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BEHAVIOURAL PATTERN OF SOLAR FILTER ENHANCED PHOTO VOLTAICS IN MANGROVE SWAMP

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ABSTRACT: It is not always true that solar cells perform better across the board. Certain colors induce electrons inside the cell to writhe and twist, raising the temperature and making the cell less effective. To address this issue, solar cells must be subjected to a variety of light bands in order to identify those that make them less effective. The goal of this scientific investigation is to discover what happens when solar power, solar flux, and photovoltaic (PV) panels with changing solar filters are all combined. One of the objectives is to discover the filter that increases the power and efficiency of PV panels. Solar power and solar flux meters were used to measure how much solar power and solar flux struck the surface of the PV module. Color filters were utilized in the wavelength selection process. A smart photovoltaic maximum power point tracker was used to determine the maximum voltage, current, and efficiency of the PV module for a given amount of solar power and flux. Outside, real-time experimental observations of shifting solar power and irradiance were made. The results showed steady voltages and sites of rise. There were also filters that kept voltages stable at lower solar power levels (400 W/m2 for the orange and blue filters, and 45 Klx for the lemon filter). According to the data, when the amount of solar radiation increases, the module's effectiveness decreases below the red filter. In terms of sun power, both the natural spectrum and the red filter produced greater energy. However, as the amount of solar power increased, so did the module's efficiency. The natural spectrum is to blame for this. This study demonstrated that the frequency and kind of radiation to which a solar module is subjected might affect how well it operates and behaves.

Keywords*: Solar power; solar flux; solar filter; pv module; efficiency.*

1. INTRODUCTION

Modern society requires stable energy [1]. Any industrial, technological, social, or economic advancement administration prioritizes energy. Last decade, global power usage climbed dramatically [2]. Global population expansion strains energy. Alternative energy sources with steady-power are needed. Safe, pure, and widely used solar energy can assure future energy [3].

Earth gets solar energy. A fast-growing renewable [4]. It is calm, safe, pollution-free, and constantly available. Due to fossil fuel depletion and climate change, technology and solar radiation-to-electricity solutions are growing [5-6]. Around 80% of worldwide energy comes from fossil fuels, contributing to climate change [7]. Solar energy is become more accessible and convenient. It shows that global carbon dioxide emissions and climate change can be reduced [8,9]. With low environmental impact, renewable

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energy technology generates power [10]. Solar is safer than polluting fossil fuels [11]. Solar energy can meet global energy and environmental needs [12]. Solar efficiency should be 7%–40% [13-14]. Pollen, bird droppings, sunlight intensity variations, and partial shadowing affect solar system efficiency [15]. Improved solar system efficiency is being sought to close the gap with gas turbines and steam generators [16].

Battery type, module technology, inverter design, and charge controller technology limit solar systems. Despite these materials, shadow, temperature, dust, age, sunshine nature, and accessibility affect solar system performance [17]. Climate change greatly affects solar panel sunlight. This affects panel and ventilation temperatures. All affect solar panel performance and efficiency. Solar tracking technology requires increase photovoltaic system solar radiation consumption to increase power output and efficiency [18]. Global photovoltaic cell performance depends on radiation type because solar energy is sustained [19]. Solar panels absorb, reflect, or transmit light. When radiation energy is low and electrons must travel in their mean position, bonds form. After returning to low energy, the energy they absorbed will be released as heat, trapping them [20]. Heat from electrons raises cell temperature and limits use [20].

Solar systems work better in Nigeria and Africa due to year-round sunlight. Due to Nigeria's average daily temperature above the standard operating temperature for solar modules, photovoltaic modules lose power at 0.40% to 0.50% each degree, hence alternate solar radiation harnessing and usage methods are needed. Although STC manufactures and tests photovoltaic modules, solar power, flux, and radiation type affect their performance in residential settings in a given region or location. Radiation quantity and kind affect solar cell energy output. Sun and flux are reliable renewables. Weather affects solar flux [22]. The only meteorological characteristics evaluated were solar power, flux, and radiation.

Improve PV system efficiency, cell design, and manufacturing [23]. Shade severely damages PV systems. Understanding shadowing impacts solar PV system design, manufacturing, and efficiency. Shade impacts solar efficiency [24]. The blocked PV module or array may damage the system despite its apparent insignificance. Unlike PV/T solar systems, where 5% module shadowing affects power generation. PV modules under 5% shade lose 80% power [25]. Shade-free PV cells are needed during the day.

Hard, moderate shadows. A complete shadow blocks solar cell light. Bird droppings, leaves, or a tree branch over the glass may cause this. PV panels lose electricity when partially occluded. A distant phone pole, tree, cloud, or structure that links provides a soothing shade. Solar cells receive less light [25]. Partial shading influences cell count and energy output. Total encasement may cut power.

The PV module in this experiment has flexible and rigid solar screens. Stiff shadow stops cell radiation completely. Instead of moderate shade, it blocks, filters, or selects a wavelength to reduce radiation. It's planned. The sun filter blocks or absorbs other wavelengths while letting the chosen hue through, providing significant resistance. However, slight tints

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dim color.

Kazem et al. [26] extensively studied polycrystalline PV module performance in heavy shadow. Only illuminating series-connected cells reduced power loss, scientists found. Shadowing parallel-connected cells lost energy.

Researchers Sai Krishna and Moger [27] rearranged solar arrays to reduce partial shade. Uneven irradiance hinders solar module or array production. They found that shading pattern and array order affect power drop, not shaded area.

El-Shaer et al. [28] found that current parameter varied more when investigating light intensity on crystalline silicon modules. Joshi et al. [29] say red light affects modern solar equipment. PV/T surface energy orange-red. Ogherohwo et al. [30] found red light increased PV panel power. Photovoltaics may also benefit from red light. However, Ali et al. [31] found that red light greatly reduced photovoltaic cell functionality. Research shows yellow-green sunlight. With colored filters, Kazem and Chaichan [32] found that solar panels benefited best from natural spectrum exposure. Solar energy greatly affects solar cell performance, argue Tobnaghi and Naderi [33]. Rani et al. [34] say solar cell power generation is affected by sunlight. Touati et al. [35] observed that monocrystalline and amorphous solar systems' power output rises linearly with energy.

Solar power and radiation affect photovoltaic system efficiency, drawing attention. The majority of regional data does not address solar screen integration into PV systems. Solar power, flux, and photovoltaics in Nigerian mangrove wetland zones are unknown. Designing, building, and sizing solar modules is harder. PV module responsiveness to that wavelength is limited by solar screen reflections. Scientists can then determine which wavelength raises module temperature and efficiency.

A rare study examines PV modules with solar filters in a Nigerian mangrove swamp. This study will realistically determine if solar filters boost PV panel efficiency. Solar panels and sun shields in Nigerian mangroves and filters are examined. The study succeeded with color filters. This had visible and non-visible filters. A study helps clients customize the system to increase solar module voltage or current.

2. MATERIALS AND METHODS

Materials Used in This Study

Africell Solar's model AF-100 W monocrystalline solar module was used in the experiment(D).Thismodule's maximum rated output is 100 W (see Figure 1). Table 1 contains the technical specs for the module. During the investigation, an additional item illustrated in Figure 1 was also used. To measure solar flux (C), an HS1010A digital solar flux light meter is used, while an SM206 digital solar power meter is used to measure solar power (B). The peak power output of solar module (A) was calculated using a digital high precision photovoltaic smart panel maximum power point tracker (MPPT) tester of model WS400A. Several colored filters were used to identify the correct spectrum (E).

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Experimental Setup

The study was carried out outdoors at the Cross River University of Technology (CRUTECH), which is located in Calabar at 4055'43.6379" North latitude and 8019'52.2361" longitude.

The solar cell was set up six meters above sea level, splayed out in the sunshine on a level surface. Figure 2 depicts the link between the output of the solar module and the input of the photovoltaic smart panel MPP tracker. In this method, the highest power spots were observed and logged.

Table 1. PV module technical characteristics

Electrical Specification	Value
Maximum Power	100 W
Current at Maximum Power	5.49 A
Voltage at Maximum Power	18.2 V
Short Circuit Current	6.59 A
Open-circuit Voltage	21.8 V
Number of cells	33
Nominal Operating Cell Temperature	47±2
Module dimension	1340 mm*540 mm*25 mm



Fig. 1. materials used for the experimental setup

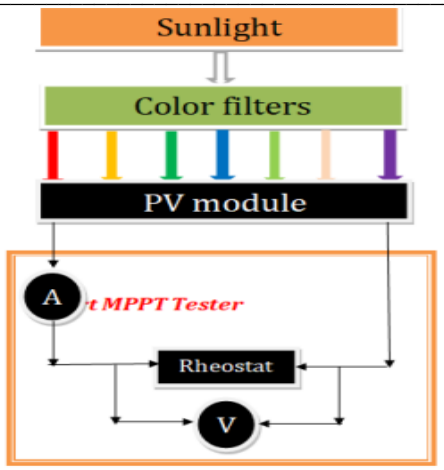


Fig. 2. PV module experimental setup

Measurement Procedure

Four months later, at 8:00 a.m. Every 30 minutes, data was collected from the solar cell in a planned manner. approximately 4:30 p.m. Before applying each color filter one at a time, measurements were collected without the filters throughout the data gathering process. The module was fitted with a different color filter, and the quantity of solar power and flux that passed through it was measured. The maximal power output of the module at that level of solar power and flux was also discovered. The exact amount of radiation that hit the surface of the photovoltaic module was determined by measuring the radiation that passed through the solar filters and was transferred (solar power and solar flux). Similar studies track the incident radiation that reaches the surface of the solar filter, and the transmitted radiation is estimated using the transmittance formula, which takes the thickness of the filter into consideration. Because the transmitted radiation is measured directly, the thickness of the screen is irrelevant in this case, hence it is not listed in Table 1. Because the solar filter is always in use, its transmittance quality deteriorates with time. This is why

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the filters are physically checked before being inspected every day. Heat, or the high temperature of the PV module, causes uneven screen thickness. As soon as this issue is identified, the filter is modified to ensure that the radiation being supplied is consistent throughout the whole surface of the photovoltaic module.

Data Processing and Measurements

The experiment was conducted outside during various times of the day in real-world situations, such as shifting solar power and flux. The observed and recorded solar flux and transmitted solar power were assigned to each color filter employed. The instantaneous voltage Vmp and current Imp at full power were captured and examined in a specific real-time condition. The smart panel MPP tracker was immediately utilized to monitor the open circuit voltages (Voc, Vmp, Imp, and Pmax). Design, maintenance, and solar power (G) all have a significant impact on the performance of photovoltaic (PV) panels. Methods (1) and (2), as demonstrated by Ali et al. [36] and Muhammad et al. [37], can be employed to determine this effectiveness. (2) was used to get the normalized power output efficiency.

$$\eta = \frac{P_{max}}{G \times A} \quad (1)$$

$$\eta_P = \frac{P_{mea}}{P_{max}} \times 100 \quad (2)$$

Pmax and Pmea represent the maximum power at steady-state (STC) and measured power of the PV module, respectively. A represents the surface area of the module.

Study Location

The mangrove swamp we chose, Calabar, is at 4057'06" N and 8°19'19" E. It is 32 meters above sea level and the capital of Cross River State in southern Nigeria. The unusual tropical monsoon climate dominates. Precipitation occurs almost year-round except for the dry season's core months, which fall between January and March and October and December [38]. Rainfall is heavy most months, with the brief dry season having little effect. Calabar has year-round heat and humidity, with clouds in the rainy season and clouds in the dry season. Most of the year, the temperature stays between 640F (17.780C) and 920F (33.330C) [39]. The average cloud cover changes throughout the year. The clearest skies are November 25–February 15, with December being the clearest. April has the most clouds, with 89% of the time cloudy from February 15 to November 25 [39]. Calabar's daytime hours average 12 hours and 24 minutes year-round. December 21 has the shortest daylight time at 11 hours, 50 minutes, while June 21 the longest at 12 hours, 25 minutes [39]. Seasonally, Calabar's average hourly wind speed fluctuates greatly. August has the most wind, 7.5 mph on average. Windy weather occurs from May 23 to October 15 (4.7 months). The calmer part of the year lasts from October 15 to May 23 (7.3 months), with December being the calmest month with an average hourly wind speed of 4.2 mph [39]. January is the hottest month in Calabar, with an average high of 95.40F (35.20C) and a low of 74.80F (23.80C). August is the coolest, with an average high of 82.90F (28.30C). In January and April, 1020F (38.90C) and 660F (18.90C) were the hottest and lowest recorded temperatures [40]. January has the lowest mean relative humidity (69%), while July–September has the highest at 87%. July has the least rainfall (13.5 days) and December

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the most (29.9 days) [40]. August (4 hours) and December (9.5 hours) get the most sunshine.

3. RESULTS AND DISCUSSION

This section is divided into two parts, each with experimental measurement and analysis data: the first looks at how solar power affects the electrical properties and efficiency of the filter enhanced photovoltaic (PV) module across different light wavelengths, while the second looks at how solar flux, also shown in Figure 3, affects the PV module's above parameters.

Tables 2 and 3 describe the solar flux and power that reach the photovoltaic module through the solar filters, and Tables 4 through 7 depict the output electrical features of the photovoltaic module with the solar filters in place.

Influence of Solar Power on the Electrical Parameters of Filter Enhanced PV Module

Figure. 3a shows the solar filter enhanced PV module's voltage response pattern with varying solar power. The chart shows that solar power voltage rises between 0 and 500 W/m2 without filters. At maximum solar power, the module's output voltage approaches 500 W/m2. Above that point, voltage is stable. The red filter raised voltage from 0 to 700 W/m2 before stabilizing near Vmp. The orange filter stabilized voltage at 400 W/m2 quickly, but not near Vmp. The lemon filter drove voltage to 600 W/m2 before stabilizing. The blue filter stabilized voltage at 400 W/m2 solar output, although not close to Vmp. The green filter stabilized at 550 W/m2. Before stabilizing, the PV module beneath the peach filter raised voltage to 710 W/m2, whereas the violet filter stabilized at 600 W/m2. The chart reveals that the lemon and green filter had the highest rising segment voltage and the peach and blue filter the lowest. Without filters, stable zone voltage was higher.

Figure 3b displays the PV module's current response to solar power and light wavelengths. The graph confirms Njok et al. [19] that solar power increases current linearly and that the red filter creates the maximum current.

In Figure 3c, the PV module's power output grows linearly with solar power even without filters, validating Touati et al. [35], who found that monocrystalline PV technologies' power output increases linearly with radiation.

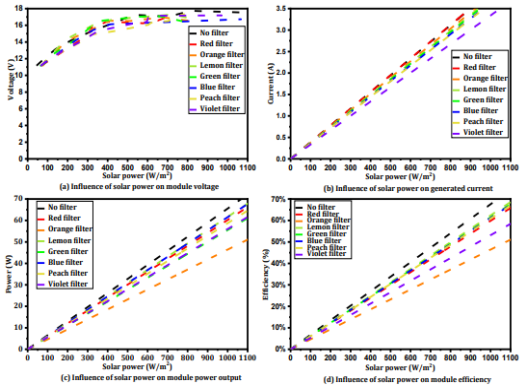


Fig. 3. Influence of solar power on the electrical parameters of filter enhanced PV module

Table 2. Uncertainty analysis of transmitted solar power (W/m2) reaching PV module surface

Statistics	No filter	Red	Orange	Lemon	Green	Blue	Peach	Violet
Minimum	44.47	68.93	73.97	69.37	61.73	67.63	66.37	65.07
Maximum	1115	702.9	816.1	838.2	773.65	810.8	782.05	968.97
Mean	535.01	428.84	525.85	425.15	452.2	430.09	454.8	456.32
Median	541.55	396.9	511.9	459.2	462.7	328.8	427.4	501.88
Variance	80217.82	37931.89	96335	43007.59	43639.85	63528.93	53610.99	53146.88
Standard deviation	283.23	194.76	310.38	207.38	208.9	252.05	231.54	230.54
Standard error	64.98	44.68	71.21	47.58	47.92	57.82	53.12	52.89

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Table 3. Uncertainty analysis of transmitted solar flux (Klux) reaching PV module surface

Statistics	No filter	Red	Orange	Lemon	Green	Blue	Peach	Violet
Minimum	5.78	6.07	7.73	7.47	7.63	7.53	6.93	7.03
Maximum	119.68	63.05	82.93	86.68	85.83	76.2	73.7	95.3
Mean	64.35	39.36	49.16	45.81	49.75	44.61	46.41	45.09
Median	69.33	33.83	51.12	46.45	52.6	37.2	46.53	52.3
Variance	1001.4	307.81	508.98	559.04	510	516.56	490.23	524.98
Standard deviation	31.65	17.55	22.56	23.64	22.58	22.73	22.14	22.91
Standard error	7.26	4.03	5.18	5.42	5.18	5.21	5.09	5.26

The trendline shows that more power was produced without the filter, which was expected because the higher current generated by the filter was expected to result in more power produced by the filter (Fig. 3b). The higher power produced without the filters is also due to the module reaching a higher voltage, which confirmed the expectation.

The influence of sunlight on the electrical parameters of a photovoltaic module fitted with a better filter

Fig. 4. Influence of solar flux on the electrical parameters of filter enhanced PV module

Table 4. Uncertainty analysis of voltage (V) generated by PV module

Statistics	No filter	Red	Orange	Lemon	Green	Blue	Peach	Violet
Minimum	11.39	11.18	11.12	11.14	11.12	11.19	11.13	11.13
Maximum	17.79	17.05	17.56	17.3	17.13	17.41	17.37	17.19
Mean	15.94	15.41	15.31	15.22	15.16	15.06	15.27	15.1
Median	16.52	15.67	15.79	15.57	15.76	15.45	15.54	15.41
Variance	3.98	1.93	3.58	2.98	3.56	2.93	3.65	3.27
Standard deviation	1.996	1.39	1.89	1.73	1.89	1.71	1.91	1.81
Standard error	0.46	0.32	0.44	0.4	0.44	0.39	0.44	0.42

Table 5. Uncertainty analysis of current (A) generated by PV module

Statistics	No filter	Red	Orange	Lemon	Green	Blue	Peach	Violet
Minimum	0.31	0.27	0.27	0.28	0.25	0.26	0.26	0.25
Maximum	3.46	3.75	3.66	2.98	2.99	2.78	2.94	3.05
Mean	2.1	1.71	1.78	1.59	1.62	1.57	1.69	1.54
Median	2.25	1.58	1.89	1.57	1.7	1.55	1.72	1.34
Variance	1.05	0.63	0.77	0.63	0.55	0.64	0.7	0.66
Standard deviation	1.03	0.79	0.88	0.79	0.74	0.8	0.84	0.81
Standard error	0.24	0.18	0.2	0.18	0.17	0.18	0.19	0.19

Table 6. Uncertainty analysis of power (W) produced by PV module

Statistics	No filter	Red	Orange	Lemon	Green	Blue	Peach	Violet
Minimum	3.48	2.98	3.04	3.08	2.79	2.92	2.92	2.8
Maximum	61.52	58.73	65.64	49.61	49.28	43.45	47.92	52.4
Mean	35.24	26.94	28.62	25.27	25.72	24.73	27.13	24.51
Median	36.55	24.72	30.65	25.73	25.55	22.21	26.34	21.92
Variance	364.45	172.44	255.15	196.34	165.76	190.63	219.56	207
Standard deviation	19.09	13.13	15.97	14.01	12.88	13.81	14.82	14.39
Standard error	4.38	3.01	3.66	3.21	2.95	3.17	3.4	3.3

Table 7. Uncertainty analysis of efficiency (%) level reached by PV module

Statistics	No filter	Red	Orange	Lemon	Green	Blue	Peach	Violet
Minimum	3%	3%	3%	3%	3%	3%	3%	3%
Maximum	62%	60%	66%	50%	49%	43%	48%	52%
Mean	35%	27%	29%	25%	26%	25%	27%	25%
Median	37%	25%	31%	26%	26%	22%	26%	22%
Variance	4%	2%	3%	2%	2%	2%	2%	2%
Standard deviation	19.09	13%	16%	14%	13%	14%	15%	14%
Standard error	4.38%	3%	3.66%	3.21%	2.95%	3.17%	3.40%	3.30%

Furthermore, Figure 3d depicts the efficiency of the photovoltaic (PV) module in relation to solar power, both with and without the filters. The figure shows that the PV module's efficiency rises linearly with solar power, which is consistent with Njok et al.'s [19] findings. The module was less efficient when the orange filter was used, and more efficient when the filters were not used.

The effect of solar flux on the electrical parameters of PV modules with filters.

Influence of Solar Flux on theElectrical Parameters of Filter Enhanced PV Module

With different solar flux levels, Figure 4a shows the solar filter enhanced PV module's voltage response pattern. The graphic shows that without filters, voltage rises from 0 to 90 Klx. Above 90 Klx, the voltage reaches Vmp and stabilizes. Under the red filter, voltage increased up to 65 Klx, then stabilized near the Vmp. With the orange filter, voltage increased up to 70 Klx before stabilizing. The lemon filter showed voltage stability with a low solar intensity of 45 Klx, however the voltage was not close to Vmp. The PV module

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under the green filter produced a constant voltage of 60 Klx, close to Vmp. The blue filter produced a constant voltage of 75 Klx near Vmp. With the peach filter, voltage stability was attained at 60 Klx, but it was still far from Vmp. Under the violet filter, voltage increased up to 95 Klx before stabilizing near the Vmp. No matter the solar flux, stability was obtained first by increasing voltage. Fig. 4a shows low voltage performance from the lemon, peach, and blue filters. Red, orange, and green filters improved voltage.

Figure 4b shows how solar flux affects PV module current for different wavelengths. Similar to Njoket et al. [19], the graph illustrates that PV module current increases linearly with solar flux when exposed to different wavelengths of light. It also reveals that red filters produce the maximum current, followed by orange filters.

According to studies [19], a PV module's power output rises linearly with solar flux, as seen in Figure 4c. The red filter had the maximum strength, followed by orange, lemon, and violet with the least. The red filter is the most efficient, followed by the orange filter, and the violet filter is the least efficient, which is not surprising since the red filter produced more power.

4. CONCLUSION

Monocrystalline photovoltaics with solar filters were tested at Calabar mangrove swamp in Cross River State, Nigeria. Different wavelength solar filters improved PV modules. Outdoor tests examined how solar filters affected monocrystalline module behavior at different wavelengths. Under the same temperature and humidity, electrical working parameters, maximum power, and efficiency were determined at different wavelengths. Solar power and flux through filters were used to test the module. Close inspection indicated that the module behaves like filters. The analysis reveals that the module's voltage rises before stabilizing near the Vmp as transmitted solar power and flux reach it. But module temperature produces ripples in the constant voltage band. A slight temperature rise lowers voltage and vice versa. Transmitted solar power and flux through each filter increase module current, power, and efficiency, the study revealed. The study found that the red filter boosts module current, power, and efficiency when solar radiation increases. The red filter and natural spectrum produced current in solar power, boosting module efficiency as solar power increased. Photovoltaic module effectiveness relies on radiation type and wavelength, according to this study.

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