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INVESTIGATION OF POWER AND EFFICIENCY LOSSES DUE TO BIRD DROPPINGS

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ABSTRACT

The study investigated the effects of bird droppings on solar panel efficiency and power output. The study was carried out using two different photovoltaic (PV) modules that are, clean and soiled panels. Between 1000 and 1300 hours on a testing day, data for relevant parameters were obtained and recorded at 30 minutes interval for both clean and soiled modules. Data collected include those of solar intensity, generated current and voltage as well as module surface and ambient temperatures which are needed to calculate system performance. In all cases, the power and efficiency obtained for the clean panel was significantly greater compared with the soiled module. Typical power and efficiency calculated for the clean module are 6.330 W and 17.16% respectively compared with 3.124 W and 8.46% for the soiled module. Comparing the two modules, it is found that the highest percentage decrease in power and efficiency are 54.22 % and 54.13 % respectively. From this study, it is concluded that bird dropping on solar photovoltaic (PV) system has a negative impact on overall performance.

Keywords: Contaminants, Insolation, Irradiance, Photovoltaic, Solar Intensity

1 INTRODUCTION

The sun creates its energy through thermonuclear fission process that converts tons of hydrogen to helium every second. This energy in the sun is enormous. Ability to harvest just a few percentages could probably meet human total energy requirement. Various technologies have been developed to harness this renewable and non-polluting energy source. It is therefore understandable, the focus on this green energy source [1]. Of all the features in our solar system, the sun is the most prominent of all, with a temperature of about 6000ºC [2]. However, only a little fraction of the total radiation reaches the earth. and it can be received by photovoltaic cells which converts it into electricity [3]. The converted electricity is stored in a storage unit (battery) for later use because of the intermittency of the solar energy. Solar energy conversion follows two technological routes; concentrating solar thermal power plants and the solar photovoltaic (PV) system. The solar PV is basically a p-n junction that converts solar energy into electrical energy. Essentially, when sunlight strikes the PV cell, some of this is absorbed within the semiconductor material which tends to knock the electrons loose thus allowing free flow of electrons and generating electricity. By converting solar radiation into direct electric current, each photovoltaic cell in the solar panel is estimated to generate 0.5 volts. Placing these cells in-series produces maximum power when it is desired to sum up the voltage or in parallel to increase the current. The PV system comprises one or more modules (panels), a battery, a charge controller and the load. Solar PV panels are usually mounted on roofs and wired into a building through an inverter which converts the direct current into alternating current. There are many types of solar PV cells and these include monocrystalline silicon cells, multi crystalline silicon cells, thick film silicon, and amorphous silicon. The available PV cell surface area for absorption of the solar energy is affected by other environmental factors such as geographical location, ambient temperature, solar intensity, wind, humidity, dust, bird droppings and other cell surface pollutants. The DC power conversion to AC is affected by the inverter efficiency and all these combines to determine the output power. Studies show that the efficiency of power production in solar system is affected by soiling effect. Soiling refers to accumulations of snow, dust, bird droppings and other particles on the surface of the PV modules. Bird droppings on solar cells is a stubborn and very aggressive contaminant on photovoltaic module. In intensive sunlight, the acidic manure can literally burn into the glass partial shading module to reduce the flow of current through the solar cell and this could cause local overheating [4]. If the bird droppings are not removed in time, the tab and bus wires can burn open. Bird droppings differ in phase; some are normally solid whereas the others are wet. Air temperature, humidity, panel inclination, installation type, general environmental pollutants in addition to wind speed play a significant role in defining how bird droppings accumulate on the cell. High wind may spread the droppings on the surface of the PV panel. The performance of a solar energy system is primarily influenced by the ability of the glass cover to transmit solar radiation to the collection surface. Other factors contribute to performance level, however, the most significant gradual degradation of transmittance depends on the presence of extraneous particles on the module. Therefore, the aim of this study is to investigate the effects of bird droppings on solar panel power output and efficiency. The study will also use the opportunity to investigate the effect of mean contaminant particle size on power generation.

2 MATERIALS AND METHODS

2.1 Materials and Equipment

For this study, the following materials and equipment were employed: Bird droppings, two Renogy 18V monocrystalline solar PV modules, ammeter, digital weight scale, sieve, infrared thermometer, plate.1a Fluke digital multimeter, plate. 1b, flexible 2.5 mm x 10 m twin electric cable and thermocouple.

Plate 1. (a) An infrared thermometer and (b) A digital multimeter

2.2 Method

Plate 2 shows the test modules both the control and the soiled. The ambient temperature of the immediate vicinity of the PV modules as well as the surface temperatures of the test modules were recorded at 30-minute interval using an infrared thermometer and thermocouples. Similarly, the performance parameters (output current and voltage) for the control and soiled module were recorded the same time using the digital multimeters. The power, percentage variation in power, efficiency and its percentage variation were calculated and recorded for each of these modules at the intervals.

Plate 2. Clean and Soiled Modules

Table 1 represents the characteristics of the modules used.

Table 1. Module Characteristics

PARAMETERS	SPECIFICATIO
Peak power (Pmax)	32.11 W
Voltage at Pmax (Vm)	17.94 V
Current at Pmax (Im)	1.79 A
Short circuit current (Isc)	2.8 A
Open circuit voltage (Voc)	19.31 V
Output Tolerance	+ or – 5 %

2.3 Data Analysis

The output power and the daily energy yield of the modules were obtained using the following equation 1.

$$\text{Power (W)} : V \ x \ I \tag{1}$$

2.3.1 Fill Factor

The fill factor (FF) is defined as the ratio of the maximum power from the actual solar cell to the maximum power from an ideal solar cell equation 2, [5].

$$FF = \frac{\text{Max power from real cell}}{\text{Max power from ideal cell}} = \frac{V_m I_m}{V_{oc} I_{sc}} \tag{2}$$

Where FF = Fill factor, V_m = Voltage at maximum power, I_m = Current at maximum power, V_{oc} = Open-circuit voltage and I_{sc} = Short-circuit current as shown in equation 3.

$$\text{Efficiency } (\eta) = \quad \eta = \frac{(I \ x \ V \ x \ FF)}{(G \ x \ A)} \tag{3}$$

Where η is the efficiency, V the output voltage (V), *I* the output current (A), A is the area of the panel (m^2) and G is the Solar irradiance (W/m^2).

2.3.2 Percentage Decrease in Power

This is the difference between the production capacities of the two solar panels in comparison to the power output of the control solar panel. Mathematically, it is given in equation 4:

$$\% \text{ decrease in power } (P_{decrease}) = \frac{(P_{control} - P_{test}) \times 100\%}{P_{control}} \tag{4}$$

2.3.3 Percentage Decrease in Efficiency

This is the difference between the efficiencies of two solar panels multiplied by 100%, divided by the control panel efficiency, results in the efficiency deduction of the two solar panels. It is expressed mathematically as shown in equation 5.

$$\% \text{ decrease in efficiency} = \frac{(\eta_{\text{control}} - \eta_{\text{test}}) \times 100\%}{\eta_{\text{control}}} \qquad (5)$$

3 RESULTS AND DISCUSSION

3.1 Results of Analysis of Solar Panels

From the data collected in a typical three days testing, the following equations 1, 2, 3, 4 and 5 were used to calculate the mean of the following: power, percentage decrease in power, efficiency and percentage decrease in efficiency for both panels.

Table 2. Calculated Power, Efficiency and their Percentage Decreases

Days	Power (clean) (W)	Power (dusted) (W)	Percentage decrease in power	Efficiency (clean) (η)	Efficiency (dusted) (η)	Percentage decrease in efficiency
1	6.086	2.780	54.22	16.49	7.55	54.13
2	6.330	3.124	50.71	17.16	8.46	50.69
3	5.940	3.020	49.15	16.09	8.18	49.16

Table 2 presents data on the performance of solar panels over three typical test days. In this table power output, efficiency and efficiency variations under "clean" and "dusted" conditions are compared. On all the three days selected for comparison, the "Power (dusted)" is significantly lower than the "Power (clean)". This clearly demonstrates that the contaminants including bird droppings on solar panels reduce the power generation capability. The percentage decrease in power ranges from 49.15% to 54.22%, indicating a substantial loss of power due to these droppings, the contaminant. This is critical as it highlights the detrimental effect of soiling. Similarly, the "efficiency (dusted)" is consistently lower than the "efficiency (clean)" across all days. The percentage decrease in efficiency ranges from 49.16% to 54.13%. This closely mirrors the percentage decrease in power, which is expected since efficiency is directly related to power output for a given solar panel area and incident solar radiation. The findings in this study are consistent with those in the literature. In a study [6] it was found that settled dust affected the module performance by reducing its power output by 28.7% and panel efficiency reduction by 5.6%. In another work, [7] the same trend is maintained as results indicate that cumulative soiling considerably reduced the power output of the soiled panel as compared to the clean one (12% reduction). There are still variations in the value of power generated between the chosen typical days. This difference is attributed to the variation in incident solar irradiance (sunlight intensity) on the panel between the days. Cloud cover, haze, or atmospheric conditions can reduce the amount of sunlight reaching the panel, leading to the observed differences. In a study conducted by,[8] in Niamey, the impact of climatic parameters on the performance of solar photovoltaic (PV) module was investigated by measuring the sensitivity of mono-crystalline solar PV module towards dust accumulation, ambient temperature, relative humidity, and cloud cover between May to August 2015. The study found that the dust accumulation has the greatest impact on the performance of the PV module followed by temperature, relative humidity and cloud cover. By exposing the module for 23 days, the study observed a reduced energy output in a range of 15.29%. The power output and the conversion efficiency of the PV module also dropped by 2.6% and 0.49% respectively. The relative humidity also contributed to a reduced energy output by 4.3 Wh/m^2. In another investigation**[9],** it was found that PV module performance was significantly affected by both environmental conditions such as outside temperature, wind velocity, and humidity, as well as the accumulation of dust on the module surface. However, overall improvements in P_{max} after cleaning ranged from 3.5% to 19.4%, with an average value of 9.8% and an average improvement in short circuit current of 6.7%. A study [10] found that dust has an effect on the performance of solar PV panel. The authors also observed a reduction in the peak power generated of up to 18%. In a Dutch study [11] the contribution to efficiency losses by factors such as localised soiling phenomena, deposition thickness and absorbance were considered. The study found an efficiency loss of roughly 9%. In another investigation by, [12], it was found that settled dust affected the module performance by reducing its power output by 28.7% and panel efficiency reduction by 5.6%. All these other studies are either in agreement or follow similar trend as the current work.

4 CONCLUSIONS

From the study, the following conclusions are drawn: Dusted solar panels reduces the power generation capability. The percentage reduction in power generation is variable depending on various parameters including mean size and surface concentration of the contaminant, insolation intensity etc. The reduction could range from 0% for the clean module to over 50% contaminated module. Similarly, the generation efficiency of a contaminated solar module is lower compared with that of the clean module. For the same contaminant loading (kg/m^2), the smaller the mean contaminant particle size, the higher the resistance to power generation.

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