with either the Atmel AVR or Atmel ARM microcontroller chip. They normally have a range of input and output pins for connecting other devices such as sensors and actuators. For example they normally have at least six analog input pins and at least fourteen digital input/output (I/O) pins. Different types of Arduinos are readily available in the market and they generally differ in specifications such as the input/output ports, processing speed, etc. Figure 1 shows a typical Arduino UNO [11].

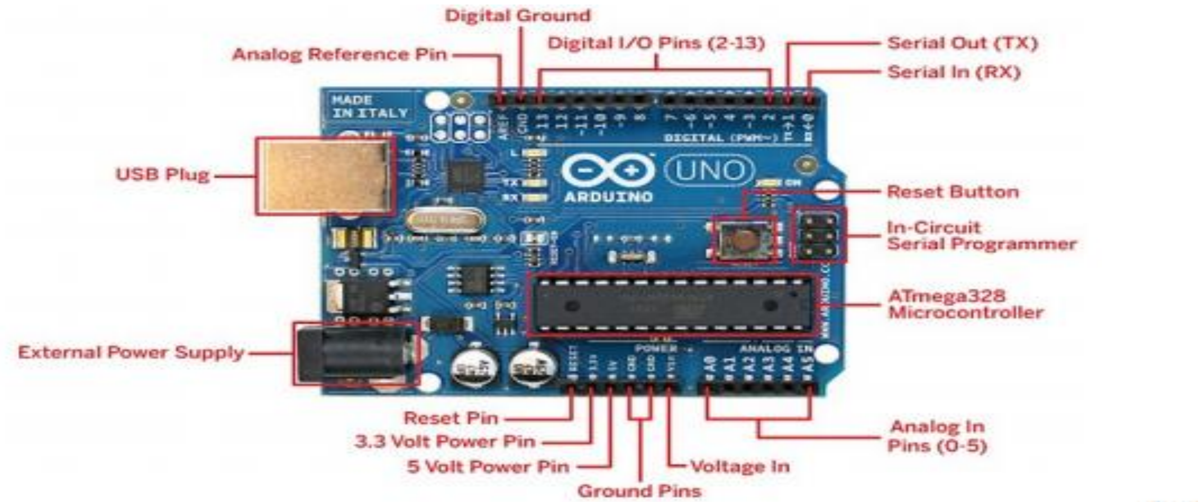

Figure 1 - Arduino UNO

(b) PV panel:

The panel used on the experiment was rated at 17.8V, 0.68A, 13W. Figure 2 shows the panel used in the experiment

Figure 2 - PV panel used on dust-cleaning system demonstration

(c) ACS 712 Sensor

The ACS 712 sensor was used on the project. This is a Hall Effect linear current sensor and was considered suitable for the project because of its linear output voltage. Another advantage of the sensor was that it could easily be used micro controller such as Arduino which was used in the project. It had an operating range of ±20A and a typical sensitivity of 100mV/A.

Figure 3 shows the ACS 712 sensor which was used in the experiment [**4**].

Figure 3 – ACS 712 sensor

ACS 712 Technical specification (according to the datasheet):
1) ACS 712 measures the positive and negative 20Amps, corresponding to the analog output 100 mV/A
2) Even though there is no test for the current, the output voltage is VCC / 2 =5v/2=2.5V
3) The output voltage offset was 2.5V

Calibration:
- The analog reading produces a value of 0-1023, equating to 0v to 5v
- Analog read 1 = (5/1024) V =4.89mv
- Value = (4.89*(analog read value))/1000 V
- But as per the data sheets, the offset is 2.5V
- Current in (amp) =(value-2.5) *5 A

(d) Voltage measurement unit

A voltage divider was used as part of a voltage measurement device as shown in Figure 4. The voltage was determined as follows:

Voltage = (Analog value / resistor factor) * reference

Where;

Analog value = Analog output of Voltage divider

Resistor factor = 1023.0/(R2/R1+R2)

Reference Voltage = 5 volts

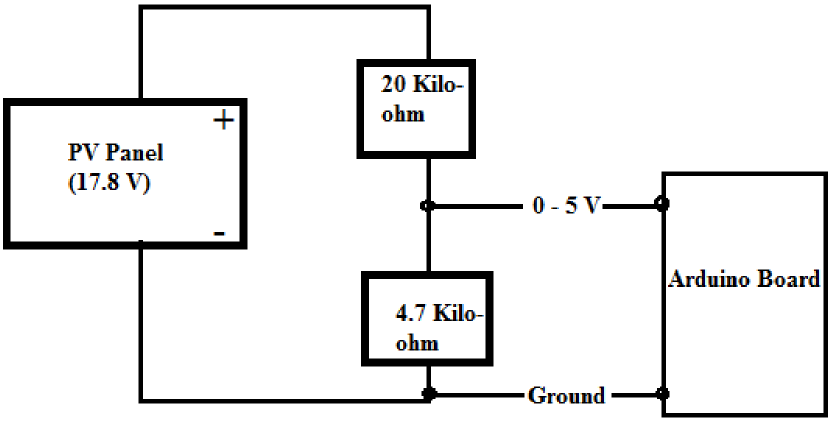

Figure 4 - connection of voltage divider circuit to Arduino board

(e) DC servo motors:

A servo motor is an electrical device which can push or rotate an object with great precision. It can rotate and stop at any angle as per the received signal or instruction. They can also turn in opposite direction as and when required to. They use the principle of pulse width modulation whereby the duration of a pulse applied to the control pin controls servo motor's angle of rotation. A picture of a servo motor is shown in Figure 5 [12]

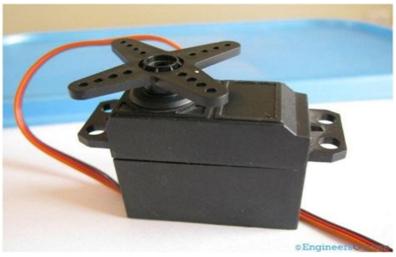

Figure 5- Servo motor

(f) Photoresistor

A photoresistor also referred to as light dependent resistor (LDR) or photocell. The principle of operation of the LDR is based on the change in conductivity of a semiconductor material as the intensity of incident radiation changes. The more the light intensity the less resistance

II. METHOD

(a) Circuit connection

The circuit was connected using a breadboard and connecting cables as shown in the Figure 6. The 4.7 kΩ and 20 kΩ were used on the voltage divider. Figures 6(a) and (b) shows layout of circuit components and their connections. Figure 6(c) shows the built or assembled dust cleaning system. The resistor values were selected such that the ARDUINO analog pin input voltage is restricted to 5V. The output voltage can therefore e expressed as follows: Output voltage = (4.7/24.7)*17.8 = 3.4V

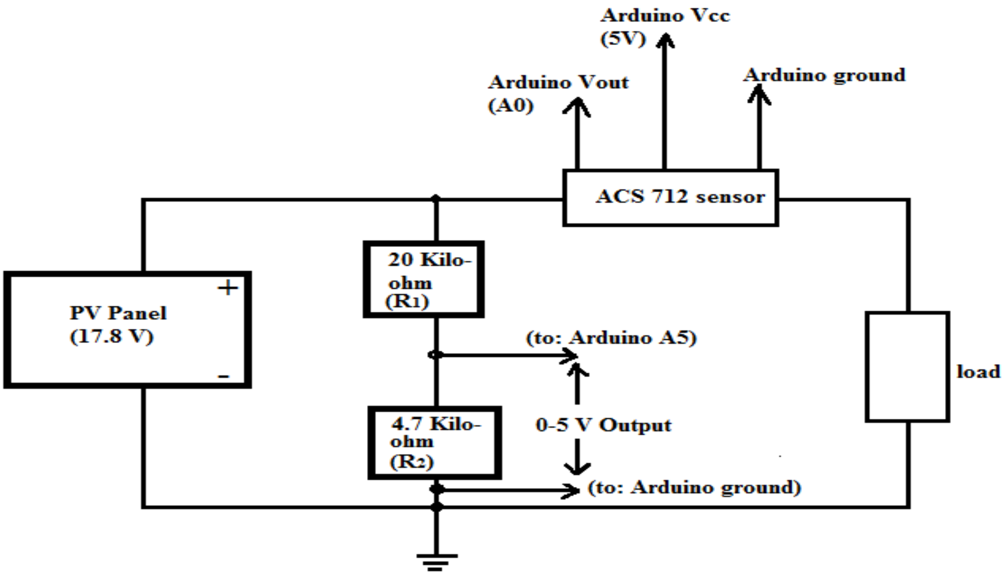

Figure 6(a) - PV module performance monitoring circuit design

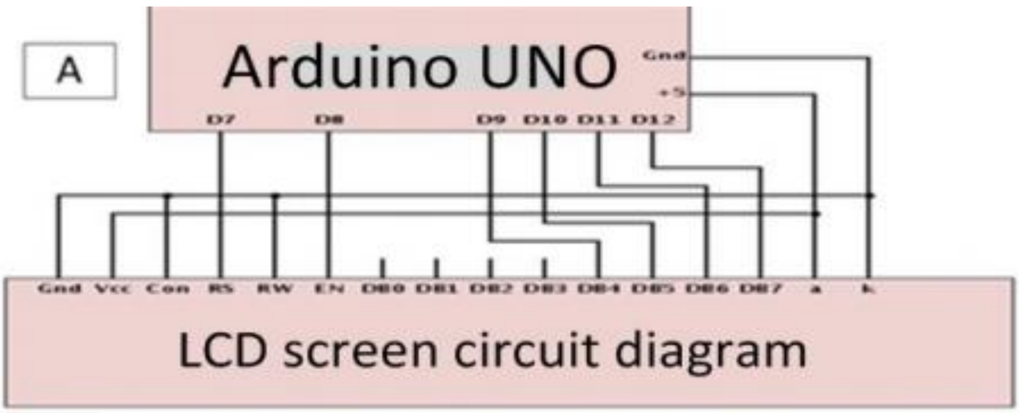

Figure 6(b) - Design LCD connection to the microcontroller (Arduino)

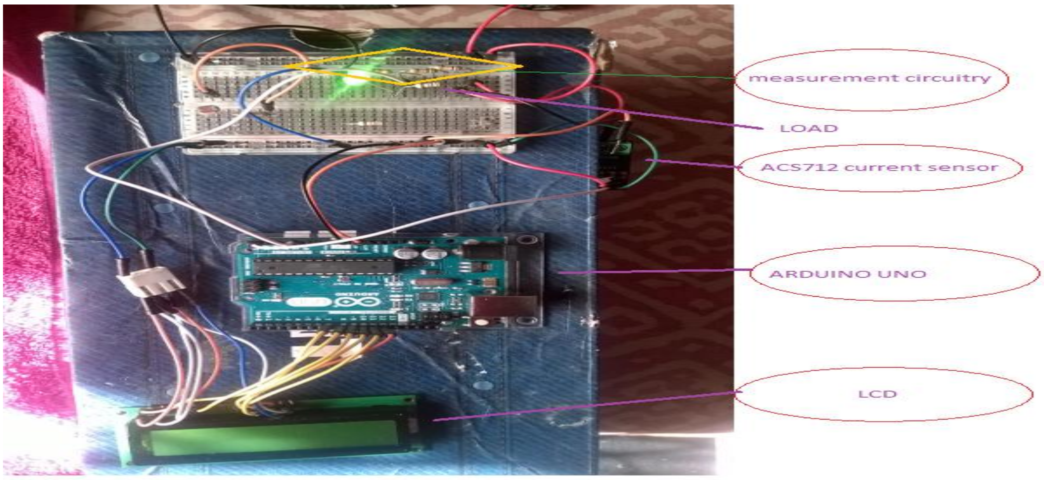

Figure 6(c) - PV panel performance monitoring circuit with LCD connection

(b) Wiper mechanism assembly

Figure 7 shows wiper mechanisms mounted on the PV panel. The wiper has an aluminium frame and a rubber blade to wipe off the dust. The wiper frame was connected to the servo motor shaft through a mechanical actuator mechanism.

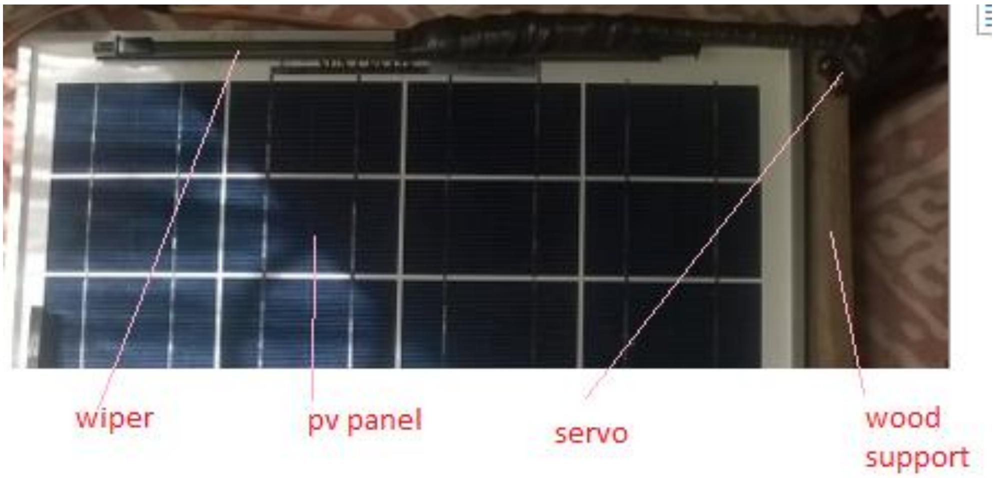

Figure 7 - Wiper mechanism mounted on the panel

(c) Connection of servo motors to external power supply

The servo motors rated at 4.8V to 6V were supplied separately from external batteries instead of Arduino supply to avoid damage to microcontroller voltage regulator as shown in Figure 8.

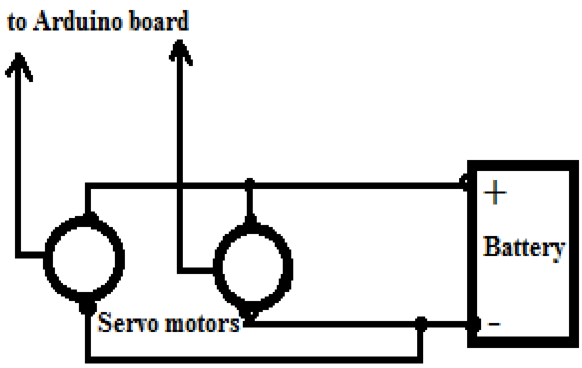

Figure 8 - Schematic diagram of servo motors connected to the external source and to the Arduino board

III. RESULTS, ANALYSIS AND DISCUSSIONS

The whole circuit including the servo motors and wipers was connected and the program designed using Arduino IDE was uploaded in the micro-controller (Arduino UNO) [3]. The behaviour of the circuit was observed as the PV panel output voltage, current and power were displayed in the LCD. The testing of the automated cleaning mechanism was carried out by firstling using a PV module with a clean surface and late having a dirty module surface.

The system was programmed such that 15 V output voltage was set as a threshold. If the output voltage is more than 15 V, the system would interpret the PV module surface as clean and no action would be taken. If the output falls below 15 V the system would start clean the module surface by operating the wiper. The results obtained were divided in two categories as follows:

(i) Dust-cleaning mechanism's response on clean PV panel

Figure 9: Dust-cleaning mechanism's response on clean panel

Figure 9 shows the setup used to demonstrate the dust-cleaning mechanism's response on clean panel. The PV panel output showed results which are close to the rated values. As shown in Table 1, both the values of voltage, current and power were not far off from the rated values with a voltage deviation of 5.67% from the rated value. With an output voltage of more than 15 V threshold, the cleaning mechanism wipe as it interpreted the results as for a clean panel.

Table 1: Rated and recorded values of clean PV module

RATED VALUES	RECORDED VALUES	DEVIATIONS
V=17.8V	**V=16.79V**	**5.67%**
I=0.68A	I=0.64A	5.88%
P=VI=12.104W	P=10.75W	11.86%

(ii) Dust cleaning mechanism's response on dirty panel

The tests carried out included putting accumulated dirt (paper) on the surface of the panel to resemble a layer of dust and to monitor how it would affect the PV module output voltage. The setup was as shown in Figures 10 and 11. The voltage output was reduced to 14.94 V, being a deviation of 16.07% from the rated value. This trigger the wipers to wipe across the PV module surface because the system interpreted the results (less than 15 V) as being due to dusty module surface. When the paper had already moved out of the module surface by the wiper, the output voltage increased again to more than 15V, thus leading to the wiper-mechanism stop wiping.

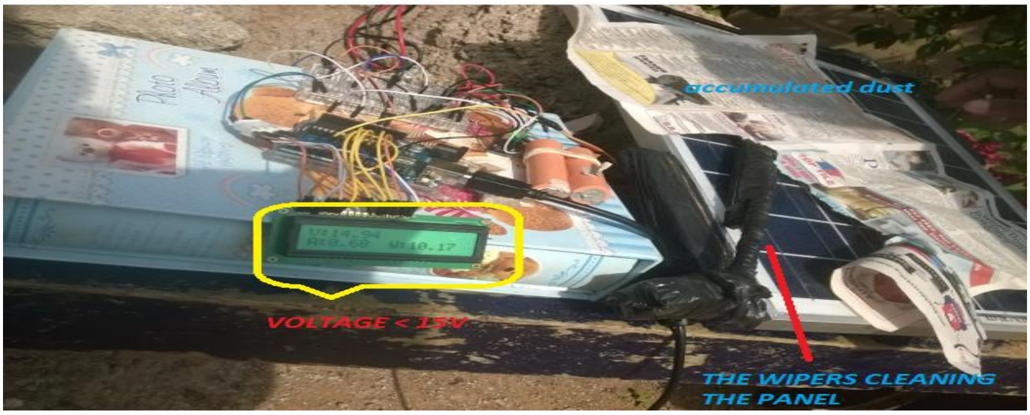

Figure 10: A dusted panel with reduced output voltage and activated wiper mechanism

Figure 11: A dusted panel with reduced output voltage and activated wiper mechanism

IV. CONCLUSION AND FUTURE WORK

The cleaning system monitored the PV module output and compared it with a set threshold of 15 V. For a clean panel, the output voltage remained above 15 V hence the cleaning mechanism was not triggered to operate. With a dirty panel the output voltage fell below 15 V and the cleaning mechanism was triggered to wipe. It led to recovery of output voltage to more than 15 V, and this resulted on the wiper mechanism stop wiping. This shows that the dust-cleaning mechanism was successfully implemented and this offered a good solution of developing a PV panel cleaning system which can benefit most of the PV system installations by improving their overall efficiency.

Further work would be the implementation of the dust-cleaning system by incorporating it on existing PV systems. The future work will further explore the possibility of having a cleaning mechanism which uses air instead of a wiper whereby the air will be blown over the surface of module to take out dust.

V. REFERENCES

[1]. Mohammed Mostefaoui, Ammar Necaibia, Aderrezzaq Ziane, Rachid Dabou, Abdelkrim Rouabhia, Seyfallah Khelifi. Power loss due to soiling on solar panel: A review, Renew. Sustain. Energy Rev., vol. 59, pp. 1307–1316, Jun. 2016.

[2]. Mohammed Mostefaoui, Ammar Neçaibia, Abderrezzaq Ziane, Rachid Dabou, Abdelkrim Rouabhia,Seyfallah Khelifi, Ahmed Bouraiou, Nordine Sahouane. Importance cleaning of PV Modules for Grid-Connected PV Systems in a desert environment – 978-1-5386-4225-2/18, 2018, IEEE,

[3]. Ahmed Bouraiou, Nordine Sahouane. Photovoltaic Module Performance and Degradation as Compared in Distinct Climatic Regions J. Campbelll, Y. Zemenl,2, B. Richardsonl, B. Striner, 12489 Berlin, 978-1-4673-0066-7/12, 2011 IEEE.

[4]. Darlene Field1, Thomas Rogers1, Andrea Sealy. The Effect of Saharan Dust on PV System Yields in the Tropical Environment of Barbados. 978-1-4799-7944-8/15, 2015 IEEE

[5]. Impact of Carbon Dust Particle Deposition and Partial Shadow of PV Array, Swapna Roy, 978-1-4799-7537-2/14, 2014 IEEE

[6]. ENVIRONMENTAL EFFECT ASSESSMENT ON PERFORMANCE OF SOLAR PV PANEL, 2015 International Conference on Circuit, Power and Computing Technologies [ICCPCT], Rajeshwari Bhol, Ritesh Dash, Arjyadhara Pradhan, S.M Ali, 978-1-4799-7075-9/15, 2015 IEEE

[7]. Emulation for De-rating and Degradation/Turbidity Factors Effects on PV Module, Salman Alturaiki, Ziyad Salameh

[8]. Muhammed J. Adinoyi, Syed A.M. Said. Effect of dust accumulation on the power outputs of solar photovoltaic modules, Volume 60, December 2013, Pages 633-636, http://www.sciencedirect.com

[9]. Tsamaase K., Ramasesane T., Zibani I., Matlotse W., Motshidisi K.. Automated dust detection and cleaning system of PV module, Volume 12, Jul-Aug 2017, PP 00-00

[10]. "Solar Panel Cleaning - Automatic Cleaning System: Heliotex." [Online]. Available: http://www.solarpanelcleaningsystems.com/. [Accessed: 05-Oct-2017].

[11]. R. Tejwani and C. S. Solanki, "360° sun tracking with automated cleaning system for solar PV modules," in 2010 35th IEEE Photovoltaic Specialists Conference, 2010, pp. 002895–002898.

[12]. Available online: http://www. electrosome.com

IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) is UGC approved Journal with Sl. No. 4198, Journal no. 45125.

Kelebaone Tsamaase. " Dust-cleaning system for improved PV Module Output." IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) 13.5 (2018): 26-33.