Dirt sensing on PV modules with automated cleaning request

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Abstract

This paper will focus on the sensing of soiling on PV modules and request automated cleaning. The PV module will be checked three times daily for soiling. The dust detection system comprises of a photoelectric sensor to detect soiling and photodiode pyranometer which measures the solar irradiance (in W/m^2) which varies between 1,999 W/m^2 and 0 W/m^2 in no cloud and cloudy conditions respectively. This system will be synchronized with a communication system which constitutes a programmed Arduino mega 2560 microcontroller with inserted GSM shield capable of transmitting a signal via SMS to a cell phone requesting automated cleaning.

I. Introduction

The research stemming from the 1800's on the photovoltaic (PV) effect has grown to the point where it's used for one of the most efficient renewable energy sources. To improve and maintain the performance of these systems further research leads to methods of ensuring the system gets efficient sunlight. One way of doing this is by keeping the system clean.

II. LITERATURE REVIEW

The most affected performance characteristics by dust deposit on the surface of the PV modules are P_{max} , I_{max}, I_{sc} and FF [1]. Furthermore, there is an 18% reduction in generated power and up to 50% reduction in system's efficiency due to dust depositions on PV module surface [2]. Correspondingly, the accumulated dust on the surface of the PV module can reduce the system's efficiency and peak power generated by up to 35% and 20%, respectively [3]. On the contrary, there was a contradictory finding of 15% difference in the reduction in system's efficiency between the findings [2] and [3], this contradiction was based on the method utilized by [2] which was to place artificial dust on the PV modules which significantly reduced the system's efficiency compared to [3] which was to place the PV module in outdoors to naturally accumulate dust

Photoelectric Sensor

Photoelectric sensors have been applied to systems in which particle detection was required. According to [7] "Photoelectric-type alarms aim a light source into a sensing chamber at an angle away from the sensor. Smoke enters the chamber, reflecting light onto the light sensor; triggering the alarm." The photoelectric sensor use in this system gives credit to its ability to detect small particles, since smoke is defined as a cloud of fine particles suspended in a gas.

Photodiode Pyranometer

The accurate measurement of solar irradiance expressed (in W/m^2) is significant in determining the performance of PV modules. Pyranometers are characterized based on the sensors that it utilizes, which may either be thermal (thermopile) or photovoltaic. In fact, the principal advantage of photovoltaic sensors in measuring solar irradiance is there response time which is approximately 10 µs compared to thermopile sensors having a response time in the range of 1-10 s [4]. In addition, photodiode pyranometers are very cost effective compared to thermopile pyranometers. Additionally, photodiode based pyranometers are designed to measure solar irradiance in the visible spectrum approximately 400 nm to 750 nm [5] While, thermopile pyranometers have broader spectral range between 385 nm and 2105 nm [6].

III. METHODOLOGY

The proposed dirt sensing system will consist of a combination of photoelectric sensor and a photodiode type pyranometer which is used to measure solar irradiance. A transparent glass will be used as the reflective surface for the sensor. The communication mechanism will consist of an Arduino mega 2560 microcontroller, programmed using C++. This will transmit a signal to an output device requesting automated cleaning when dirt is sensed on PV modules. In addition, the PV module will be used as the power supply of the proposed system. The circuit diagram, isometric and side-view layout of the design is shown in figures 1, 2 and 3 respectively.

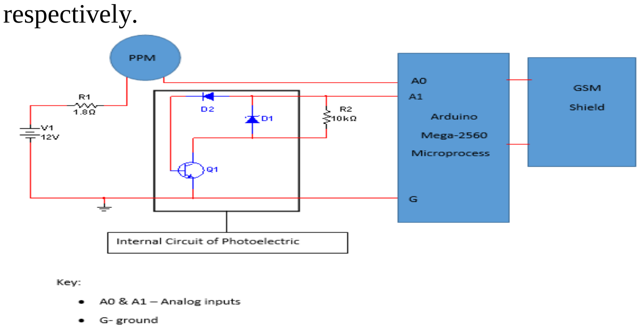

Figure.1 Circuit diagram of proposed system

$R_1 = V_s/I = 3V/ 1.67\ A = 1.80\ \Omega \pm 5\%$

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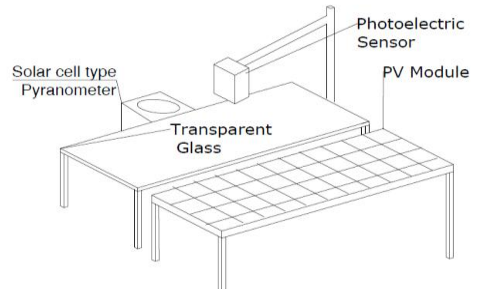

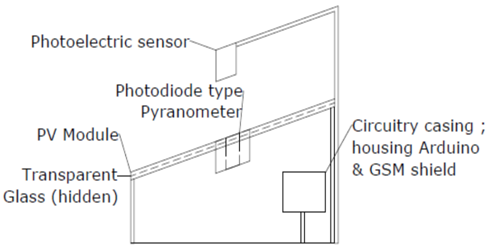

Figure 2 (top) and figure 3(bottom) showing isometric and side view of layout

IV. EXPECTED RESULTS

TABLE 1
Showing clouds, altitudes and expected solar irradiance measurements.

Cloud names	Altitude (h) / ft	Irradiance (I)/ W/m^2	No clouds Irradiance / W/m^2
Cirrus	≥ 20000	$1945 \leq I \leq 1960$	1999
Altostratus	$6500 \leq h \leq 20000$	$700 \leq I \leq 1600$	-
Cumulus	≤ 6500	$0 \leq I \leq 600$	-

TABLE 2
Showing soiling classifications and soiling categories on the surface of the PV module.

Soiling classifications	Soiling categories
Natural dust accumulations	Heavily
Debris*	Moderately
Bird droppings	Lightly

Debris* include dry grass, dry leaves, paper etc.

V. DISCUSSIONS

Based on the expected results in table 1, it can be deduced that the expected irradiance measurements of high level cirrus clouds are within the range of 1945 – 1960 W/m^2 with an accuracy of ±5% in sunlight. Medium level altostratus clouds have lower expected solar irradiance measurement compared to high level clouds with a range of 700 – 1600 W/m^2 with accuracy of ±5% in sunlight. However, low level cumulus clouds expected irradiance measurement range 0 – 600 W/m^2 with ±5% in sunlight. The no cloud irradiance measurement is 1999 W/m^2 with an accuracy of ±10 W/m^2. The spectral sensitivity range of the photodiode pyranometer is 400nm-1100nm. Based on table 2, the natural dust accumulations on the PV module will mostly contribute to the soiling of the modules which forms the based layer soiling. Debris forms a second layer of soiling which is moderately soil compared to bird dropping that is lightly soil. Furthermore, based on the soiling categories present, the photoelectric sensor will transmit an IR light beam to the PV module three times daily, if there are any change in the amount of IR light that reach the receiver, it will change the output voltage of the sensor which indicate that soiling is present on the PV module surface even when there are no cloud cover. Hence, the communication system will send a text via SMS to a cell phone requesting automated cleaning.

CONCLUSIONS

The dust detection system can detect soiling whenever the output voltage of the photoelectric sensor changes state. The measurement of solar irradiance indicates a secondary factor that affect the performance of the PV module. Under no cloud condition and heavy cloud condition, the expected irradiance measurement is 1999 W/m^2 and 0 W/m^2, respectively. The soiling categories indicate the soiling classifications.

RECOMMENDATIONS

It is recommended that energy storage technology be incorporated in the system which will serve as a backup power supply in the event of prolonged cloudy conditions during the day. This backup power supply will enhance reliability of the system.

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