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Research Article

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The Effect of Dust Particles on Solar Panel Efficiency in the Mangroves of Calabar

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Abstract Dust particles on photovoltaic (PV) modules is a common occurrence in in our society. Its system performance is often affected by the amount of dust particles on PV modules. The effect of dust particles on solar panel efficiency when plotted against other parameters was investigated using two identical solar panels in this study. A digital multimeter was used to measure the variations in current and voltage from the control and dusty PV modules during an outdoor experiment with 80-watt monocrystalline PV modules. Additional, measurements of other environmental parameters including solar radiation, ambient temperature, and relative humidity were recorded using hygrometer, thermometer, and solar power meter. Efficiency was also calculated using appropriate formula. Hence, the amount of sunlight that reaches PV modules was drastically reduced by dust particles on their surface by over 20.50%, which lowers the system's overall efficiency. The relationship between ambient temperature, solar radiation with efficiency is linear and directly proportional, while the relative humidity is linear but inversely proportional. Efficiency against time peak at 12 noon for both panels without dust above 80%, while that with dust about 60%. The study highlighted the need for regular cleaning of the surface of the PV module to maintain its optimum efficiency.

Keywords Photovoltaics, efficiency, variation, solar panel, measurement.

1. Introduction

PV modules are constructed with many layers to protect the cells from the environment and guarantee optimal energy output, such as a protective cover, an anti-reflective coating, and a cell encapsulation layer. Silicon is typically used to make the cells, which can be thin-film, polycrystalline, or monocrystalline [1],[2]. The most efficient cells are monocrystalline ones, which are created from a single silicon crystal, as opposed to polycrystalline ones, which are created from several silicon crystals and are less efficient [3],[4].

The main advantage of PV system is that it uses solar radiation. Solar radiation is abundant especially at the Sun Belt regions around the equator which is mostly arid and has abundant sunlight [5]. However, most of these areas exhibit high ambient temperature and low frequency rain which aids dust accumulation. These two environmental factors can be detrimental to the performance of PV systems [6].

The effect of temperature on the PV modules is taken into account when constructing the PV system, however the amount of dust that accumulates on the modules is typically ignored or added randomly (3%) while designing, deploying, and operating the PV system [7].

The power output of PV modules can be greatly decreased by dust since it naturally prevents sunlight from reaching the PV cells. Due to the rising number of PV installations in the sun belt countries, the problem of dust on PV modules has only lately gained attention [8].

The term dust is defined as any substance or particle of matter that exist in the atmosphere with less than 500μm diameter (10 times smaller than the diameter of human hair) but not limited to solid inorganic and organic

particles such as soil particles, smoke (including factory smoke, vehicular smoke and firewood smoke) volcanic vapor, bacteria, pollen, fungi, microfibers and eroded limestone [9],[10].

[11],[12] investigated how dust deposition affected the efficiency of PV modules. They discovered that dust buildup on PV is the cause of energy loss in PV modules. Nonetheless, their research offers some mitigation strategies that can be used to keep performance at a given level. According to their review, more thorough research is required to determine the effects of dust in Nigeria's geopolitical regions in order to gather information that will be useful for designing PV module systems that take into account the best methods for minimizing or eliminating the effects of soiling in each particular location.

According to [13],[14] there should be greater focus on how dust affects solar PV modules. They claim that although there is a lot of potential for solar radiation, it is restricted due to dust buildup in northeastern Nigeria. Thus, their study examined how dust affected the efficiency of solar photovoltaic modules in northeastern Nigeria. To evaluate the module's performance, they conducted a field experiment in Maiduguri that involved continuous dust deposition for 14 days throughout the dust accumulation period.

Their findings demonstrated that after 14 days of continuous deposition, a power output decrease of more than 50% was seen. On the fourteenth day of the trial, the effectiveness of the module dropped from 17.1% on the first day to 7.2%. Their research also shown that the PV's performance decreases under high humidity. Performance is improved by solar radiation. It is still advised to install solar PV energy supply systems notwithstanding the difficulties caused by dust collection. During periods of high dust, it is advised to clean the system once a week in order to maintain adequate performance.

Through the use of a model, [15], assessed the impact of dust deposition on the electrical performance of silicon-based photovoltaic cells. They examine how electrical properties are lost in relation to dust. This allows scientists to assess how much dust is formed on the surface of these solar modules in Dakar, Senegal, and how much of the electrical properties of monocrystalline silicon-based photovoltaic cells—such as production efficiency, power output, short-circuit current, and fill factor—are lost. First off, their research demonstrated that dust accumulation on PV cell surfaces has no discernible effect on open circuit voltage. However, short-circuit current affected by this dust deposit with loss of about 51% for a dust layer of 70µm (corresponding to dust deposit of 3.3 g/m2) compared to clean cell current. Their key finding was that, given a dust layer thickness of 70µm (equivalent to a dust deposit of 3.3 g/m2), cleaning the cell should be taken into consideration in order to improve its electrical performance [16].

[17], [18] study was based on the effect of dust particles accumulation and solar filters on the performance of solar photovoltaic panels and also to remove dust particles accumulation on the surface of PV panel using mitigation method that require minimum amount of energy and less use of water. Their research was conducted to determine the influence of dust particle accumulation on solar panel with constant light source deliver by halogen lamp, to establish the output power generated and the efficiency. It was concluded from their study results that dust accumulation on the surface of PV panel can reduce solar panel system efficiency by up to 30-50%. It was notice that the output power of the solar panel after cleaning with pressurized water and soap is 2.31 W, water and surfactant is 2.295 W, while the output power for solar panel surface coated with thin glass nano-structure is 2.43 W. The results clearly show that coating the surface of PV panel with conducting material is the best method to mitigate dust accumulation. This method has good advantages since water is not require, which is rare and quite expensive in northern part of Nigeria.

2. Experimental Materials:

FIG 1: *Solar power meter, multimeter, solar panel, thermo-hygrometer*

FIG 2: *Solar power meter*

FIG 3: *Solar panel*

FIG 4: *Thermo-hygrometer*

From the sample materials stipulated above, one solar panel had natural dusts applied on it and the other left permanently clean in an outdoor experiment to ascertain the difference in the panel efficiency. The Fluke digital multimeter was used to measure the open circuit voltage (Voc) and short circuit current (Isc). This measurement was done every day from 6:00 a.m. to 6:00 p.m. at intervals of thirty minutes. The digital thermometer was used to obtain the ambient temperature, and the sensing probe were attached to the solar panel and used to measure the temperature of the panel. Additionally, the relative humidity was obtained using the hand-held hygrometer and time of day recorded accordingly.

From the data collected, the module efficiency was calculated using the equation (1) as shown by [19].

$$\eta_{mod} = \frac{\text{Power of solar panel x 100\%}}{\text{Area of solar panel x 1000W/m}} \quad (1)$$

while normalized efficiency and output power was obtained via equation (2) and (3) as shown by [20] and [21].

$$\eta_p = \frac{\text{Pmea}}{\text{Pmax}} \text{ X } 100 \quad (2)$$

but $$P_{mea} = V_{mea}\ X\ I_{mea}\ (V\ X\ I) \quad (3)$$

where $P_{mea,}$ V_{mea}, $I_{mea,}$ P_{max} are the measured power, measured voltage measured current and maximum power respectively. Also, $\eta_{mod,}$ η_p is the module efficiency and normalized efficiency

3. Results and Discussions

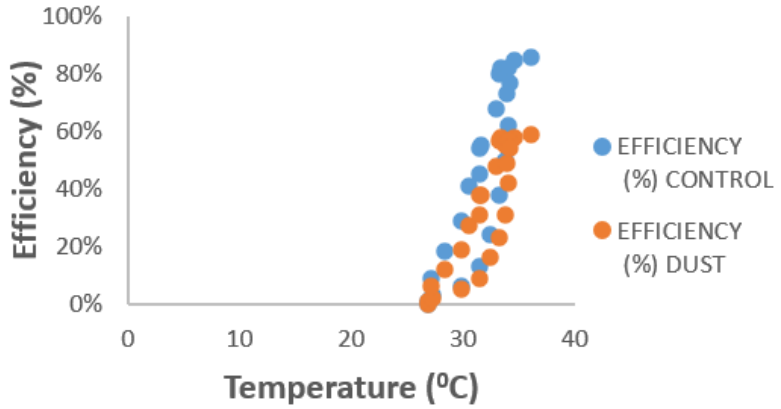

FIG 5: *Efficiency (%) against Temperature (^0C)*

From figure 5 we see that efficiency depends seriously on ambient temperature. The graph above shows that increase in ambient temperature leads to increase in efficiency of the modules. Although, there is a clear difference in the two panels (control and dust) throughout the measurement as the control panel has its peak efficiency at 86% against 59% for the dust and this agrees with [8].

The presence of dust on the surface of photovoltaic modules affects their performance. The effect of this dust on solar modules' efficiency was examined in this study. Hence, two 80W monocrystalline commercial sunshine solar modules were used in addition to additional equipment. The solar modules were exposed to an external environment as part of the study, and measurements were made for voltage, current, and panel temperature, respectively. Hygrometers, thermometers, and solar power meters were used to measure additional environmental factors, such as relative humidity, ambient temperature, and solar radiation, at 30-minute intervals from 6 a.m. to 6 p.m., every day for two months. Efficiency was computed based on the findings. The results showed that as dust accumulation increases on solar modules, their efficiency and performance decline. The study sheds light on how dust affects solar energy systems and emphasizes the necessity of thorough cleaning to preserve photovoltaic module performance.

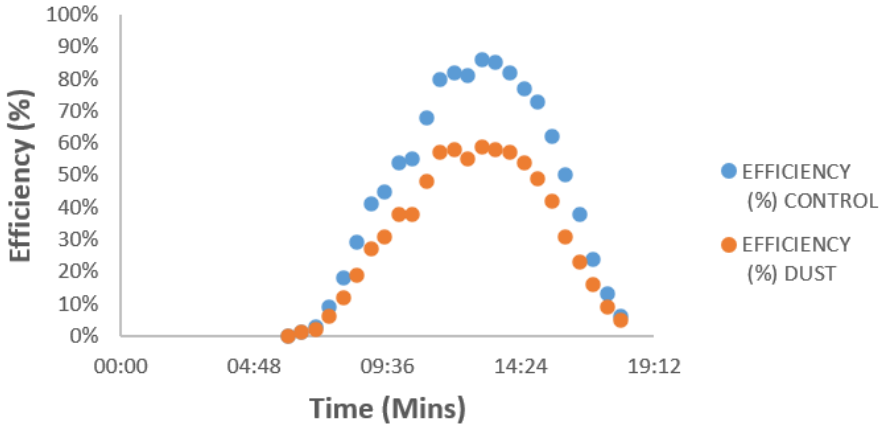

FIG 6: *graph of efficiency (%) against time (mins)*

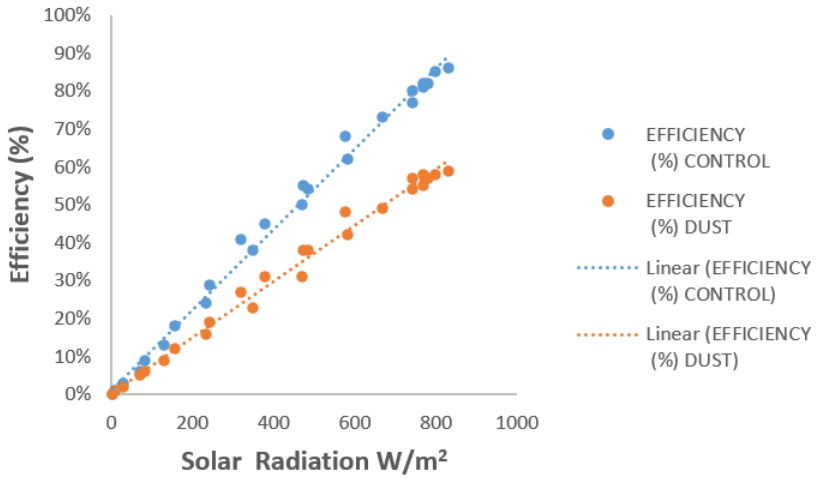

FIG 7: *graph of efficiency (%) against solar radiation (W/m^2)*

Shows that high level of solar radiation favors an increase in the efficiency of PV modules. Although, the panel with dust accumulation is less efficient in terms of overall performance as seen in figure 7 above.

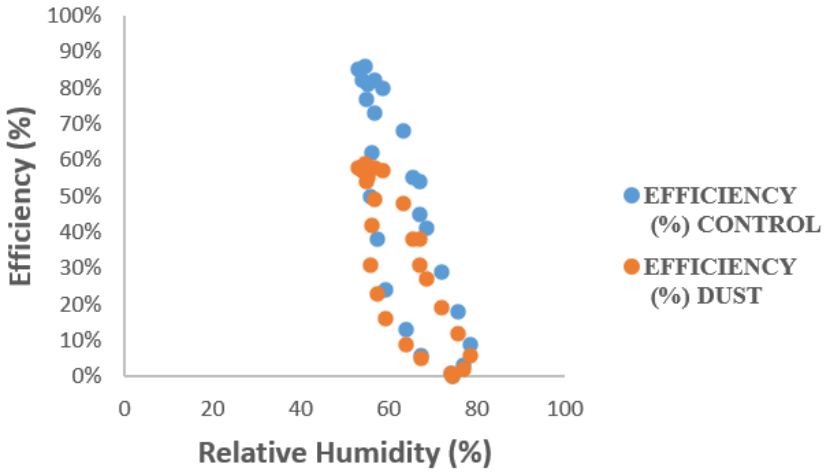

FIG 8: *a graph of efficiency against relative humidity*

Figure 8 depicts that the efficiency of the two panels is not constant throughout the day. The control panel is more efficient in performance than the dusty panel which in turn makes the control panel to be more efficient than the dusty panel. Also, continues increase in relative humidity leads to decrease in efficiency for both panels.

4. Conclusion

Though the works mainstay was on the effect of dust particles, it also incorporates other environmental challenges (Parameters) like solar radiation ambient temperature and relative humidity on how it affects the performance of the solar panels, using their efficiency as the test of performance. The work was carried out in the mangrove of Calabar city and a 70.50% of the sunlight radiation did not reach the PV modules due to dust alone. A high solar radiation means a high efficiency and while increase in relative humidity means lower efficiency. Both panels peaked at 12 noon each day.

The overall experiment suggests a continuous cleaning of the panel to experience better performance.

References

[1]. Rathore, N., Panwar, N. L., Yettou, F. and Gama, A. 2021. A comprehensive review of different types of solar photovoltaic cells and their applications. International Journal of Ambient Energy, 42(10), 1200-1217.

[2]. Njok, A.O., Ogbulezie, J.C. and Akonjom, N.A. 2022. Evaluation of the performance of photovoltaic system under different wavelengths from artificial light in a controlled environment, Journal of Applied Sciences and Environmental Management, 26(6), 1015-1020.

[3]. Battaglia, C., Cuevas, A. and De Wolf, S. 2016. High-efficiency crystalline silicon solar cells: status and perspectives. Energy & Environmental Science, 9(5), 1552-1576.

[4]. Akonjom, N.A. and Njok, A.O. 2022. Effect of meteorological parameters on the performance of photovoltaics installed under the guinea savannah atmosphere in Ogoja, Cross River State, Nigeria, Journal of Applied Sciences and Environmental Management, 26(7), 1299-1306.

[5]. Bhattacharjee, R., & Bhattacharjee, S. 2020. Viability of a concentrated solar power system in a low sun belt prefecture. Frontiers in Energy, 14, 850-866.

[6]. Njok, A.O., Ewona, I.O. and Akonjom, N.A. 2022. The effect of relative humidity on photovoltaics enhanced with automatic cooling mechanism," Unicross Journal of Science and Technology, 1(1), 172-283.

[7]. Njok, A.O., Akonjom, N.A. and Ogbulezie, J.C. 2022. Design and performance evaluation of photovoltaic systems with automatic dust wiper in a natural dusty environment," Asian Journal of Physical and Chemical Sciences, 10(4), 1-15.

[8]. Oyom, E. B., Ettah, E. B., & Akonjom, N. A. 2023. Impact of dust particles on the output power of photovoltaic modules in Calabar, Cross River State. Science World Journal, 18(3), 380-385.

[9]. Njok, A.O. and Ewona, I.O. 2022. Diurnal analysis of enhanced solar photovoltaic systems using automatic cooling mechanism, World Journal of Advanced Engineering Technology and Sciences, 5(2), 16-23.

[10]. Darwish, Z. A., Kazem, H. A., Sopian, K., Alghoul, M. A. and Chaichan, M. T. 2013. Impact of some environmental variables with dust on solar photovoltaic (PV) performance: review and research status. International J of Energy and Environment, 7(4), 152-159.

[11]. Njok, A.O., Archibong, E.A. and Fischer, G.A. 2023. Diurnal analysis of the performance of photovoltaic systems under the Guinea Savannah Atmosphere in Ogoja, Cross River State, Nigeria, Physical Science International journal, 27(1), 1-15.

[12]. Chanchangi, Y. N., Ghosh, A., Sundaram, S. and Mallick, T. K. (2020). Dust and PV Performance in Nigeria: A review.Renewable and Sustainable Energy Reviews, 121, 109704.

[13]. Njok, A.O. and Kamgba, F.A. 2023. Monocrystalline Photovoltaic Panel Response Pattern to Relative Humidity and Temperature under Distinct Wavelengths in Mangrove Swamp Environment in Calabar, Cross River States, Nigeria, Journal of Applied Sciences and Environmental Management, 27(8), 1825-1837.

[14]. Abdulkarim, H. T., Sansom, C., Patchigolla, K., Almond, H. and Karim, M. 2022. Impact of dust on electrical power output of solar PV modules in North-East, Nigeria. Minna International Journal of Science and Technology, 1(1), 20-31.

[15]. Diop, D., Diagne, M., Sambou, A., Bassene, P. D., Niang, S. A. A. and Sarr, A. (2021). Influence of Dust Deposition on the Electrical Parameters of Silicon-Based Solar Panels Installed in Senegal (Dakar Region). Energy and Power Engineering, 13(5), 174-189.

[16]. Njok, A.O., Ogbulezie, J.C. and Archibong, E.A. 2023. Behavioral pattern of photovoltaics enhanced with automatic cooling mechanism, Asian Journal of Physical and Chemical Sciences, vol. 11, no. 4, pp. 1-11.

[17]. Chukwuekum, O. and Oseme, O. S. (2020). Solar cell cleaning and efficiency performance analysis on dust particles accumulation on solar panel in Nigeria. A case study of Northern Nigeria. Journal of Sustainable Energy & Environment, 11, 135-141.

[18]. Njok, A.O., Ogbulezie, J.C. and Osang, J.E 2023. Behavioral pattern of solar filter enhanced photovoltaics in mangrove swamp," Asian Journal of Research and Reviews in Physics, vol. 7, no. 4, pp. 30-42.

[19]. Njok, A.O., Ogbulezie, J.C., Panjwani, M.K. and Larik, R.M. 2020. Investigation of Monthly Variations in the Efficiencies of Photovoltaics due to Sunrise and Sunset Times," Indonesian Journal of Electrical Engineering and Computer Science, 18(1), 310-317.

[20]. Njok, A.O., Kamgba, F.A., Panjwani. M.K. and Mangi, F.H. 2020. The influence of solar power and solar flux on the efficiency of polycrystalline photovoltaics installed close to a river," Indonesian Journal of Electrical Engineering and Computer Science, 17(2), 988-996.

[21]. Ogbulezie, J.C., Njok, A.O., Panjwani, M.K. and Panjwani, S.K. 2020. The impact of high temperature and irradiance source on the efficiency of polycrystalline photovoltaic panel in a controlled environment," Indonesian Journal of Electrical and Computer Engineering, 10(4), 3942-3947.