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The Impact of Using Solar Colored Filters to Cover the PV Panel in Its Outcomes

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Abstract: The solar radiation intensity is the primary parameter that affects the PV panel outcomes. However, the solar radiation has a group of wavelengths, and each one of them can influence the solar cell in a different way from other wavelengths. The spectrum wavelengths are related to the energy's frequencies. The present study aimed to find the wavelength/color that causes the highest PV panel outcome and the best electricity conversion. Seven colored filters were added once solo and once again combined but except one. The study results reveal that the PV panel output for the natural spectrum is the highest compared to the other colored light. This is almost certainly due to the loss of light intensity inherent to the tint of the color filters. The blue screen employment resulted in lowest output power compared to the other colored filter. The study results proved that the visible spectrum of the solar radiation affects the solar panel outcomes.
Keywords: Solar spectrum, wavelength, PV panel, colored filter.

INTRODUCTION

The growing need for energy in the whole world has caused increasing global warming and air pollution dramatically in addition to the depletion of fossil fuels for power generation [1]. The clean solar energy use and available in most parts of the world considered the optimal solution to the problems caused by excessive burning of fossil fuels for power generation [2]. The conversion of solar energy into electricity has been a priority; this issue has become a matter of broad prospects in both space and terrestrial applications [3]. Photovoltaic cells as solar energy applications are used to convert the solar energy directly into electricity by pairs of semiconductor interact with the effect of light [4]. The limited efficiency of the photovoltaic is the hindering reason for the widespread use of solar cells. The primary cause of the photovoltaic cell low efficiency is that it uses a small part of the energy in the solar spectrum [5].

The solar radiation falling to the ground is divided from the wavelength to three wavelengths with different energy content [6]:
• Ultraviolet (UV) (less than 400 nm), with an energy content of 5-10% from the total energy.
• Visible light (VL) (400-700 nm); energy content of 40% from the total energy.
• Infrared (IR) (above 700 nm); energy content of 50% from the total energy.

The earth is protected from ultraviolet waves by the ozone layer in the atmosphere, and thus what enters the atmosphere is up to 90% of the solar radiation which is the visible and the infrared wavelengths [7]. Since the photovoltaic cell uses a part of the solar energy spectrum which is determined by the band gap of a semiconductor [8]. The photons which have a power greater or lower than the band gap generate heat that can be dissipated by the transmission loss. These heat generations called thermalization process where the photons are absorbed with less energy than the solar cells band gap energy. This thermalization process is the dominant loss that limits the conversion performance of solar cell [9].

As shown above, the spectrum of the solar energy is not fully utilized in photovoltaic cells. So many researchers suggested that other applications can provide an effective way and an alternative to the use of solar radiation and waste heat to take full advantage of the solar energy spectrum.

Orosz *et al*. [10] proposed a novel method to determine the optimal division of the solar spectrum in the application of hybrid PV. The application was a novel designed PV/T collector who also modeled in detail using tracking software ZEMAX 12. X. The researchers demonstrated that the optimal wavelengths of the solar spectrum in this collector were compatible with 732 and 1067 nm. These wavelengths represent the spectrum region, which should be directed to the PV cells. Moreover, in this way photovoltaic cell was able to receive 47% of the solar spectrum energy.

Galleano *et al*. [11] fabricated a nanoparticle fluid filter consisted of gold nanoparticles and indium tin oxide nanocrystals to evaluate the optical properties. The researchers tried to integrate the solar spectrum at air mass (AM 1.5) to estimate the produced efficiency that passes the photovoltaic cell band gap to generate electrical energy directly. Researchers have concluded that the filter-PV assembly efficiency was up to 62% of the solar spectrum.

DeJarnette *et al*. [12] have done a solar spectra modeling for four sites located in the northern hemisphere in addition to the experimental work for 12 months. The results obtained from the two locations in Spain were clear, impressive results. The study results showed that the maximum monthly variations of spectral gains taking place in the A- Si PV cells, ranging from16 % (winter) to 4 % (summer) in Stuttgart, Germany. The spectral monthly deployment effects of decreased with the latitude of the site.

Alonso-Abella *et al.* [13] proposed a method to measure the impact of the solar spectrum at any location of the atmosphere in the condition of providing their necessary information. The method can predict if the semiconductors in the PV module can be advantageous when employed under non-standard conditions.

Despite the high quality and value of the literature that has been mentioned in the preceding paragraphs, but it did not explain which solar spectrum wavelength is the most influential on the PV cell performance. The extent of the distribution of wavelengths of the solar spectrum changes from one location to another and from time to time causing an increase or decrease in electricity produced from PV cell.

The present work aims to test which solar spectrum wavelengths package is the most influential in the production of electricity from the photovoltaic cell. This work is a part of continuous efforts of the Omani Sohar University Renewable Energies team in the field of using renewable energies in the Arab Gulf countries and Iraq [14- 60].

EXPERIMENTAL SETUP

In the present study, a PV system consists of a monocrystalline module, which its specifications are listed in Table 1, was used. Several colored filters were used to absorb variable wavelengths of visible sunlight. The colored filets absorb all visible light and reflect that of their color. So, to expose the PV panel to a specified wavelength light, it must be covered with a color filter. The used photovoltaic solar module was covered with different color filters, and the changes in panel voltage and current output were measured and recorded. Six filters of different colors and transmittances were utilized (Neely, blue, green, red, yellow, orange, and purple lights). A DC ammeter and DC voltmeter were used to measure the PV panel voltage and current. The experiments were conducted several times, once without the filters and the other with each colored filter alone.

A potentiometer was used to change the load resistance; this device was attached to the panel. Also, the voltage, current, and light intensity were measured. A set of color filters were used to change the color of the incident light. In each trail, the color filter was taped directly to the sun. The PV panel current and voltage were measured for five bright days. Seven variable colored filters (Red, Yellow, Blue, Green, Purple, Neely, Orang) were used in the experiments. The tests were conducted five times to confirm its repeatability and reduce its uncertainty. The primary two studied cases:

Table 1: The used PV panel specifications

The PV cell module type	10(17) p285*350
Peak power	10.0 W
Open circuit current	22.0V
Short circuit voltage	0.64
Peak voltage	17.0 V
Peak current	0.59 A
Max system voltage	600 V

1. Case one: one colored filter was used to cover the PV panel, and the panel outcomes were measured and compared to no filter case.
2. Case two: all the colored filters were used to cover the PV panel except one, and the panel outcomes were measured and compared to no filter case.

The tests were conducted in Sohar city, Oman at January-2016, where the temperature didn't exceed 25ºC, and the relative humidity was between 40-45%.

RESULTS AND DISCUSSIONS

In case one tests, the purple color generated the highest voltage and current that's because it has the shorter wavelengths (400nm) and the highest energy. The Neely color produced the smallest voltage while the red color has the lowest current. These results are compatible with Fitzgerald *et al.* [61] results, who concluded that the red color has the least amount of light pass through panel because it didn't have more energy to excite the electrons on the silicon atoms. Table 2 represents the color effect on the PV panel produced voltage and current. When no filter was used (visible light) the PV power was the highest. The results show in different filters the power was significantly reduced in comparison with module without the filter. For the photovoltaic solar cells, the cells output such as voltage is a function of many parameters as the temperature, solar intensity, and the wavelength (color) of the incident light. The voltages (Fig. 1), current (Fig. 2) variations of the used module with different filters are presented

Table 2: The PV panel average outcomes

Filter color	V	I	Power (W)
No filter	19.12	0.21	4.015
Purple	18.82	0.21	3.952
Orange	18.72	0.21	3.931
Yellow	18.62	0.2	3.724
Red	18.51	0.12	2.221
Green	18.18	0.2	3.636
Blue	17.75	0.2	3.55
Neely	17.4	0.19	3.306

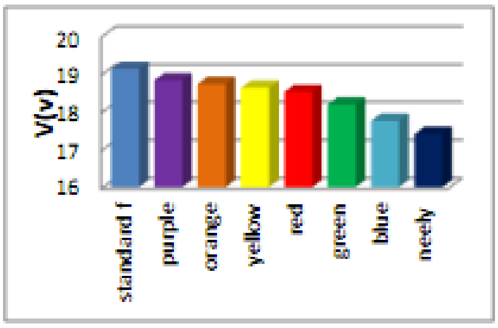

Fig-1: The relation between the filters color and the output voltage

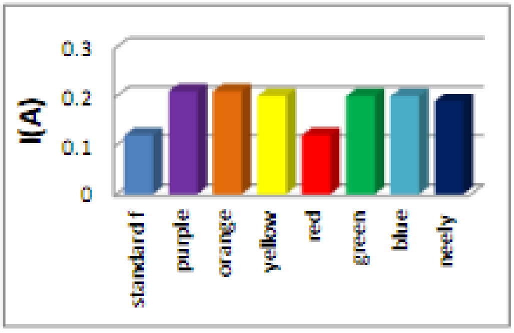

Fig-2: The relation between the filters color and the output current

In the second set of experiments: all filters were fixed above each other on the solar panel except one each time. As a result, when the blue color filter was excluded, higher current and voltage were produced from the PV panel, as figures 3 & 4 reveals. When the red color filter was used, it eliminated less current and voltage was generated by the panel. The resulted V and I depend on which colored filter has less or more wavelength.

The light frequency is influenced by the color which allows a limit of the energy to pass through an object and this light color defines how many photons are allowed to pass to the solar panels. Some filters absorbed less spectrum of light than other filters. The filters affect the photons quantity that passes through it to the solar panel and thus changing the power generated.

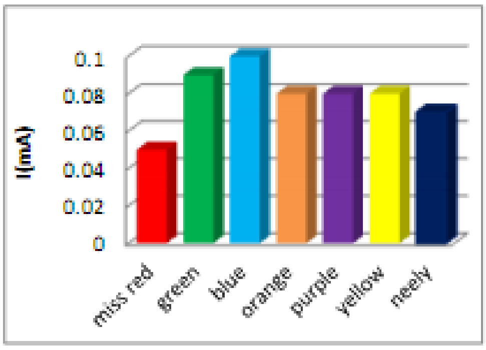

Fig-3: the relation between excluded filters color and the current

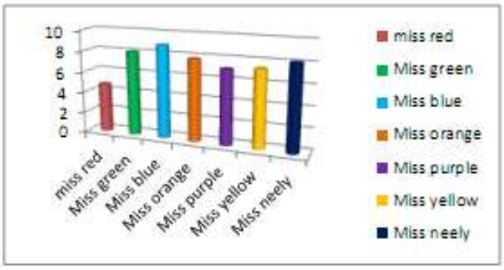

Fig-4: the relation between the excluded filters color and the voltage

Due to the addition of colored filters, the PV panel output power was reduced significantly compared to the case without filters. The generated current was increased with the longer wavelength filters use. In the present work, there was interest in neutralizing the external conditions, for this reason, the tests were conducted on days when the outside temperature didn't exceed 25ºC and the relative humidity never exceeded 45%.

CONCLUSIONS

The sunlight spectrum colors affect the solar photovoltaic (PV) panels. The present study was conducted practically to find these effects on PV current, voltage, and power. The study results show that the using spectrum colored filters can reduce the performance of solar panels, and it is always preferred to use no colored filters. Covering the PV panel with the purple colored filter produced the highest reading of the current and voltage, and using the red filter generated the lowest readings because the purple color has the shortest wavelength and higher photon energy but less efficient. So, the red color light generates more electricity than other spectrum colors. Also, it has longer wavelengths, less photon energy and more efficient. In general to get more efficiency, high solar radiation intensity is needed without colored filters.

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