International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 7 Issue 7, July 2020

ISSN: 2394-4404

Photovoltaic System Performance In The Presence Of Contaminants

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***Abstract:** It has been recognized in the energy sector that the status quo is unsustainable not just because of the depleting conventional energy resources but also because of the associated environmental degradation. Solution to this menace is the gradual replacement with renewable energy. There are many sources of the renewables and these include wind geothermal, solar and hydro. The photovoltaic appears to have a great potential as it is globally widely available and has near zero carbon footprint. In this study the effect of dust on solar electric energy generation has been studied. The experiments have shown that the generated voltage is hardly affected by the dust loading but the generated current and power decrease with increasing dust loading. Again, for a constant dust loading, the power generated increases with increasing dust particle size.*

***Keyword:** irradiance, transmittance, footprint, photovoltaic, monocrystalline, semiconductor.*

I. INTRODUCTION

In the energy sector today, the burning issue centers on how to control and possibly reverse global warming and the associated adverse environmental impact. The awareness that the status quo is unsustainable not only because of the fast depleting conventional energy resources but more importantly also, the conventional energy resources contribute immensely to global environmental degradation. Solution approach that has been adopted is the gradual replacement with renewable energy in its various form. Wind, geothermal, hydro, wave, biomass and photovoltaic (PV) are all forms of renewable energy and each of them has its merits and demerits. Solar energy, among all of them, appears to have the greatest potential especially in regions where the availability of the sunshine is guaranteed in greater part of the year. As a result, the solar energy technology has in the last decade evolved and grown rapidly. Some of the advantages the solar energy technology has over its rivals include the absence of emission of pollutants, user friendliness, easier to harness, near zero carbon footprint, ability to be used in remote areas and low running cost. As a recognition of the huge potential of the solar technology some governments have introduced intervention measures in the form of subsidy such as the Feed-in Tariff scheme (FITs) so as to encourage individuals to install solar energy systems. In this arrangement, the individual who installs solar energy system is authorized to generate more than one’s requirement and sell the excess to the national grid. Broadly speaking, solar energy is used to raise hot water for space heating or other domestic/industrial applications and for electricity generation using the photovoltaic approach. The main drawback for the photovoltaic system is the storage facilities in addition to the panel cost. Since the sun is only available in the daytime and even some days the sky could be overcast with little or no sunshine and as a result the need to store the energy when it is available is imperative. Currently battery storage is most commonly used but the cost of batteries is high and this has been a big constraint to the popularization of solar electric generation. However, of recent, the cost of panels and batteries have been falling to the extent that parity has been achieved in some locations between grid and solar electricity. Some sectors where the photovoltaic system has found application include water pumping, energy supply to remote

ISSN: 2394-4404

buildings, solar home systems, communications, satellites, space vehicles and for large power plants. Owing to this capability, the demand for photovoltaic is increasing all over the world and it has been found that PV electricity is gradually becoming economically competitive with conventional energy sources, Moss and Ledwith (1987).

The ability of the solar module to perform optimally depends on a number of factors which include the ease with which the cover glass transmits the solar radiation to the collector surface, the tilt angle of the absorbing surface, the intensity of solar radiation, the module cell surface temperature and the type of the solar cell employed in the design. Tilt angle is a function of latitude at each location, Said and Walwil (2014). As a general rule of the thumb, output power can be optimized by adding 15 degree to a site's latitude in the winter and subtracting 15 degree to a site's latitude in the summer, Bas (2020). The effect of an array's tilt angle on solar PV power output may be up 20% compared to that of a flat panel. Dirt tends to accumulate about twice more on a flat panel compare to a tilted panel. Solar cell temperature is one of the most important factors that modify the power output and efficiency of a PV module, (Achara, Dignite, (2020) and Jakhrani et al (2011). The cell temperature depends on the irradiance intensity, ambient temperature, wind speed, thermal dissipation of material of construction, the module encapsulating material, etc., Perraki and Tsolhas (2013). Research has shown that solar cells work better in certain temperature range, beyond which the efficiency drops. In Nigeria, the ambient temperature rise could be substantial over 25^{0}C on average for the year.

The ability to transmit the solar radiation can be affected by contaminants such as birds' droppings and dust which can lead to the gradual degradation of transmittance. Birds find it convenient to build their nest under the solar panel where it is quiet, serene and un-disturbing. Here they live and breed and from time to time perch on the panels to enjoy the sunshine and in this process leave their droppings on the panel surface. Even other birds whose nests are miles away in their daily hunt for food find the solar panel on their trail a suitable place to rest and after leave their mark in the form of droppings. The other source of contaminants is dust accumulation which is usually wind bourne that will eventually settle on the surface of the solar module. The sources of the dust have been studied and conclusion reached that it comes from both organic and inorganic materials, Alwaeli (2015) and Elminir et al (2006).

Dust may be considered to originate from the crushing and attrition of materials and to end up as minute particles having size less than 500 µm. Dust may originate from different sources such as constructional sites, industries and dust storm. Dust is made of visible and invisible, floating and falling particles of solid material. Dust aggregation on the panel surface depends mainly on the property of the dust, local environment, tilt angle and surface of solar panel. Dust accumulation on the solar module has been investigated to conclude that its presence creates a significant adverse impact on the performance of the solar PV panel, Gupta (2017).

Solar panel naturally gets dirtier over time because of the deposition of dust and other contaminants. These foreign bodies owe their origin in the atmosphere from various sources such as dust lifted up by wind, pedestrian and vehicular movement, volcanic eruptions and pollution, Dajuma et al (2016) and Mekhilef et al (20120). The accumulation of dust on the surface of PV module reduces the glass cover transmittance and hence decreases the amount of solar irradiance reaching the cells, over time, reducing the performance. Dust accumulation is also a function of location. Kaduna where this study is carried out is a city just south of the Sahara desert, therefore dust accumulation on the solar module is expected to be much higher than that on a location quite removed from the desert. The importance of dust accumulation studies cannot be overemphasized because data obtained will not only help photovoltaic system designers but also manufacturers have better understanding of allowances to factor-in to account for losses due to dust in the design of solar systems. As a result, the aim of this study is to investigate, experimentally the effect of dust accumulation on the power generation of photovoltaic module.

II. MATERIALS AND METHOD

The materials and equipment required to carry out the tests include a pair of multimeters, a pair of digital temperature read-out units, thermocouples, a pair of monocrystalline photovoltaic modules and sand of various sizes.

The test rig is arranged as shown in plate 1 with each of the thermocouples inserted appropriately in place on the solar cell in the module and connected to a digital temperature read-out unit. Similarly, the digital (current/voltage) multimeters are connected to each of the module terminals.

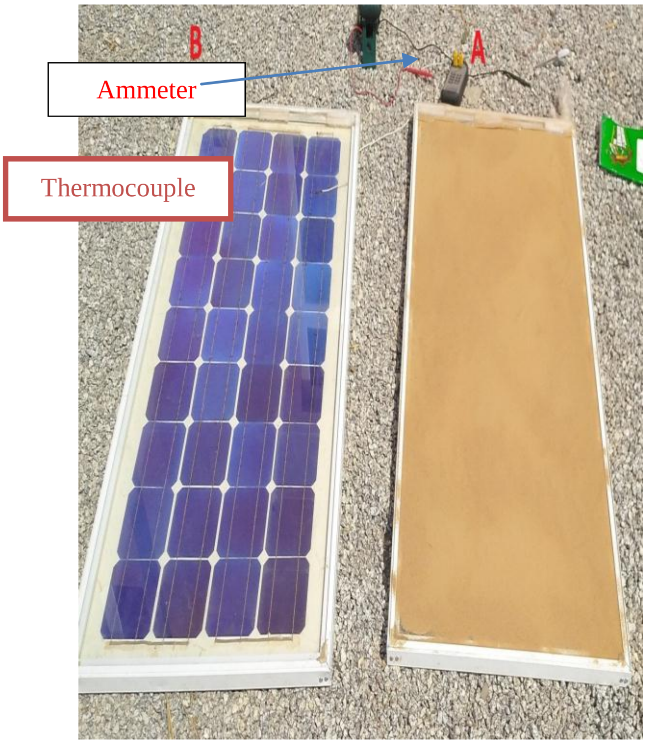

Plate 1: Experimental Setup Showing Typical Clean and Loaded Modules

In each test operation, one of the solar modules is used as the reference unit. The module by the left hand side, is the

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reference panel whereas module by the right is the dust laden panel. In order to avoid any bias in the result obtained, the two modules are test run simultaneously under the same ambient conditions. This makes it possible to confidently compare the two test results. In each test run, a measured weight of the sand dust is spread evenly on the module cover and this, for repeatability is expressed per unit area of module referred to as area density (kg/m^2). After the setup, the rig temperature is allowed to stabilize and the reading taken after every 15 minutes.

III. RESULT AND DISCUSSION

The data obtained is used to plot figures 1 to 7. Figures 1 and 2 show the effect of dust loading on voltage generated by the module. The effect of dust loading on the current is depicted by figures 3 and 4. Shown in figures 5 and 6 is the effect of the dust loading on power generated by the photovoltaic module. Finally, figure 7 shows the effect of particle size on power generation

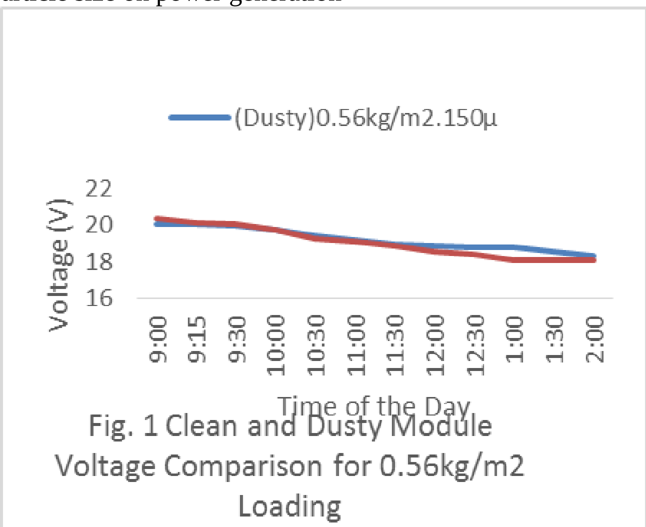

Figure 1

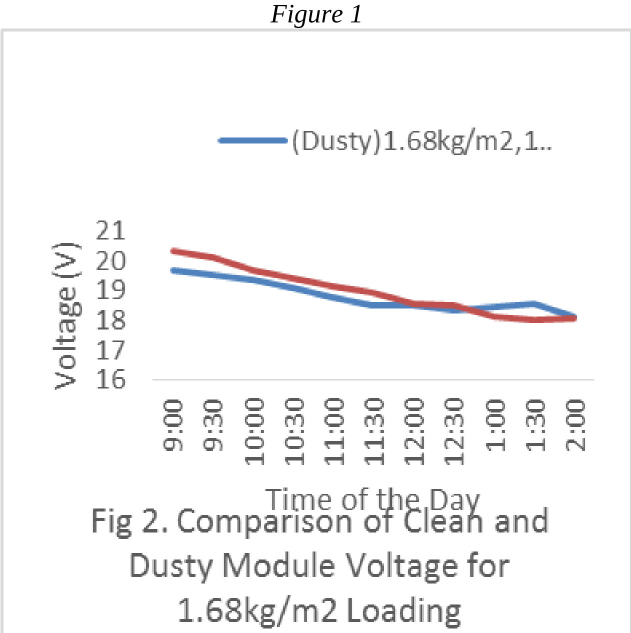

Figure 2

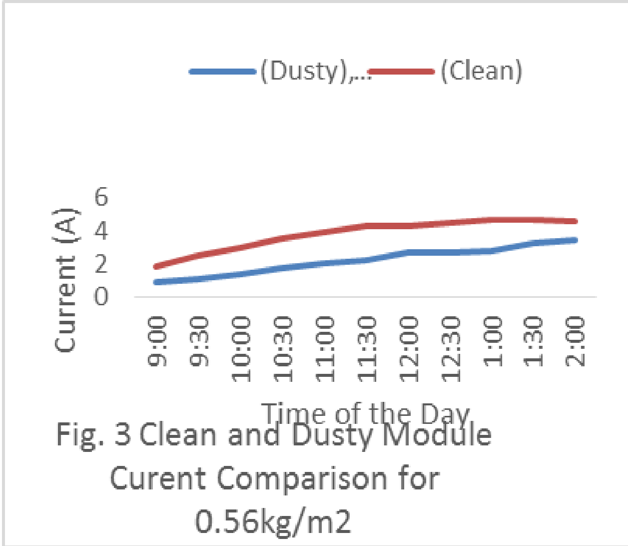

Figure 3

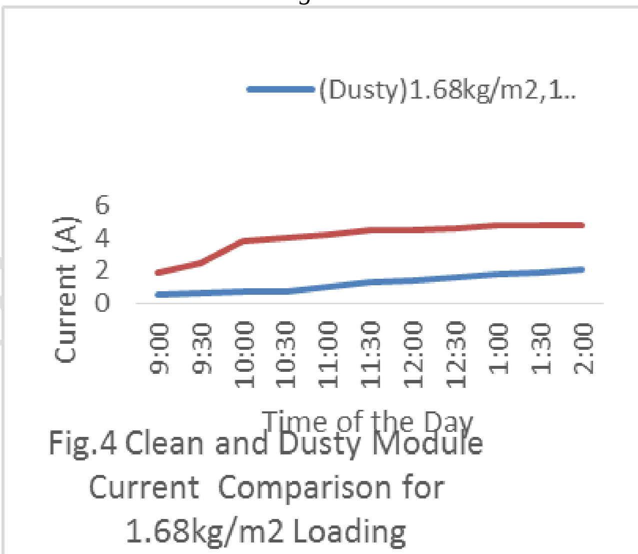

Figure 4

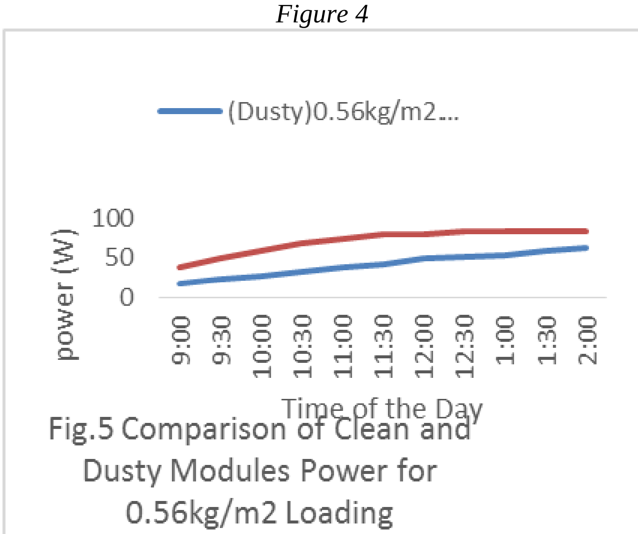

Figure 5

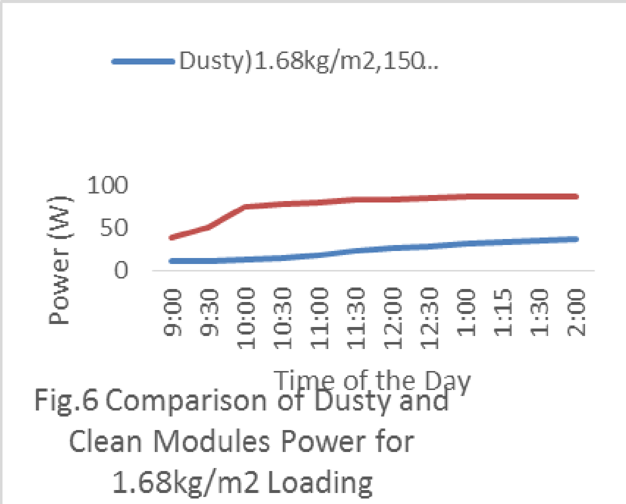

Figure 6

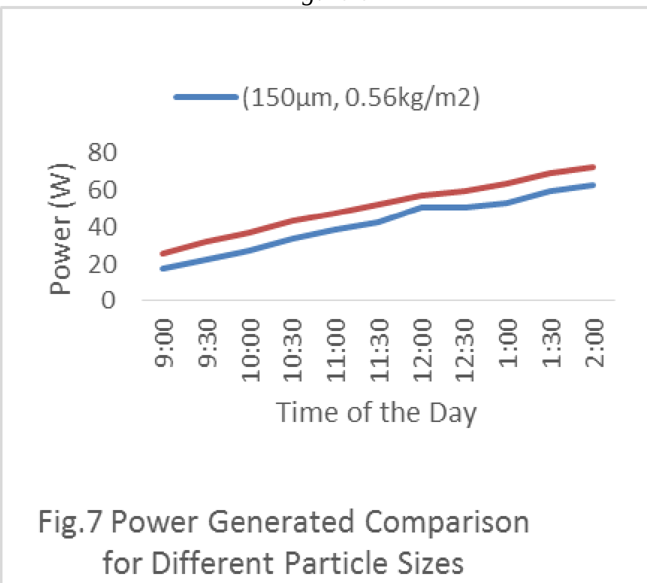

Figure 7

From figures 1 and 2 where the effect of dust loading on the generated voltage is shown, it can be said that the effect of dust loading on generated voltage is negligible especially when the module is lightly loaded with dust. However, as the loading increases, figure 2, the dusty module generated voltage starts to lag that of the clean module. In the case of current, the effect of dust loading is quite discernible both for the lightly loaded test, figure 3 and the heavier dust loaded module, figure 4. A comparison of figures 3 and 4 shows, however, that as the dust loading increases, the generated current difference between the clean module current and the dusty module increases. This behaviour can be attributed to the fact that as the dust loading increases, the irradiance reaching the PV cell surface decreases consequently reducing also the current generated. The effect of dust loading on generated power is shown in figures 5 and 6. The effect of dust loading on generated power curves follow the same trend as the current curves. This is not surprising as it has already been found out that the effect on voltage is marginal and power is a product of current and voltage. At any particular time, the voltage is more or less constant, therefore the power curve resembles the current curve. Finally, figure 7 shows the power curve when the particle size is the variable with the dust loading constant. In figure 7 it is shown that the generated power increases with increasing particle size. This behaviour is not surprising since for the same dust loading, the finer dust size, being closely packed, would make it more difficult for irradiance to reach the cell surface.

IV. CONCLUSION

The performance of the photovoltaic system in the presence of dust has been studied to find that the presence of dust only marginally affects the generated module voltage. However, as the dust loading increases, both module current and power are affected. In both cases, the module current and power decrease as the dust loading increases. When the dust loading is held constant, the generated power increases with increasing dust size.

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