International Journal of Electrical and Computer Engineering (IJECE)
Vol. 10, No. 4, August 2020, pp. 3819~3825
ISSN: 2088-8708, DOI: 10.11591/ijece.v10i4.pp3819-3825

Spectral filtering experimentation on Photovoltaic cells using novel bio-filter made from copper coated hibiscus-ethanol extract

Emetere Moses E.[1], Gabe-Oji Testimony[2], Durodola B. M.[3]
[1,2,3]Department of Physics, Covenant University Canaan Land, Nigeria
[1]Department of Mechanical Engineering Science, University of Johannesburg, South Africa

Article Info

Article history:

Received Jul 27, 2019
Revised Nov 6, 2019
Accepted Feb 2, 2020

Keywords:

Bio-filter
Photovoltaic cells
Solar
Solar energy
Spectral filtering

ABSTRACT

The challenges facing solar power grid system in Africa is huge. Most salient of these challenges is the inefficiency of the photovoltaic (PV) module to sustain its output for more than a year. Certainly, the harsh weather condition in the region can be said to be one of the reasons for the shortcoming that was earlier highlighted. In this research, bio-filters were suggested to filter the harmful radiation hitting the PV module. The bio-filter is made up of copper coated hibiscus extract. The hibiscus extract was done using ethanol solution. It was observed that the bio-filter was able to filter the some of the harmful radiation as expected. Using the current, voltage and power output, it can be observed that the efficiency of the PV module improved by >8%. This result is impressive compared to other simple optical filters. The quantity of the harmful solar radiation was not estimated because of the limitations of the equipment used for the research. The authors recommend that the spray pyrolysis device be used to have the exact layer of the bio-filter. It is also recommended that the degradation of the spray film due to prolonged exposure to sunlight should be studied within some months. More work can be done in estimating the percentage of infrared the biofilter can absorb per time.

Corresponding Author:

Emetere Moses E.,
Department of Physics,
Covenant University,
Canaan land, P.M.B 1023, Ota, Nigeria.
Email: emetere@yahoo.com

1. INTRODUCTION

The sun is the source of solar energy. Solar energy is an option of renewable energy. Research on solar energy is as old as man existence [1, 2]. The technology for harvesting solar energy [3, 4] keeps involving depending on three main factors i.e. efficiency of the solar device, the sunshine hours over the geographical region and the lifespan of the solar device. The sunshine hours in the tropics are more than in the temperate regions. Within the tropics, the solar sunshine hours varies according to geographical locations [5, 6].

The coastal regions of the tropics have the lowest sunshine hour due to convective activities. There are lots of solar shading due to different clouds formation and movement [2]. Moving forward, tropical geographical locations that is close to coastal areas do have a different sunshine hour. Also, locations close to the desert have higher sunshine hour. In other words, the sunshine hour is determined by the climatic system of a geographical location [5]. The most salient challenge is the signatures of the solar radiation pattern (SRP) as it has been found to differ around the tropics. More so, SRP has dangerous or harmful solar radiation that is capable of destroying the photovoltaic (PV) module. This fact is supported by recent patronage in the solar market in Africa. At the moment, South Africa has been able to generate about 124

MW to the solar grid chain. This feat has significantly dropped in the subsequent years [7]. This challenge may imply that the photovoltaic (PV) modules are no longer at their optimal working conditions.

When solar energy technology was introduced into the African solar market, it was initially very expensive due to purchasing and maintenance cost. The solar market in the region received a boost when manufacturer reduced purchasing cost. Over the years of a good patronage of solar devices in most parts of Africa, it has been observed that the solar market in Africa have not thrived significantly. This means that despite changing brands of PV modules, the users have not been greatly impressed. Within the space of six years, the PV manufacturers have introduced into the market-product such as monocrystalline PV modules, polycrystalline PV module and hybrid PV modules. Initially, the injection of these products into the African market significantly improved energy generation, however, the unimaginable drop in PV performance to about 60% within the first or second year of purchase is highly disappointing.

The modifications of solid-state technologies in various photovoltaic cells in the market were done in the manufacturer's environment [8]. In other words, there are basic design lapses that make the PV module not to work appropriately in another environment-other than the manufacturer's environment. This is the origin of the poor performing PV modules in the tropical belt of Africa. Knowing fully well that the solar radiation pattern emits dangerous radiation that could destroy the solar PV module, and it was reported earlier that this harmful radiation varies from one location to another, it is salient-based on the above, to introduce the concept of solar spectral filtering (SSF). SSF helps to screen the solar radiation reaching the surface of the PV module [9, 10].

In this research, the bio-filter was synthesized to perform the SSF processes, as it is known that the solar module only needs the visible light [11]. It is envisaged that if this research receives further contribution, it will help to reduce maintenance cost and boost patronage. The bio-filter used for this research was obtained from plant extract. The plant extract was obtained from Hibiscus Sabdariffa as shown Figure 1. Before this experiment, it is widely known that the hibiscus extract are used for flavours, medicinal, pharmaceuticals, agrochemicals, fragrances, treatment of wastewaters and local dyes [12-15]. The major component in the flower is the cyanidin 3- sophoroside.

Before now, there have been several works on spectrum filters for PV [16, 17]. Kanfara et al. [16] used a low-pass filter for testing the performance of PV modules. The experiment showed little success. Hamdad and Brawiech [17] worked on short pass filter and UV hot mirror"as an optical filter on the performance of PV cells. It was observed that the short pass filtered PV module and the hot filtered module caused a drop in the temperature by 6°C and 10°C respectively. In general, the efficiency of the PV module was improved by <6%.

Figure 1. Hibiscus sabdariffa L. flower

2. RESEARCH METHOD

The materials used for thus experiment includes: three 3W Monocrystalline solar modules; three 4W polycrystalline solar modules; 2mm Connecting wires; data logger; digital Multi-meter; retort stand, solarimeter. The rating of the monocrystalline solar module is: open circuit voltage (voc)=10.8v; short circuit current (isc)=418mA; maximum power voltage (vmp)=8.2v; and maximum power current (imp)=366mA. The rating of the polycrystalline solar module is: open circuit voltage (Voc)=22.466V; short circuit current (Isc)=0.235A; maximum power voltage (Vmp)=18.436V; and maximum power current (Imp)=0.220A. The Hibiscus sabdariffa flower was blended with ethanol and filtered. The filtrate collected into a beaker.

The 10 ml of the filtrate was mixed with 0.0045 mole of Cu $(NO_3)_2.3H_2O$ and left a day to enable proper dissolution of copper. Similar methods have been used in past experiments [18-21]. The filtrate is stirred vigorously at certain interval of time.

The data logger can accommodate four modules in total (two monocrystalline and two polycrystalline) as presented in Figure 2. The sensitivity of the sensors was synchronized with a multimeter. It was observed that the percentage accuracy was 99.23%. The offset was then configured through the Ardiuno board to reflect the shortfall. One monocrystalline and polycrystalline module was unsprayed and the other two modules (monocrystalline and polycrystalline) were sprayed. The unsprayed modules were used as control mechanism to monitor the sprayed modules. Before the modules were sprayed, it was cleaned with distilled water. The modules were afterwards put under the sun and the readings from the modules were recorded on the logger and stored in an SD card.

Figure 2. Experimental set-up of sprayed and unsprayed PV module

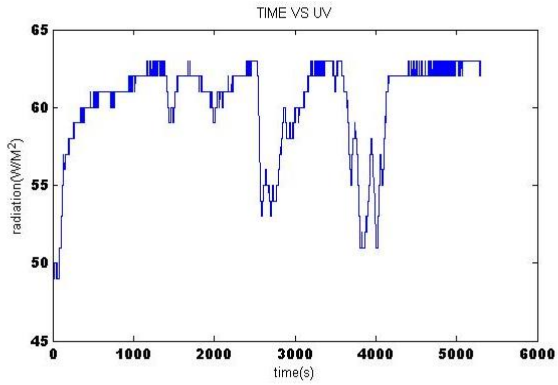
3. RESULTS AND ANALYSIS

Figure 3(a) shows the solar radiation recorded on the monocrystalline module. The figure shows fluctuation in solar radiation with respect to time and the peaks represent the time at which radiation is maximum. Figure 3(b) shows the solar radiation recorded on the polycrystalline module. The figure shows disturbing perturbations or fluctuations at some time intervals. The pattern of the solar radiation recorded in the monocrystalline and polycrystalline PV modules do not have a definite pattern to the describe them. However, it can be inferred that the unsual pattern may be attributed to solar shading due to cloud formation in the research site. The research site is an active convective region, hence high solar variation has been observed in past research paper [22-24].

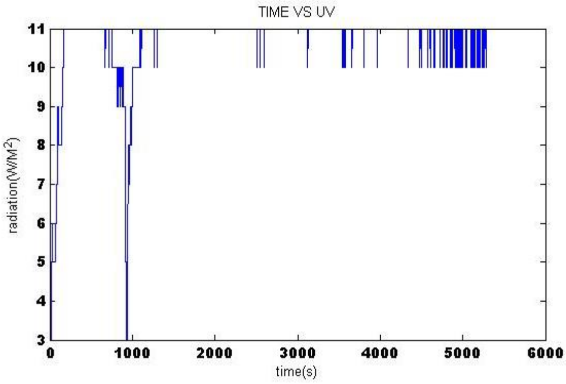
Figure 4(a) shows the current generation in the sprayed and unsprayed monocrystalline module. The current of the sprayed module is lower than that of the unsprayed module. The figure takes the same form as radiation pattern, inferring the amount of solar radiation is directly proportional to current. In the polycrystalline module, it is observed that both the sprayed and unsprayed module had same current generation Figure 4(b). It was observed that the bio-filter did not have significant effect on the current output. The bio-filter is not measured by output but how it stabilizes the measured parameter. Based on the above, the bio-filter partially stabilized the output.

The figure of the voltage generation in the sprayed and unsprayed monocrystalline PV module is presented in Figure 5(a). The voltage of the unsprayed module was slightly higher than the voltage of the sprayed module. The figure takes the same form as radiation pattern, inferring the amount of solar radiation is directly proportional to voltage generated in the monocrystalline PV module [25]. It was observed that sprayed and unsprayed polycrystalline module generated almost same voltage as the current.

The figure of power against time in the sprayed and unsprayed monocrystalline module is presented in Figure 6(a). The power of the sprayed module is lower than that of the unsprayed module. The figure takes the same form as radiation pattern, inferring the amount of solar radiation is directly proportional to power of a solar module. The polycrystalline module shows that the power generation of the sprayed and unsprayed modules was almost the same. It can be inferred that the bio-filter was able to an extent to stabilize the measured parameter i.e. power in both polycrystalline and monocrystalline modules.

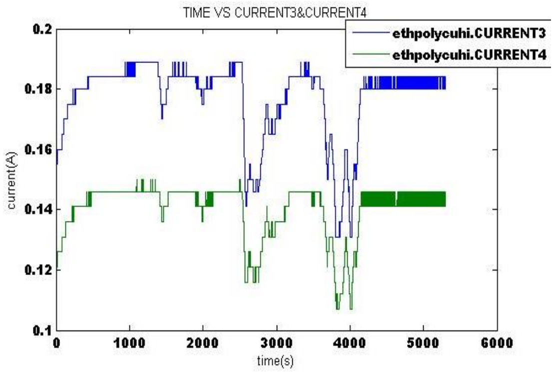


(a)

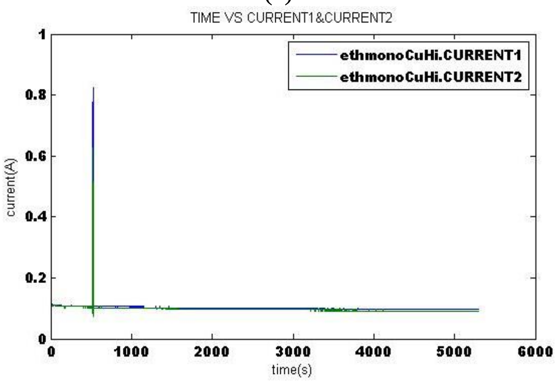


(b)

Figure 3. Solar radiation during experimentation (a) monocrystalline module (b) polycrystalline module

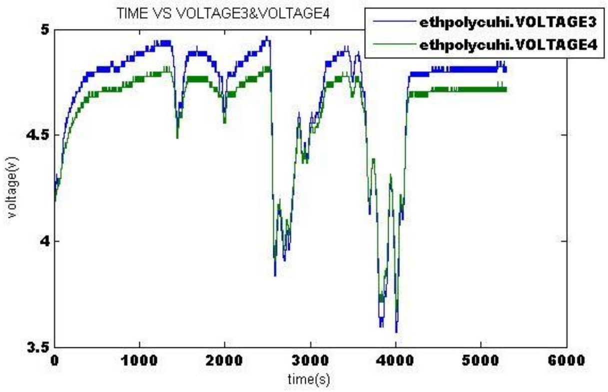


(a)

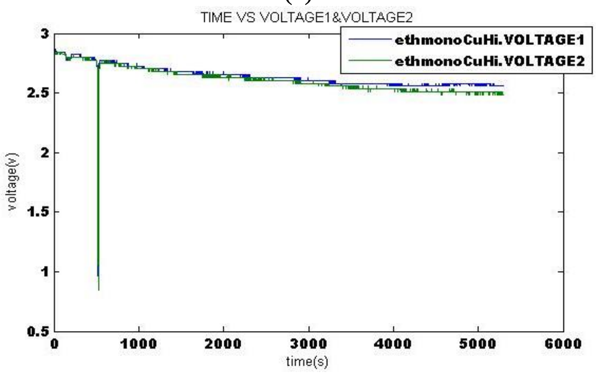


(b)

Figure 4. Current production for (a) monocrystalline module (b) polycrystalline module

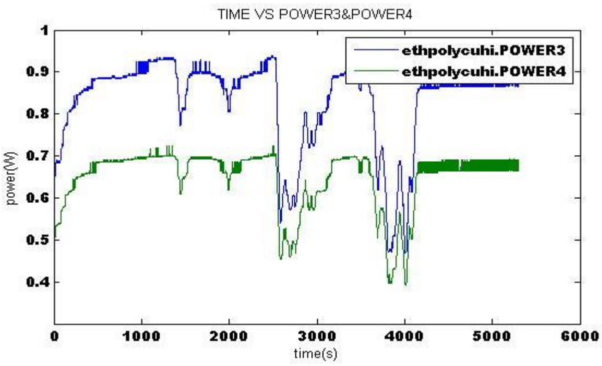


(a)

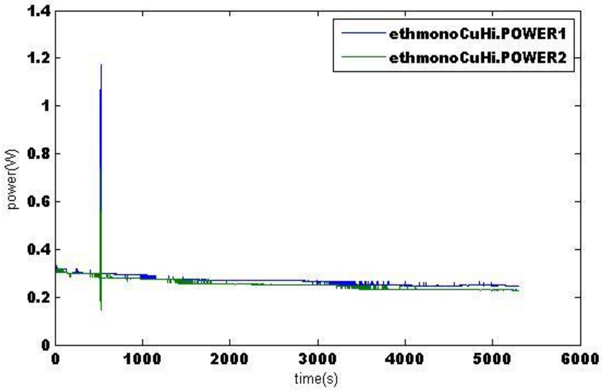


(b)

Figure 5. Voltage production for (a) monocrystalline module (b) polycrystalline module



(a)



(b)

Figure 6. Power production for (a) monocrystalline module (b) polycrystalline module

4. CONCLUSION

The synthesized bio-filter has demonstrated good optical qualities to absorb most of the harmful radiation hitting the surface of the monocrystalline and polycrystalline PV modules. Using the current, voltage and power output, it can be observed that the efficiency of the PV module improved by >8%. This result is impressive compared to other simple optical filters. The quantity of the harmful solar radiation was not estimated because of the limitations of the equipment used for the research. It is recommended that this highlighted shortcoming of the research should be taken further to ascertain i.e. in percentage the harmful radiation that was filtered by the bio-filter. The shortcoming of this work is that the uniformity of the spray was estimated based on the volume of biofilter and surface area of the PV module. Hence, the authors recommend that the spray pyrolysis device be used to have the exact layer of the bio-filter. It is also recommended that the degradation of the spray film due to prolonged exposure to sunlight should be studied within some months.

ACKNOWLEDGEMENTS

The authors appreciate Covenant University for partial sponsorship.

REFERENCES

[1] Emetere Moses E., Marvel L., Akinyemi, and Etimbuk B. Edeghe, “A Simple Technique for Sustaining Solar Energy Production in Active Convective Coastal Regions,” *International Journal of Photoenergy,* vol. 2016, pp. 1-11, 2016.

[2] Emetere M.E., and Akinyemi M. L., “Prospects of Solar Energy in the Coastal Areas of Nigeria,” *2015 PIAMSEE: AIP Conference Proceedings,* 2015.

[3] Mathna C., Donnell T. O., Martinez–Catala R. V., Rohan J., and Flynn B.O., ”Energy scavenging for long – term deployable wireless sensor networks,” *Talanta,* vol. 75, no. 3, pp. 613 – 623, 2008.

[4] Little F. E., McSpadden J. O., Chang K., and Kaya N., “Toward Space Solar Power: Wireless Energy Transmission Experiments Past, Present and Future, Space technology and applications international forum,” *AIP Conference Proceedings,* vol. 420, pp. 1225-1233, 1998.

[5] Mahmoud E., Nather H., “Renewable energy and sustainable developments in Egypt, Photovoltaic water pumping in remote areas,” *Applied Energy,* vol. 74, no. 1-2, pp. 141-147, 2003.

[6] Zhou J., Yezheng W., “General formula for estimation of monthly average daily global solar radiation in China,” *Energy Conversion and Management*, vol. 46, no. 2, pp. 257-268, 2005.

[7] Schmela Michael, Aurélie Beauvais, Naomi Chevillard, Mariano Guillén Paredes, Máté Heisz, Raffaele Rossi, Michael Schmela, SolarPower Europe et al., “Global Market Outlook for Solar Power/2018–2022,” Accessed: 19th July, 2019. [Online] Available: http://www.solarpowereurope.org/wp-content/uploads/2018/09/Global-Market-Outlook-2018-2022.pdf

[8] Illinous, “Environmental Impact of Solar Module Manufacturing and End-of-Life Management: Technology and Policy Options,” Accessed; 27th July, 2019 [Online] Available: https://pdfs.semanticscholar.org/9927/47209b6976998f6094f31c11f0eb406aeda3.pdf

[9] Russo J., Zhang D., Gordon M., Vorndran S., Wu Y., Kostuk R., “Spectrum splitting metrics and effect of filter characteristics on photovoltaic system performance,” *Opt Express,* vol. 22, no. S2, pp. A528-A541, 2014.

[10] Todd P. Otanicar, Stephen Theisen, Tyler Norman, Himanshu Tyagi, Robert A. Taylor, “Envisioning advanced solar electricity generation: Parametric studies of CPV/T systems with spectral filtering and high temperature PV,” *Applied Energy,* vol. 140, pp. 224-233, 2015.

[11] Reichman J., “Handbook of Optical Filters for Fluorescence Microscopy,” *Chroma Technology Corp.*, Brattleboro, Vt, USA, 2000.

[12] Jadhav V. M., Thorat R. M.., Kadam V. J., Sathe N. S., “Traditional medicinal uses of Hibiscus rosa-sinensis,” *Journal of Pharmacy Research*, vol. 2, no. 8, pp. 1220-1222, 2009.

[13] Gaur K., Kori M. L., Nema R. K., “Investigation of immunomodulatory potential of hydro-alcoholic extracts of Euphorbia neriifolia Linn. and Hibiscus rosa-sinensis Linn,” *International Journal of Medical Sciences,* vol. 2, no. 1, pp. 61-65, 2009.

[14] Al-Snafi AE., “Chemical constituents, pharmacological effects and therapeutic importance of Hibiscus rosa-sinensis- A review,” *IOSR Journal of Pharmacy,* vol. 8, no. 7, pp. 101-119, 2018.

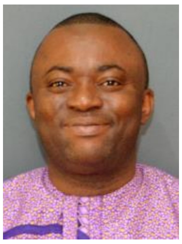
[15] Hoong, Ho Nicholas Jian and Nurhazwani Ismail, “Removal of Dye in Wastewater by Adsorption-Coagulation Combined System with Hibiscus sabdariffa as the Coagulant,” *Journal of hazardous materials,* vol. 300, pp. 808-814, 2018.

[16] M. Khanfara, R. EL Bachtiri, K. EL Hammoumi, M. Boussetta, “A comparison between two filters for PV inverter controlled to eliminate firsts harmonics,” *International Conference on Information Technology for Organizations Development (IT4OD),* 2016.

[17] Mohammad Hamdan and Amani K. Brawiesh, “Enhancement of PV performance using optical solar spectrum splitting,” *Energy Sources, Part A Recovery, Utilization, and Environmental Effects,* pp. 1-8, 2019, DOI: 10.1080/15567036.2019.1668087

[18] Emetere Moses E. and Adeyemo Nehemiah, "Spectral Filtering of Photovoltaic Cells Using Novel Bio-Filter: Silver Coated Ixora Extract Using Methanol Solution," *Universal Journal of Mechanical Engineering*, vol. 7, no. 6, pp. 424-431, 2019.
[19] Moses E. Emetere, "Photovoltaic Solar Spectral Filtering Using Bio-Filters," *Academic Journal of Interdisciplinary Studies*, vol. 9, no. 1, pp. 148-157, 2020.
[20] Emetere Moses E. and Adeyemo Nehemiah, "Spectral Filtering of Photovoltaic Cells using Novel Bio-Filter: Silver Coated Hibiscus Extract using Butanol Solution," *International Journal of Engineering and Advanced Technology*, vol. 9, no. 2, pp. 724-727, 2019.
[21] Emetere Moses E. and Gabe-Oji Testimony, "Spectral Filtering of Photovoltaic Cells using Novel Bio-filter," *IOP Conference Series Earth and Environmental Science*, vol. 331, pp. 1-7, 2019.
[22] M.O. Adeniyi, E. F. Nymphas, E.O. Oladiran, "Characteristics of total solar radiation in an urban tropical environment," *Int. J. Phys. Sci*., vol. 7, no. 30, pp. 5154-5161, 2012.
[23] I. U. Chiemeka, "Estimation of solar radiation at Uturu, Nigeria," *Int. J. Phys. Sci.*, vol. 3, no. 5, pp. 126-130, 2008.
[24] D. H. W. Li and T. N. T. Lam, (2007), "Determining the optimum tilt angle and orientation for solar energy collection based on measured solar radiance data," *International Journal of Photoenergy*, vol. 2017, pp. 1-9, 2007.
[25] M. Engin, "Sizing and simulation of PV-wind hybrid power system," *International Journal of Photoenergy*, vol. 2013, pp. 1-10, 2013.

BIOGRAPHIES OF AUTHORS



M. E. Emetere had his doctorate degrees in Solid State Physics (Ph.D.) and Atmospheric Physics (Ph.D.). He has authored two textbooks and over hundred and fifty peer-reviewed international papers listed on the Thompson Reuters indexed journals and Scopus indexed journals. He is faculty at Covenant University, Nigeria and a postdoctoral fellow at University of Johannesburg. He won the prestigious AU/TWAS Young Scientist National Award (Earth and Life Sciences) in 2015. He has won few travel grants and national awards. He is an editorial member of international journal outlet. He has been invited as conference speaker to some notable conferences in China and United States of America. Emetere is involved in collaborative research with scientists from Nigeria, Malaysia, Greece, South Africa, Germany, France and Iran. He is engaged in multidisciplinary research. He is a visiting researcher to some European facilities.

Gabe-Oji Testimony is a graduate of Renewable Energy, Covenant University. He has undertaken some laudable projects on the use of photovoltaic module in developing countries.

Durodola B. M. is a graduate of Chemistry. He is a seasoned technologist at Covenant University.