Smart system for dust detecting and removing from solar cells

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Abstract. In the last decades, solar energy gained the most demand as it represents a green and sustainable source of energy. One of the most important obstacles for solar energy production in Iraq is the dirtiness of the panel surface as it causes a shadow that reduces its performance. From other hand, Iraq location has a large frequency of sand dust storms. This research proposed a method to eliminate the impact of dust and dirtiness on the performance of the solar panel in power production. The proposed method monitors the power generation and cleans the photovoltaic surface when required. Arduino Uno microcontroller was used to control the washing task with windscreen wiper tool which energized when the output power dropped to 50% from its rate value. In addition, the proposed method presented a comparison on the solar panel performance with and without the proposed method. The results show the ability of the washing mechanism in maintaining the solar panel performance efficiently after the exposure to dust accumulation.

Keywords: Solar Cell, Dust Detection, Self-Cleaning, Arduino.

1. Introduction

Several factors may affect the generation of solar power generation. Shadows, snow, high temperatures, dust, dirt, bird's dropping pollen and sea-salt are regarded as the main factors that minimize or impede the generation of power in the Photovoltaic PV panels [1] [2] [3]. Generally, the world supports using renewable energy such as solar and wind energy, because the generated electricity is without giving rise to emissions of any carbon dioxide. Thus the demand on clean energy has grown resulting in increasing the production of PV panel's. This is represented the result of increase awareness about the environment damage that caused by using sources of fossil fuel such as coal, petroleum and natural gas over the years.

Using PV panels to produce power efficiently requires removing the dirt from them regularly, particularly, dust that is caused by pollen, sea salt and dirt particles [1].

There are many different sources that cause dust accumulation on the PV panels’ surface, and may have significant impact on production of electricity. The efficiency of power generation from the solar panel is minimized in a dusty environment and this attributed to the fact of: dust reduces the amount of sun light received by the PV panel [4].

In Baghdad at 2010, the authors of [4] found that the transmittance is minimized by approximately 50% on average, because of dust deposition on PV panels.
Thus, there is a need for monitoring and cleaning panel’s surfaces. The frequency of removing the 
dust from PV panels depends on the environment of the solar location.

This research focuses on the detection and removing dust by simple mechanism. The proposed 
mechanism based on using Arduino microcontroller with software to drive simple mechanics.

The rest of this paper is organized as following: methods of dust removal from PV is described in 
section 2. Section 3 presents the solar panel performance. Proposed system is described in section 4. 
Section 5 explains the system implementation. Results and discussion are explained in section 6. 
Conclusion is described in section 7.

2. Methods of Dust Removal from PV

Many methods were suggested and developed for automatically self-cleaning of solar panels, such as 
wiper and sprayer [6], using motorized brushes, self-cleaning with piezo-ceramic actuation [7], 
electrostatic cleaning [8] and robotic cleaning [9].

Generally the PV cleaning methods can be classified as follows:

- Rainfalls Cleaning Method: despite it is does not cost anything, it seasonally volatile. This will 
impact on the reliability of Rainfalls cleaning method passively particularly in Iraq when 
rainfall is not enough either in quantity or in intensity to wash off the soil [10].

- Manual Cleaning Method: This method depends on laborer to clean the PV surface so it is 
same as the method of cleaning buildings windows. The laborer needs to use brushes to 
remove the soil off the surface. In addition, this brushes need to be designed with special 
bristles to prohibit scratching the surface [10].

- Mobile Cleaners Method: machinery is used in this method of cleaning. In addition, this 
method may require to use a storage for water supply or sprinkler system [11].

From other hand, the authors in [12] review the recommended cleaning cycle to reduce effect of 
dust, during dry seasons it’s recommended the weekly cleaning while during intensive dust 
accumulation the daily washing is recommended.

An effective cleaning method should be performed when required with minimum requirements 
such as water or brushes.

3. Solar Panel Performance

The performance of the PV panel can calculated from the current- voltage (I-V) curve. The PV panel 
parameters for instance open circuit voltage (V_{oc}) and short circuit current (I_{sc}) are obtained from (I-V) 
curve. The power curve is obtained from the values of current and voltage. The maximum power point 
represented by the point of the maximum delivered power (P_{mp}). The maximum power voltage and 
current (V_{m}, I_{m}) represents by the current and voltage at the maximum power point.

From the aforementioned parameters, the device fill factor (FF) and conversion efficiency (\eta) can be 
obtained as represented in equation 1 and 2.

\begin{align}
F.F. &= V_{m}I_{m} \\
\eta &= \frac{V_{oc}I_{sc}}{A} \times FF \times 100\% \quad (1)
\end{align}

Where (A) is area of the panel and (G) is the irradiance falling on the surface of the panel. The performance of the studied panel is measured by the amount of energy it produces over period of time in (kWh) unit. Finally the panel performance can be represented by Yield (Ys) factor (kWh/kW_p) which is the energy generated normalized by the installed capacity in (W_p) as shown in equation 3:

\begin{align}
Y_s = \frac{E_{total}}{P_m} \quad (3)
\end{align}

4. Proposed System
The proposed system consists of three main parts as shown in figure (1). The first part is sensing, processing the dust density and sending SMS warning messages to the operators if required. The second part is the current and voltage sensors with Arduino Uno microcontroller to measure the PV panel output in real time, and then processing the accumulated dust effects on the output power. The third part is the windscreen wiper system that operates from the microcontroller signal via relay which energizes when the output power value approaches 50% from its rated values.

In this research, the effects of dust that accumulate on the solar panel are investigated by referring to the results that are obtained from sensors and microcontroller in dusty atmospheres. Also, an auto cleaning windscreen wiper system works as an auto cleaner, which is equipped on the flat solar panel. The windscreen wiper system consists of washing water sprayer, electrical D.C. power which is needed to drive the windscreen wiper system supplied from the solar plate itself by using D.C. to D.C. step down converter.

The light dependent resistance LDR sensor (that connect to microcontroller as shown in figure (1)) is used to distinguish between the day and night. Thus, the washing system can work in case of accumulation of dust depending on panel output electrical power.

![Figure 1. The Proposed System](image)

5. System Implementation
The implementation of the proposed system consists of the following devices:

5.1. Solar PV panel
Solar PV panel from FORTUNER CORP where its specifications are described in table (1).

| Table 1. P.V. Solar PV Panel Specification [13] |
|---|---|---|---|
| Module | 50Wp | Pmp(W) | 52.04 |
| Manufacturer | FORTUNER | Ambient temp | 25 |
| Model | NER | Imp(A) | 2.805 |
\begin{tabular}{|l|c|c|}
\hline
area(cm^2) & 4 & \\
Irradiance(mW/cm^2) & 100 & 3.105 \\
Vmp(V) & 18.552 & 4 \\
Voc(V) & 21.8465 & 14.51 \\
F.F. & 76.72 & 18.552 \\
\hline
\end{tabular}

\section{5.2. Arduino Uno Microcontroller}
Arduino Uno is a microcontroller board based on the ATmega328P as is used to measure dust density and calculate plate output power. The specifications of employed Arduino microcontroller are described in table 2.

The microcontroller is connected to personal computer (PC) via universal serial bus (USB) in order to upload the software. Figure 2 shows the arduino Uno microcontroller.

\begin{table}[h]
\centering
\caption{Arduino Uno Specifications [14]}
\begin{tabular}{|l|c|}
\hline
Microcontroller & ATmega328 \\
\hline
Operating Voltage & 5V \\
Input Voltage (recommended) & 7-12V \\
Input Voltage (limits) & 6-20V \\
Digital I/O Pins & 14 (of which 6 provide PWM output) \\
Analog Input Pins & 6 \\
DC Current per I/O Pin & 40 mA \\
DC Current for 3.3V Pin & 50 mA \\
Flash Memory & 32 KB of which 0.5 KB used by bootloader \\
SRAM & 2 KB \\
EEPROM & 1 KB \\
Clock Speed & 16 MHz \\
\hline
\end{tabular}
\end{table}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{arduino_uno.png}
\caption{Arduino Uno Microcontroller}
\end{figure}

\section{5.3. Dust Sensor}
The used dust sensor is of module DSM501A and it is specified as a low cost with compact size for a particle density sensor. The principle of operation of this sensor is shown in figure (3). The quantitative particle density can be measured with the dust particle counter where particles of bigger than (1 µm) could be detected and the heater induces air inflow located in to the sensor. The sensor connected to the microcontroller as shown in figure (4).

![Figure 3. Diagram of dust sensor block](image)

![Figure 4. The connections of dust sensor, G.S.M and microcontroller](image)

5.4. **Global System for Mobile Communication (GSM)**
The SIM900 GSM/GPRS modem is used to connect with the GSM network. This modem is responsible on sending warning SMS message to the maintenance officer at the power station when a dust storm occurs. This modem connected to microcontroller as shown in figure (4).

5.5. **Current Sensor**
A30 amp D.C current sensor type ACS712 is used to measure the (Isc.) which is the load current of the solar cell in order to calculate the output solar power. This sensor is connected to the microcontroller as shown in figure (4).

5.6. **Voltage Sensor**
The Arduino Uno microcontroller consist of five D.C. inputs and the output voltage of the solar cell that equal to 18 Volts, therefore the D.C voltage sensor is used. This sensor consists of voltage divider in order to measured voltage between (0-25) Volts. The sensor is connected to microcontroller as shown in figure (5).

![Figure 5. The Connections of Current Sensor, Voltage Sensor, Relay and Microcontroller](image)

5.7. **Relay**
A 5 volt relay is connected to microcontroller at a (digital output). When the accumulated dust on solar panel is increased over the maximum limit the relay switching ON. Then the windscreen wiper system works for (10 sec) period of time, in order to clean the solar cell and return the output power to the rated value.
5.8. Photovoltaic Panel P.V.
The results are obtained in Baghdad city (latitude of 33°13'N) during January month. The panel is mounted and tilted to 30° angle according to (reference) to raise the effectiveness of the panel. Figure (6. a) shows the windscreen wiper (for vehicle) consists of 12v D.C. motor that control wiper movement along the panel, 12v D.C. water pumping motor and two nozzles used to sprayed water during the survey of the panel surface. Figure (6. b) dirty Photovoltaic Panel P.V.

![Clean Photovoltaic Panel P.V.](image) ![Dirty Photovoltaic Panel P.V.](image)

**Figure 6.** The Photovoltaic Panel P.V.

5.9. Maximum Power Point Tracker (MPPT)
MPPT is specific types of charge and controller that will utilize the PV panel to its maximum potential. It is derive 5A step-down (18-12) constant voltage and constant current to charge the battery. Figure 7 shows the procedure of the proposed system based on day light while figure 8 shows the procedure of the proposed system based on dust in atmosphere.

![Flowchart for Daylight Procedure](image) ![Flowchart for Dust Procedure](image)

**Figure 7.** The Proposed System Procedure based on Daylight

**Figure 8.** The Proposed System Procedure based on Dust

6. Results and Discussion
6.1. **Short Circuit Current**

The short circuit current produce from panel (I_{sc}) and sensing by current sensor, record by Arduino microcontroller software (control panel) as show in figure (9).

![Current sensor output](image)

**Figure 9.** The current sensor output

6.2. **The Open Circuit Voltage of the Panel**

The data obtained for solar output power which accomplished at 2nd September 2017 for two cleaned and dust accumulated panels at constant tilt angle (35°) and clear sky. The temperature were found to be vary from 23 to 40 °C and the solar light intensity to be 800 to 1500 lux conditions. The amount of accumulated dust on the solar panel are obvious as the difference between the short circuit current of clean and dusty solar panels is shown in figure (4). The accumulated dust effects the solar panel performance because it caused the optical attenuation, i.e. the electromagnetic radiation is attenuated by the interaction with the dust solid particles in the external environment. The attenuation is the sum of different kinds of interactions, absorption, elastic scattering and inelastic scattering [9].

A comparison on the I_{sc} generation through a day is presented in figure (10). When the new mechanism is applied (clean PV), the I_{sc} generation is maintained higher level than without using it. The difference between the two cases is approximately 0.8 I_{sc} (Amp) along the day hours. The proposal improve the performance of the solar panel more than 50%.

7. **Conclusion**

The dust shadowing effects on the solar panel passively. It is considerable due to the fact that the output power is a complex parameter that is influenced by different environmental and weather conditions. The fixed and reliable solar panel power generation always requires clean PV panel. This research designed and implemented a mechanism that enables solar panel from cleaning itself when its performance getting less 50% its average generation rate. The proposal satisfies the opportunity of an efficient automatic self-cleaning with low frequency maintenance in order to improve solar panel performance.
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