INTERNATIONAL JOUNAL OF: SCIENCE RESEARCH AND TECHNOLOGY

TIMBOU-AFRICA ACADEMIC PUBLICATIONS
INTERNATIONAL JOURNAL, MAY, 2021 EDITIONS
VOL. 5 NO. 9 ISSN: 2623-7861

EFFECTS OF GLASS AND DUST ABSORPTION OF SOLAR RADIATION IN PV SOLAR PANELS IN KADUNA METROPOLIS

MOHAMMED MANNIR ALIYU[1], PAUL BARTHOLOMEW[2] AND HASSAN SALAWU[1]

[1]Department of Electrical and Electronic Engineering, College of Engineering, Kaduna Polytechnic, Kaduna [2]Department of Computer Engineering, College of Engineering, Kaduna Polytechnic, Kaduna

ABSTRACT
The photovoltaic solar cells are considered to play important roles as a source of green energy for the future due to its numerous advantages. However, one of the re-occurring challenges of this device is that of reduced performance due to dust accumulation, which requires frequent cumbersome cleaning. The effect of dust accumulation

INTRODUCTION

Photovoltaic (PV) Solar technology has been identified as the sustainable energy of the future: free from pollution, being environmental-friendly and with unlimited supply. From being a laboratory curiosity, these devices have been used for decades, as power supply for space craft, terrestrial (Green, 1998) and now to remote locations such as weather stations, navigational systems for aircraft and ships (Mazer, 1997). PV solar cells have been identified as the ultimate solution to the current energy challenges as well as the most ideal energy of the future (Sulaiman, 2015). With a current efficiency of about 24% for crystal silicon and 21% for thin films (Fraunhofer, 2017), implies that only a fraction of the imping photon energy is converted into electricity by the best solar cells. Thus, to make PV solar viable and price competitive, efforts have been geared towards increasing efficiency and

varies greatly with season as well as environmental variables and location. This study attempted to investigate effects of glass and dust absorption on the performance of the PV Solar modules in the Kaduna Metropolis. Two 80W monocrystalline solar panels were exposed to outdoor environmental variables while the solar panels' output parameters were measured. A glass slide placed on top of each panel so that dust deposited on the panels was equally available on the slides. Solar irradiance measurements were made at horizontal surface as well as by adjusting the inclination angle until maximum radiations were attained. By comparing the solar irradiance directly and through both clean clear glass and through dusted glass slides, the amount of light absorbed by both media were deduced. Results indicated an increase of irradiance of up to 25% can be attained by deploying solar tracking. The highest monthly average values of 569.65 and 748.24W/m^2 for I_{oh} and I_{om} respectively were obtained in the month of May, while the least values of 489.79 and 584.25W/m^2, respectively, were obtained in the month of April. As result of tracking, the largest difference was found in the months of December and May with values of 31.35% each. The lowest difference was obtained in April at 19.29%. The average absorption of I_{oh} and I_{om} in clear glass reduced the incident radiation to 89.01% and 89.69% respectively, whereas in dusted glass, the radiation was reduced to 85.75% and 82.31% respectively. The highest absorption of light due to dust was in June and the least absorption was in March. The Voc and Isc of the panel were found to follow the trends of the irradiance and since this was dependent on dust accumulation, it implies the output parameters were determined by the dust accumulation.

Keywords: *Effects, Dust Absorption, Solar Radiation, Solar Panels, Kaduna Metropolis.*

reducing costs. These have yielded good results. Recent results indicated that the multijunction perovskite has the highest efficiency of 47% (Geisz et al 2020). Similarly, the cost of production has crashed, with the average cost of solar cells fell from $76.67/watt in 1977 to just $0.74/watt in 2013, while it is shown that the average price of a solar module at $0.49/watt by July 2016, and the average price of a solar cell at $0.26/watt. (http://pvinsights.com/). Also, according to Decker (2015), electricity generated by photovoltaic systems is 15 times less carbon-intensive than electricity generated by a natural gas plant (450 gCO_2e/kWh), and at least 30 times less carbon-intensive than electricity generated by a coal plant, with cited energy payback times (EPBT) for solar PV systems are between one and two years (Deker 2015). Despite these benefits however, PV solar panels are affected by shade due to dust accumulation, which results in lower performance, resulting in loss in performance of up to 50% (Adinoyi, and Said, 2013). In another study, Sulaiman (2011) investigated the influence of not just dust, but other particles and dirt were studied. In semi-arid countries as found in Kaduna State of Northern Nigeria, the harmattan season is associated with heavy dust and mist. In order to obtain optimum return on investment therefore, there is need to understand how this phenomenon affect the performance of PV solar panels installed in and around Kaduna.

We investigated the impact of dust on the performance of solar PV panels specifically during harmattan season. The devices were exposed to atmospheric variables of wind, temperature, humidity, solar irradiance and the dust current. The amount of dust deposited was measured by a clean glass substrate placed on top of each panel and the effects of the accumulated dust was measured by taking the irradiance through the dusted glass and a clean glass.

RESULTS AND DISCUSSION

The data set consisted of measured hourly values of solar irradiance, for both horizontal surface (I_{oh}) as well as inclined for maximum incidence (I_{om}). These were taken directly, then through a clean glass slide and then through a dusted glass slide Also, the ambient temperature, Ta, relative humidity, R.H., open circuit voltages (Voc) and short circuit currents (Isc) of the solar panels were measured, hourly using appropriate tools. In order to understand the effects of dust on the solar panels, the amount of radiation absorption by both clean plane glass slide and that through

TIJSRAT
ISSN: 2623-7861

dusted glass slides were measured. These were used to assess the extent of radiation absorption in each case. The results are presented in the figures hereunder. Since the performance of a solar panel depends, amongst other variables, on the solar irradiance and ambient temperature, the values of these parameters were plotted for the period of study, December, 2019 to May, 2020, so that their variation over the months can be studied. Some of these plots are presented in Fig. 1 to Fig.3. From the figures, it is obvious that the solar irradiance and ambient temperature were high during the days for all the months, except some days where low values were observed. This could be attributed to the dependence of both quantities on the radiation of the sun. (Aliyu et al 2020). The figures show the solar irradiances taken for both horizontal surface (I_{oh}) and inclined at maximum incidence (I_{oh}) together with other variables such as ambient temperature (Ta), wind speed, (Ws), relative humidity, (RH) for various months. Thus, irrespective of the amount of dust deposited, could influence the power produced.

It is observed that the irradiance for inclined maximum direction is higher than that at horizontal surface. This is not unexpected, as the inclined surface gives maximum radiation falling the surface, especially during the mornings and evenings, when the Sun is at lower altitude. The magnitude of this difference determines how much additional energy is harvested by placing a solar tracker on the PV system (Bazyar et al 2014). Knowing this difference will determine the justification of deploying a solar tracker or otherwise. In this study, we analyzed this difference and the results are given in the monthly average values as presented in Figs. 4 to 9. Table 1 presents the monthly average values of solar irradiances as well as the differences between the I_{oh} and I_{oh}. It is seen that the highest average values of 569.65 and 748.24W/m^2 for I_{oh} and I_{om} respectively were obtained in the month of May, while the least values of 489.79 and 584.25W/m^2 were obtained in the month of April. In the case of variation due to tracking, the largest difference was found in the months of December and May with values of 31.35% each. This means that in these months, tracking the sun could result in 31.5% higher energy yield. For a large PV system this translates to substantial amount of energy gain that can justify deployment of tracking systems. The lowest

TIJSRAT
ISSN: 2623-7861

difference was obtained in April at 19.29%. The average value of the increase was found to be 25.79%. This means that about 25% increase in energy yield can be obtained by deploying solar tracker during this period at the location.

From the daily hourly data, the monthly average values of all the recorded variables were determined. From these, the the two irradiances have been plotted together with each set of variables over the six months of the study. The results are presented in Figures 5 – 9. It is observed that in all these figures, that there is marked difference between I_{oh} and I_{om}. The variations of the other variables are readily seen in comparison to the irradiances. From Fig. 5, the wind speed is observed to have a concave upwards, with its maximum values between February and March, and minimum values at December and May. Wind speeds are believed to affect dust movement and deposition. Thus, while wind speeds will contribute in transporting dust particles, the deposition of the dust depends on the local environment, such as moisture, cavity and other factors. In this case, it is expected that dust deposition will be highest around March and May, due to the rains during this period even though the heavy rains do wash off most of the dust. In Fig. 6, the ambient temperature is seen to increase as from March to May. Higher temperatures and moist will lead to readily solidification of dust on the surface, this is known as soiling. In Fig.7 where the particulate matter (PM) of various sizes were measured, it is observed that the concentration of the dust varies with the PM size. The PM 1.0 has the highest concentration, then followed by the PM10.0, while the PM2.5 has the least concentration. However, each of the PM size showed near uniformity across the period of study. Additional study needs to be made to determine the particulate size that accounts most for the dust accumulation.

Next, we considered the results of the absorption by the two media involved, glass and dust. The quantity of light absorbed was determined by taking the ratio of the irradiance from direct sunlight and the irradiance through each media; the clear glass as well as that through a dusted glass. The absorption was determined for both I_{oh} and I_{om} and the results are presented in Fig.9. It was observed that the absorption of

TIJSRAT
ISSN: 2623-7861

dusted glass was much higher than that of clear glass. This is obviously due to the additional absorption by the dust, which is not transparent, compared to glass. The average absorption of I_{oh} and I_{om} in clear glass reduced the incident radiation to 89.01% and 89.69% respectively, whereas in dusted glass, the radiation was reduced to 85.75% and 82.31% respectively. From these also, it can be deduced that the highest absorption of light was in June and the least absorption was in March. In addition, the month with the highest absorption of I_{oh} and I_{om} through dusted glass was February. Incidentally, this was the month that recorded the highest wind speed in the period of the study. This could then imply that the higher average wind speed is associated with the higher dust deposition.
When the electrical output of the panels were studied, it was found that both the open circuit voltage and short circuit current were nearly uniform throughout the months, except in March, where there was a slight drop. This is illustrated in Fig. 9 and Fig.10. When the variables are now juxtaposed with the solar irradiances, it was found that the two set of variables vary in concordance. That is the electrical output parameters vary in rhythm with the solar irradiances. This is as expected, since these output variables depend on the input solar radiation impinging the solar panels.

CONCLUSION
The study has investigated the effect of dust on the performance of PV solar panels in Kaduna metropolis. The results indicated that the solar irradiance showed high values throughout the days and across the 6 months of the study. The irradiances were determined for horizontal surface (Ioh) and for maximum incidence (Iom). It was observed that there was substantial increase in I_{om} compared to I_{oh}, with the average values of 523W/m^2 and 658.87W/m^2 respectively. This represents an increase of 25.79%. This implies that by deploying a solar tracker, yield could be increased by about 25% and a maximum increase of 31.35% were obtained in May and December. When the amount of light absorption was investigated, it was found that the highest absorption of light was in June and the least absorption was in March. In addition, the month with

the highest absorption of I_{oh} and I_{om} through dusted glass was February, with values of incident light reduced to 85.75% and 82.31% for the two irradiances. The electrical parameters, Voc and Isc were found to be dependent on the irradiances. Thus, their values were directly determined by the amount of dust deposition.

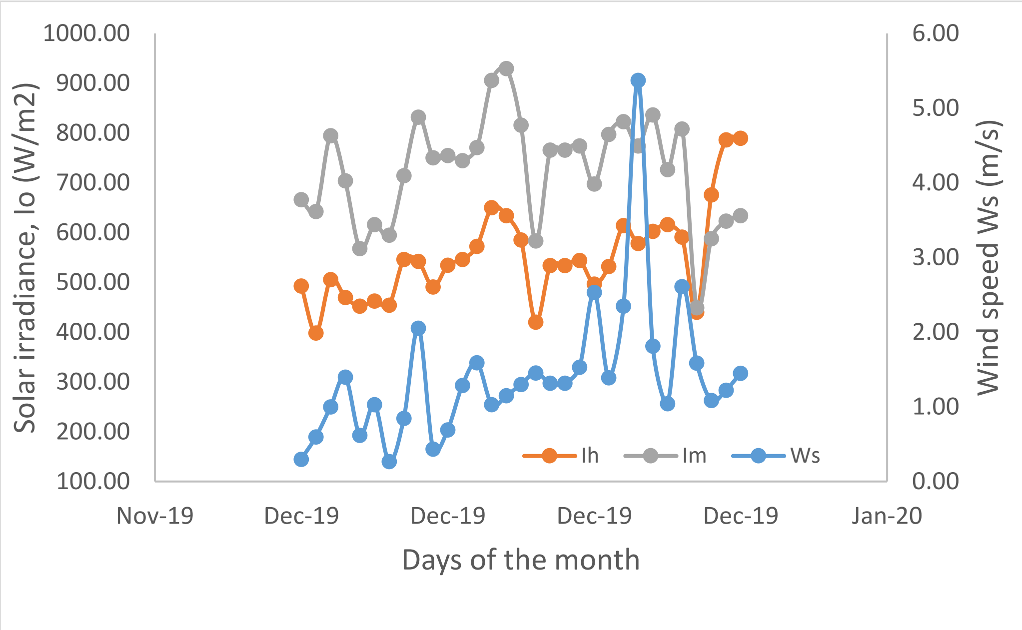

Fig. 1. Solar irradiances and wind speed for the months of December

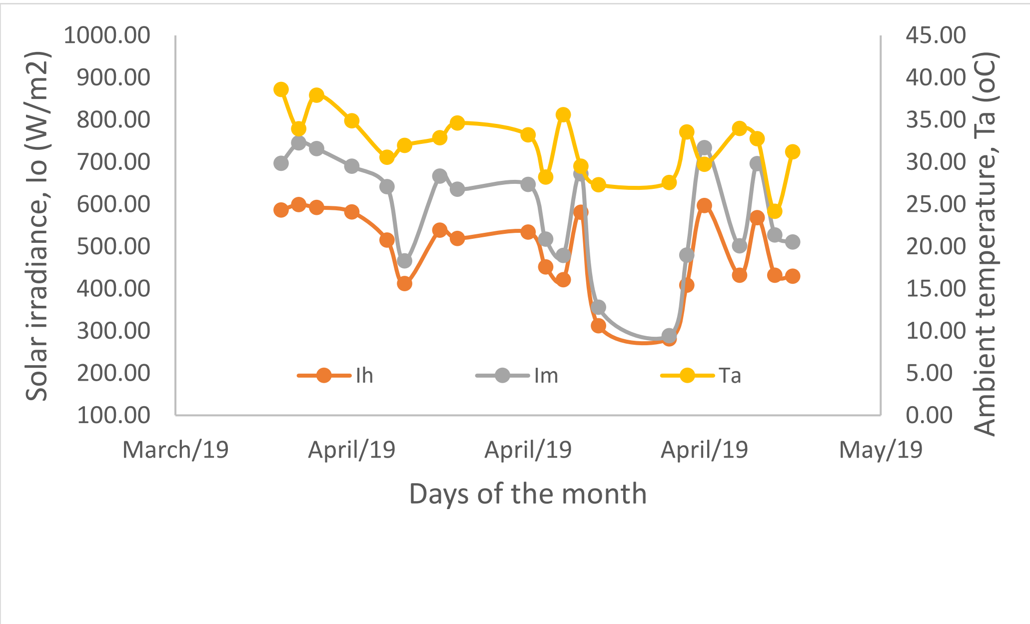

Fig. 2. Solar irradiances with Ambient temperature for the month of April

TIJSRAT
ISSN: 2623-7861

TABLE1. Values of Solar Irradiances for the months of Dec - May

Month	Ioh (W/m²)	Ioh (W/m²)	Difference %
DEC	551.45	724.34	31.35
JAN	532.32	671.17	26.08
FEB	499.79	617.26	23.50
MAR	499.7	607.98	21.67
APR	489.79	584.25	19.29
MAY	569.65	748.24	31.35
AVERAGE	523.78	658.87	25.79

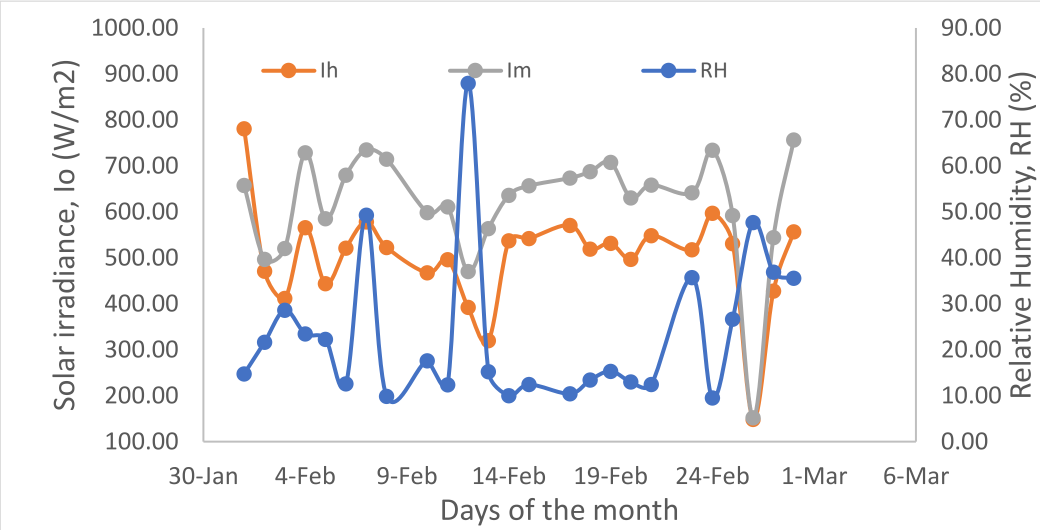

Fig. 3. Solar irradiances with Relative Humidity for the month of February

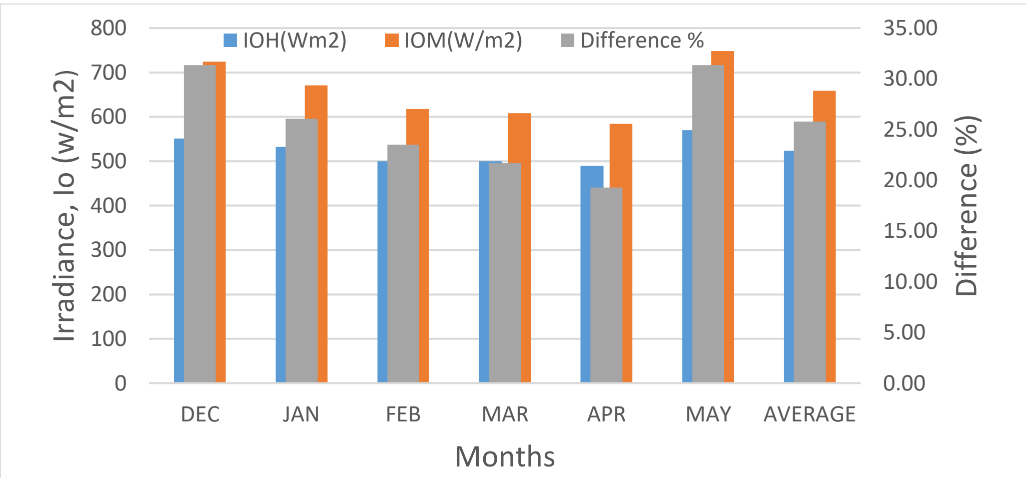

Fig. 4. Monthly Average Solar irradiances with their differences for the months December through May

TIJSRAT
ISSN: 2623-7861

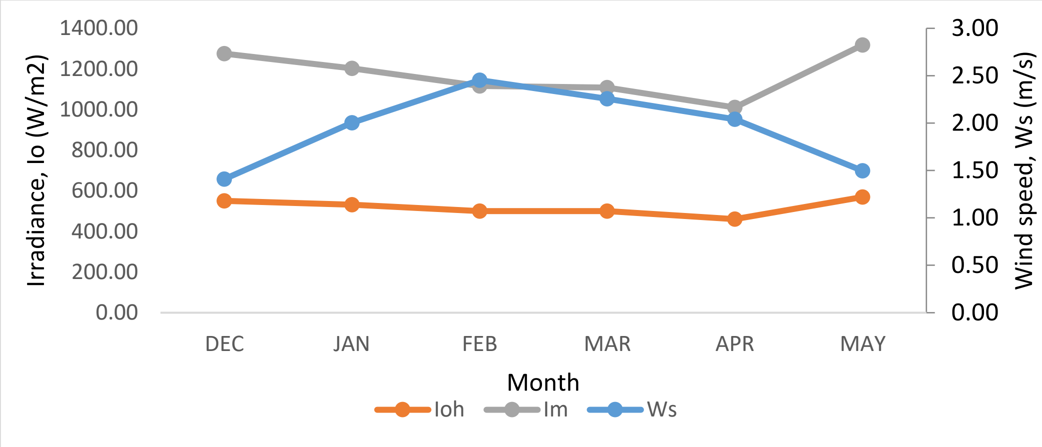

Fig.5 Average values of Solar irradiances and wind speed for the months of December to May

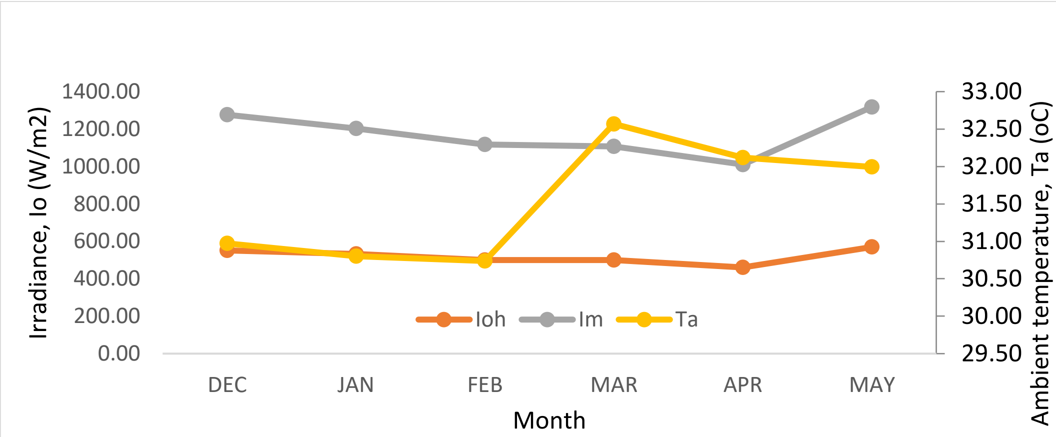

Fig.6 Average values of Solar irradiance and ambient temperature for the months of December to May

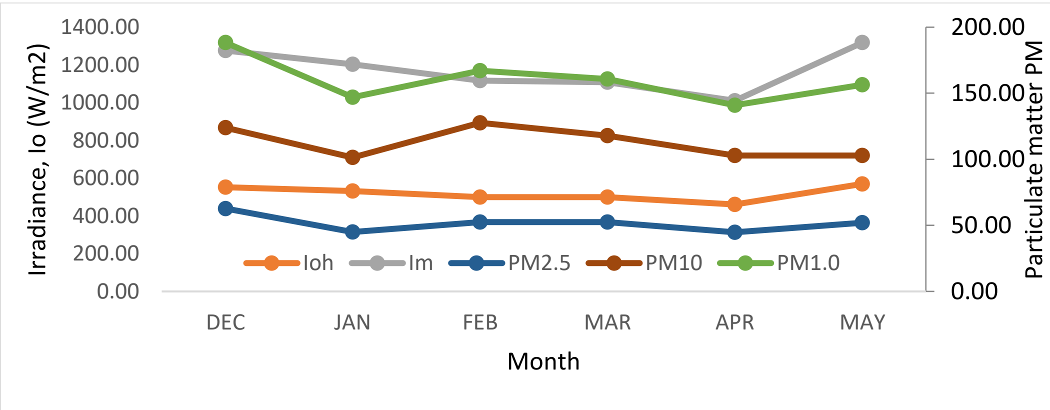

Fig.7 Average values of Solar irradiance and particulate matter for the months of December to May

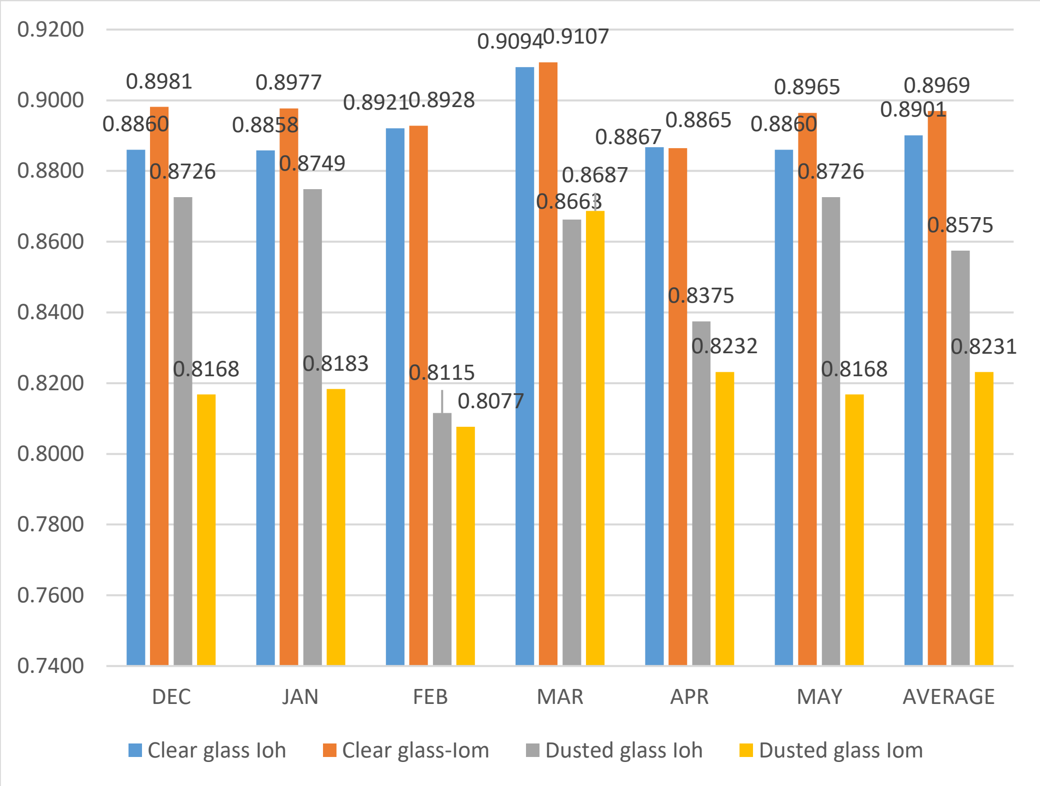

Fig. 8. Photon absorption in different media (Air, Clear Glass and Dusted Glass)

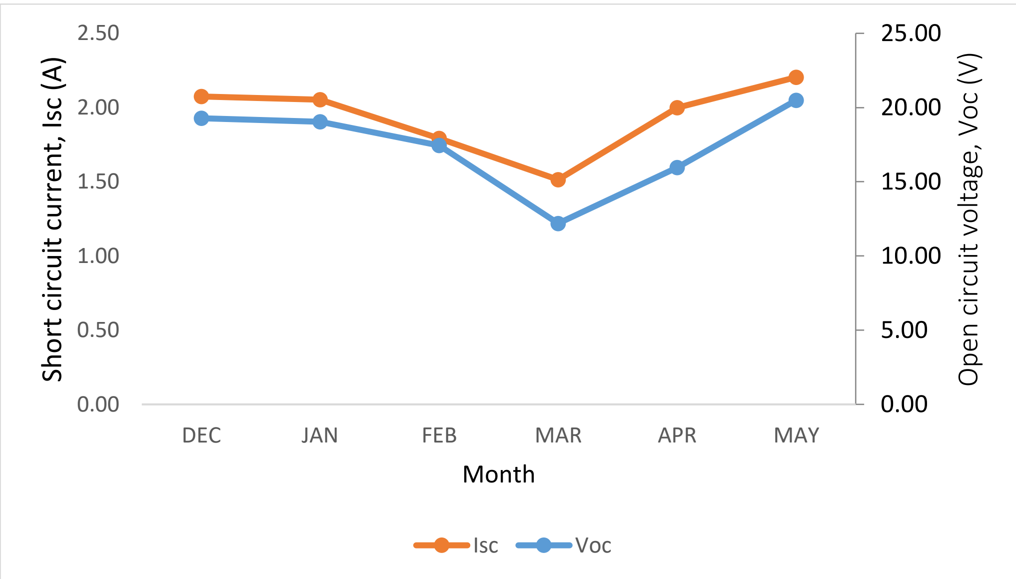

Fig.9 Plots of the monthly average values of short circuit current and open circuit voltage in the period.

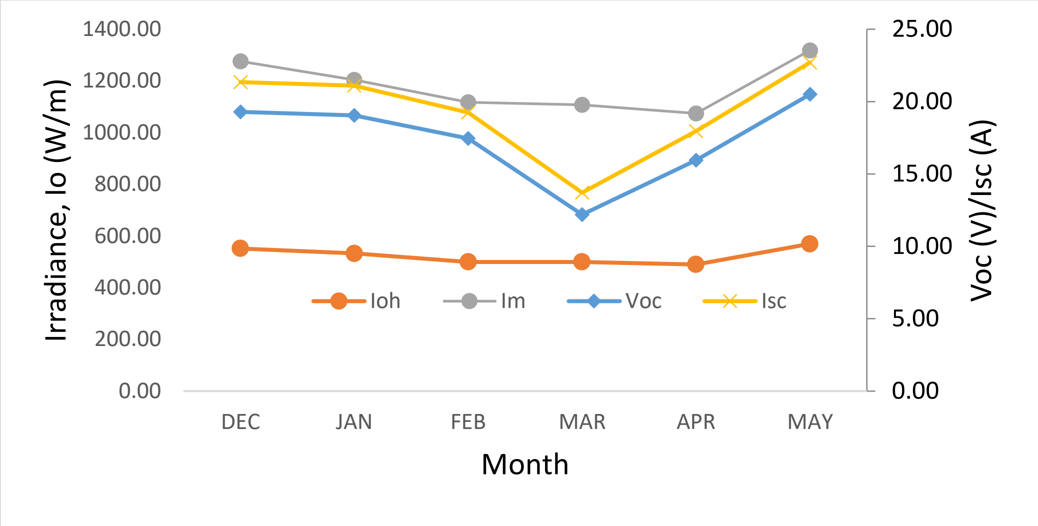

Fig.10 Plots of the monthly average values of short circuit current and open circuit voltage in the period.

REFERENCES

Adinoyi, M.J., Said, A.M., (2013), Effect of dust accumulation on the power outputs of solar photovoltaic modules, *Renewable Energy*, Vol. 60, December 2013, P. 633-636

Aliyu, M.M., Paul, B., Salawu, H. (2020), Comparative study of the Performances of Silicon Monocrystalline and Polycrystalline PV Solar Panels in Kaduna Metropolis, *International Journal of Pure and Applied Science*, Vol. 19, No. 9. P.384-195.

Bazyari, S., Keypour, R., Farhangi and S. Ghaedi, A. (2014) A Study on the Effects of Solar Tracking Systems on the Performance of Photovoltaic Power Plants. *Journal of Power and Energy Engineering*, **2**, 718-728.

Decker, K.R. (2015) How Sustainable Is PV Solar Power? L *Low-tech Magazine*, May 11, 2015.

Geisz, J. F., R.M., Schulte,K.L., Steiner, M.A., Norman, A.G., Gurhrey, H.L., Young, R.M., Song, T. and Moriarty, T., Six-junction III–V solar cells with 47.1% conversion efficiency under 143 Suns concentration, *Nature Energy*, VOL 5, April 2020 P.326–335

Green, M.A. (1998) *Solar Cells Operating Principles, Technology and System* Applications, University of New South Wales, Kensington.

Mazer, J. A., (1997) *Solar Cells*, Kluwer Academic Publishers, London.

PHOTOVOLTAICS REPORT (2017), Fraunhofer Institute for Solar Energy Systems, ISE12 July 2017

PVInsight: http://pvinsights.com/ Retrieved 10/01/2018

Sulaiman, S.A., Guangul, F. M., Mat, M. N H. and Bou-Rabee M. A. (2015) "Real-Time Study on the Effect of Dust Accumulation on Performance of Solar PV Panels in

Malaysia", 1st International Conference on Electrical and Information Technologies ICEIT'2015

Sulaiman, S.A. H.H. Hussain, Leh, N.S.H. and Razali,M.S. I.(2011) "Effects of Dust on the Performance of PV Panels", *World Academy of Science, Engineering and Technology International Journal of Mechanical and Mechatronics Engineering* Vol:5, No:10, 2011

www.ise.fraunhofer.de Retrieved on 10/01/2018.