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Photovoltaic Dust Accumulation and Cell Surface Temperature Relationship

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***Abstract*— The energy yield of a photovoltaic module is affected by many factors includingmodule active surface orientation, angle of tilt, module surface temperature, ambient temperature and contaminants. Contaminants could be bird droppings or dust. Dust is a major problem in sub-Sahara Africa. Dust can reduce the transmittance of the module cover and also can create partial shading. The performance of the solar module with reference to dust accumulation and cell surface temperature, has been experimentally studied. It has been found that for a given dust size, the cell surface temperature reduces with area density or dust loading (kg/m2). When particle size is the variable and the loading is kept constant, the cell surface temperature increases with increasing particle size. This behaviour is attributed to the wider interstitial spaces of the larger particle sizes that expose uniformly larger area of the module surface to irradiation.**

***Index Terms*— coating, contaminants, Irradiation, photovoltaic, tilt angle,transmittance.**

I. INTRODUCTION

Highlight The energy harvested by the solar photovoltaic (PV) system is affected by many factors, among which are ambient and module surface temperatures, contaminants including dust and bird droppings, wind direction, the module angle of tilt and the orientation of the module active surface. Dust accumulation in sub-Sahara Africa is a major factor as this decreases the transmittance of the cover and results in lower power generation. Furthermore, the non-uniform spread of dust, for example on the solar cell surface, creates additional power losses through shading effect [1 - 3]. For large installations, the losses can be significant. Performance loss reduction measures usually adopted to counter the adverse effect of dust on the solar module surface include physical cleaning which could be either manual or automated [4, 5]. Surface coating of the module cover is another technique that has been successfully used. The coating prevents the dust from settling especially in the tilted angleconfiguration [6].

The sources of contaminants are either natural or man-made and these include respectively, the attrition, wear and entrainment of rock particles by the wind and wildfire with the attendant smoke and aerosol that cause overcast sky. The overcast sky causes reduced irradiation and the resulting aerosol of the wildfire is carried by the wind to finally settle on the solar panel [7]. A nearby construction site can also contribute to the contaminants loading in the atmosphere and this will eventually settle on the module surface. Location of the photovoltaic system is also a factor to be taken into account when considering contaminants loading of the solar module. Kaduna, Nigeria where this study is carried out is in the sub Saharan region which is associated with dust particle menace. A coastal location is likely to see reduced dust loading. Season of the year is also a contributing factor. High dust loading is more rampant in the dry season than in the rainy season. Ironically however, the dry season is the period when the irradiation is available for longer period of the day except the few days when the sky is overcast with haze especially during the harmattan period.

The cell surface temperature which has a significant influence on PV power generation is a function of the ambient temperature. As a result, therefore, a thorough understanding of the behaviour of the ambient temperature is necessary because of its wide variation with season and regions of the world. Two studies [8] and [9], in particular have shown that the efficiency and output of PV module electric power generation is inversely proportional to its temperature. In recognition of this, various measures have been adopted to control to optimum the cell surface temperature and therefore improve the photovoltaic power generation rate.

Without cooling, more than 50% of the incident solar energy is thermally converted into heating the solar cell which as a result increases the operating temperature of the photovoltaic module [10]. In recognition of the part played by cell surface temperature, a study has been carried out in which variablequantity of cooling air was passed through ducts in a hybrid photovoltaic/thermal system to obtain efficiency rise of between 8.6% to 12.5% [11]. There are a number of other techniques that are used in controlling the cell surface temperature and among the methods are air cooling, water cooling and cooling based on the use of a phase change materials [12]. Among these is a study that was carried out to look at the inherent relationship between the crystalline silicon solar cell module surface temperature and power generation [13]. Several studies in the literature have suggested ways through which the open circuit voltage generation efficiency can be improved. The conclusion reached in an investigation using the module air cooling technique for cell temperature control isin agreement that the overall result is an improvement in the power output of the system [14]. Another study concluded that temperature and

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temperature gradient of the module are critical consideration in enhancing the efficiency of the photovoltaic system [15]. The study attributed the significant improvement in the power of the PV system to the efficient contribution of the air-cooling system. In a study using silicon oil to maintain the module surface temperature within a range 45°C - 55°C. resulted to an increased maximum power delivery [16]. By using slats as part of the surface absorber in a photovoltaic/thermal system an improved efficiency was achieved [17]. In another study, water immersion technique was used to improve the electrical performance of PV panel [18]. There appears to be a general agreement between these studies that module performance depends on cell surface temperature levels and as such different cooling techniques have been employed to reduce the cell surface temperature and thereby increase the maximum power output and overall module efficiency. Some of these studies have been carried out using air at ambient temperature as the medium for cooling the module surface temperature. The effectiveness of this method is limited because of the low temperature difference between the module surface and the ambient air. This explains why other techniques using media with higher cooling capacity have been investigated.

The foregoing has shown that both high contaminants accumulation level and high cell surface temperature individually affect the power generation of the solar module adversely. This does not however resolve the case when these two parameters are present and interacting. Therefore, the aim of this study is to investigate the behaviour of the module surface temperature with dust loading.

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 in place appropriately 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.

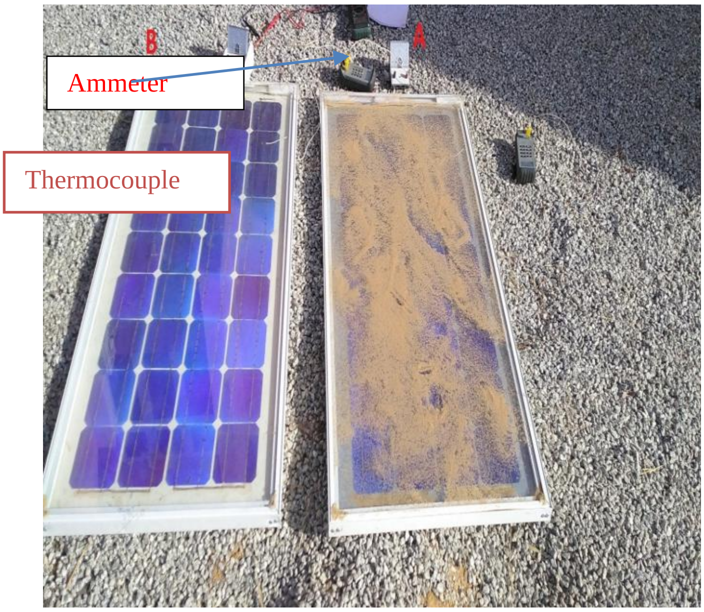

Plate 1. Experimental Setup Showing Typical Clean and Loaded Modules

In each test operation, one of the solar modules is used as the reference unit. The module by the left hand side, module A is the reference panel whereas module B on 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 and for repeatability is measured per unit of module area, 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 in the experimental are used to plot figures 1 to 6 used. Figures1 to 3 relate to the effect of dust particle size and module cell surface temperature whereas figures 4 to 6 show what happens when the focus is on dust loading (measured as area density in kg/m^2) of the of the photovoltaic module.

In the first set of runs, figures 1 to 3, the particle loading, area density is kept constant and the particle size is the variable parameter. It is noticed in figures 1 and 2 that the loaded module depicts always lower cell surface temperature. This is expected as the dust prevents the full irradiation reaching the solar cell surface. A closer look between figures 1 and 2 shows that the gap between the clean and dusty module curves are more pronounced in figure 1 where the particle size is 150µm than in figure 2 where the particle size is 425µm for the same loading. This behaviour can be explained by the fact that, unlike the larger 425µm particles, the 150µm particles are more closely packed to reduce the irradiation reaching the cell surface. In figure 2 because the particles are more loosely packed for the loaded case therefore, sun can easily reach the cell surface resulting to a situation where one can hardly notice any difference between the clean and loaded curves. The foregoing reasoning holds for figure 3 where the curves for the loaded module and for various particle sizes are compared. Even though the curves are clustered together, it can still be seen that the curve for 150µm, the smallest particle size, depicts the lowest temperature because of the close particle packing.

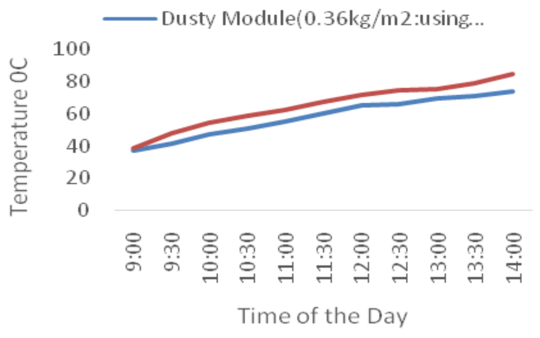

Fig. 1 Effect of Dust Prticle Size on Cell Surface Temperature

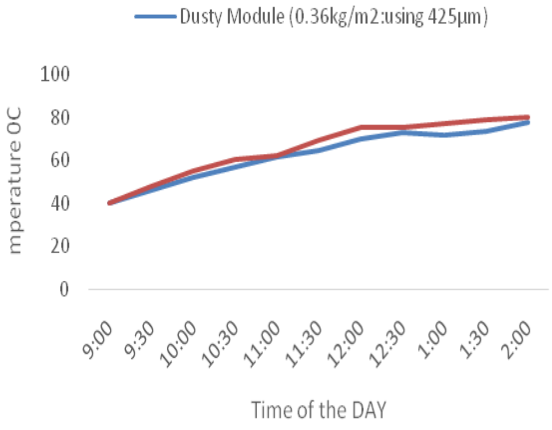

Fig. 2 Effect of Dust Particle Size on Cell Surface Temperature

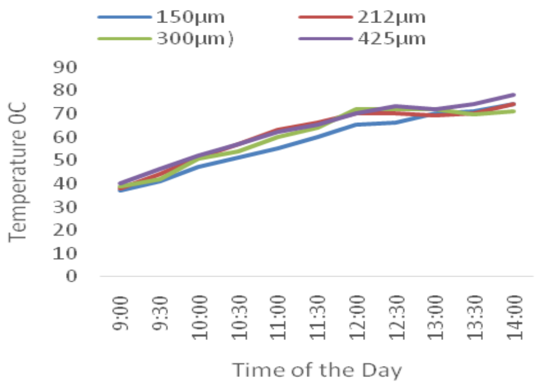

Fig.3 Comparison of Various Dust Particle Sizes on Cell Surface Temperature

In the second case figures 4 to 6, the variation is put on the particle area density, the loading. In each case in figures 4 and 5, the dusty module curve is lower than that of the clean module. This behaviour can be attributed to the shading effect as a result of the dust covering the surfaces and aided,further more,by reduced transmittance. It can also be seen that the gap between the curves in figure 4 is narrower than similar gap in figure 5. The gap in figure 5 is wider because the dusty module is more heavily loaded. Figure 6 is the comparison of the various loadings and as expected the heavily loaded runs lead to lower module cell surface temperatures.

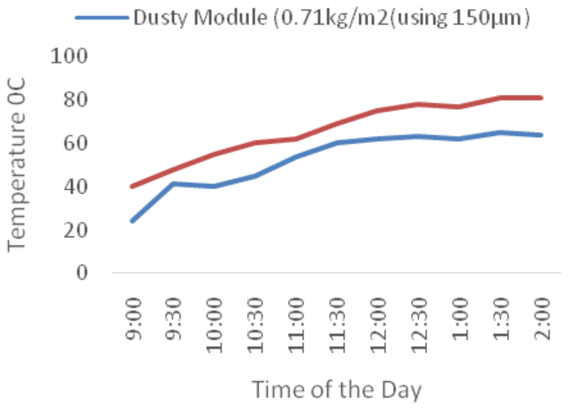

Fig. 4 Effect of Dust Loading on Cell Surface Temperature

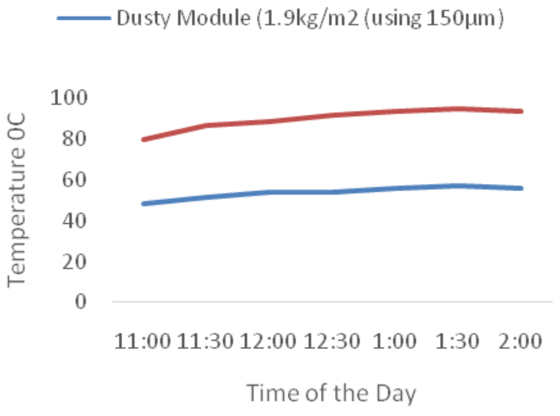

Fig. 5 Effect of Dust Loading on Cell Surface Temperature

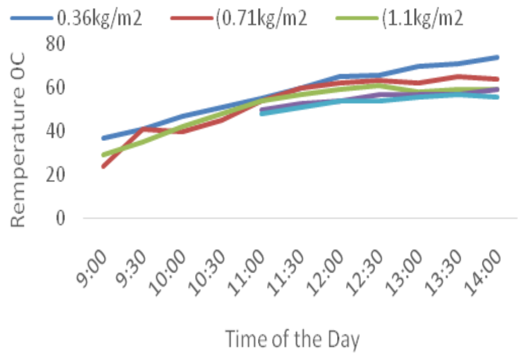

Fig. 6 Comparison of Various Dust Loadings on Cell Surface Temperature

IV. CONCLUSION

The study has been carried out experimentally and findings are: when the area density or dust loading is kept constant, the cell surface temperature reduces faster with reducing particle size, when on the other hand, the particle size is kept constant, the cell surface temperature reduces faster with increasing dust loading.

REFERENCES

[1] Sangram Bana, R.P. Saini, Experimental investigation on power output of different photovoltaic array configurations underuniform and partial shading scenarios, , Energy, Vol 127, 15 May 2017

[2] G.Meerimatha, B. Loveswara Rao,Novel reconfiguration approach to reduce line losses of the photovoltaic array under various shading conditions, Energy, Vol 196, 1 April 2020.

[3] Luis Fernando Mulcué-Nieto,LlanosMora-López,Methodology to establish the permitted maximum losses due to shading and orientation in photovoltaic applications in buildings.Applied Energy, Vol 137, 1 Jan, 2015

[4] AnjianPan, HaoLu, Li-ZhiZhang,Experimental investigation of dust deposition reduction on solar cell covering glass by different self-cleaning coatings, Energy, vol 181, 15 August 2019.

[5] MatthiasHeinrich,SimonMeunier,AllouSamé,LoïcQuéval,ArounaDarga,LatifaOukhellou, Bernard Multon,Detection of cleaning interventions on photovoltaic modules with machine learning,Applied Energy,Vol 263, 1 April, 2020.

[6] M.Piliougine,C.Cañete,R.MorenoJ.Carretero,J.Hirose,S.Ogawa,M.Sidrach-de-Cardona,Comparative analysis of energy produced by photovoltaic modules with anti-soiling coated surface in arid climates, Applied Energy, Vol 112, Dec., 2013

[7] .J.L.Gómez-AmoM, D.Freile-ArandaJ. CamarasaV. EstellésM.P.UtrillasJ.A.Martínez-Lozano,Empirical estimates of the radiative impact of an unusually extreme dust and wildfire episode on the performance of a photovoltaic plant in Western Mediterranean, Applied Energy, Vol 235, 1 Feb., 2019

[8] Virtuani. A., Pavanello. D. and Friesen. G., September 2010, “Overview of Temperature Coefficients of Different Thin Film Photovoltaic Technologies”. 5th World Conference on Photovoltaic Energy Conversion, 6-10 Valencia, Spain.

[9] Abdulgafar, S. A., Omar, O. S. and Yousif, K. M. “Improving the Efficiency of Polycrystalline Solar Panel Via Water Immersion Method”, International journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 1, 2014.

[10] Chandrasekar, M., Suresh, S., Senthilkumar, T. and Ganesh M.K. "Passive cooling of standalone flat PV module with cotton wick structures", Energy Conversion and Management, Vol.71, pp. 43–50, 2013.

[11] Teo H., Lee P. and Hawlader, M. "An active cooling system for photovoltaic Modules", Applied Energy, Vol.90, pp.309 – 315, 2012.

[12] Tao Ma, Jiaxin Zhao, Zhenpeng Li, Mathematical modelling and sensitivity analysis of solar photovoltaic panel integrated with phase change material Applied Energy, Vol 228, 15 Oct., 2018

[13] Furkan D, Mehmet E. M. “Critical Factors that Affecting Efficiency of Solar Cells”, Smart Grid and Renewable Energy, 2010, 1, 47-50.

[14] Y.M. Irwan, W.Z. Leow, M. Irwanto, Fareq M, A.R. Amelia, N. Gomesh, I. Safwati, “Analysis Air Cooling Mechanism for Photovoltaic Panel by Solar Simulator”, International Journal of Electrical and Computer Engineering (IJECE), Vol. 5, Issue 4, pp. 636-643, August 2015

[15] H.G. Teo , P.S. Lee , M.N.A. Hawlader, “An active cooling system for photovoltaic modules”, Applied Energy 90 (2012) 309–315

[16] P G Nikhil, M Premalatha, “Performance enhancement of solar module by cooling: An experimental investigation”, International Journal of Energy and Environment Volume 3, Issue 1, 2012 pp.73-82

[17] M. Srinivas, S. Jayaraj, “Investigations on the performance of a double pass, hybrid - type (PV/T) solar air heater”, International Journal of Energy and Environment Volume 4, Issue 4, 2013 pp.687-698

[18] Sayran A. Abdulgafar, Omar S. Omar, Kamil M. Yousif, “Improving the Efficiency of Polycrystalline Solar Panel via Water Immersion Method”, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 1, January 2014.

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