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Performance Analysis of 300W Solar Photovoltaic Module under Varying Wavelength of Solar Radiation

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Abstract: ***The electrical output of solar photovoltaic module is depending on the magnitude of incident radiation and its wavelength. In this paper, an experimental study is carried out to evaluate the effect of wavelength of light on the solar photovoltaic module performance. A study is experimentally conducted by using various colour filters to verify the effect of variation of wavelength of light on the performance of 300W solar module at Department of Mechanical Engineering, Poornima University and Jaipur, India. Based on the solar cell temperature, solar irradiance and photovoltaic theory, the solar module efficiency and its power output have been evaluated. An analytical model is also developed based on physical parameters to evaluate the efficiency of solar panel. The results show that the in-today's scenario photovoltaic technology is influenced by the red colour of light. In other words, we can say that the energy of the PV system lies between the wavelengths of orange and red colours whereas the exergy of the photovoltaic system lies between yellow and green colours of light.***
Keywords**:** ***Solar module, photovoltaics, wavelength effect, analytical modelling, energy efficiency, solar energy***

I. INTRODUCTION

Solar photovoltaic system has gained significant attention rapidly since the last decade, due to the depletion and adverse environmental impacts of conventional fossil fuels [1] India is a tropical country close to the equator zone which enables a high amount of sunlight reception throughout the year, making Solar PV as potential renewable energy resource. Solar cells are an alternative method for generating electricity directly from sunlight. Solar photovoltaic technology is the technology that converts solar energy directly into electricity, through the use of solar cells. It is a technology that has been developed since the 20th century. This technology is growing rapidly, and is expected to reach full maturity in the 21st century [2].A photovoltaic generator, also known as a photovoltaic array, is the total system consisting of all PV modules connected in series or parallel with each other [3].Solar photovoltaic conversion efficiency has improved as the general technology has advanced, growing from the first passive collection methods (efficiency approx. 1%) to the current applicable methods (efficiency approx. 15-20%)[4].Studies have been done towards the next advancement for increased output and efficiency. The color of light is determined by its wavelength and dictated in the color spectrum. [5].

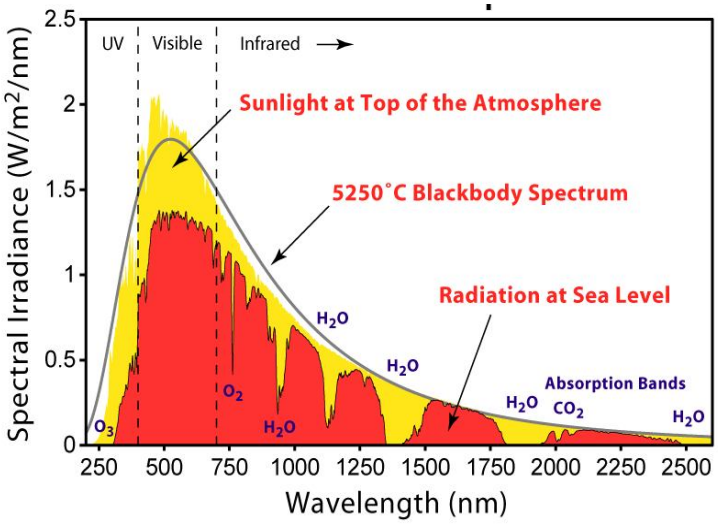

Figure 1. Solar Radiation Spectrum [6].

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Light coming from the Sun includes all colours of the spectrum and wavelength ranges from about 400 nanometers (nm) to about 780 nm. The energy of the photons is determined by their frequency, E=hf. Where E is the energy of the photon, f is its frequency in Hz, and h is Planck's constant, h = 6.663*10^-34 Js. Sunlight is a different colour - it contains more of the high-energy violet end of the spectrum. Red photons have the least energy, and blue photons have the most energy. Green is in between the two. It is becoming increasingly apparent that wavelength of light has a significant influence on the performance of photovoltaic modules. Currently available solar cells respond well to some, but not all, wavelengths. Different solar cells are designed to operate efficiently at different wavelengths depending on the materials used to manufacture them. Research in the area of solar cells continues with an increasing interest to develop cells that will respond well at the widest range of wavelengths. The aim of this study is to investigate the effect of different wavelengths of light on the power output and efficiency of the Solar panel. The study is also intended to develop a more efficient method of using light for solar energy.

II. MATERIALS AND METHODS

The system consists of a mono crystalline solar module of 36Wp power capacity mounted on a stand that can be adjusted for optimum tilt and exposure to sunlight. A solar power meter (Make: Tenmars, Taiwan) was used to measure solar irradiance. The photovoltaic solar module was covered with different color filters and the changes in panel voltage and current output is measured and recorded. Six colour filters were used (red, yellow-orange, white, green, blue, and violet light). Colored filters for light perform a rather simple function: they absorb all wavelengths of light except that of their own color, thus tinting the light that color. So, when a panel is covered with a colour-filter, it means it is exposed to a light of specified wavelength: shorter for blue, medium for green and longer for red. Using an ammeter and voltmeter Voc and Isc of the solar panel is measured as a series of filters are placed over the solar panel. The experiment is repeated for module without filters on a bright sunlight. The module properties and other experimental parameters are given in the Table 1. The system set up is as shown in the Figure 2.

TABLE 1. SPECIFICATIONS OF 300W SOLAR MODULE EMPLOYED FOR THE EXPERIMENTAL STUDY

Solar PV Module Specification	
Model	ELDORA 300
Make	300 W
Open Circuit Voltage	45.1 V
Short Circuit Current	8.74 A
Maximum Current	8.05 A
Maximum Voltage	37.28 V
Efficiency	15.63 %
Fill Factor	76.13%
NOCT	45^{0} C

Figure 2. 300W solar module for experimental set up

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The ratio of the solar panel power output shaded by the filter to the output of the panel without a filter can be used to investigate the dependence of the solar cell output on wavelength. This information can also be used to evaluate the wavelength of light emitted by the source.

III. RESULTS

TABLE 2: POWER OUTPUT AND VARIATION OF EFFICIENCY OF SOLAR MODULE

Colour	Wavelength	Current	Voltage	Power	Efficiency
Violet	390 - 455	2.18	43.1	93.99	7.52
Blue	455 - 495	1.97	42.3	83.74	6.89
Green	495 - 575	2.42	43.2	104.67	8.62
Yellow	575 - 595	2.31	44.7	103.44	8.54
Orange	595 - 625	2.17	44.1	96.05	7.91
Red	625 - 780	2.66	44.4	118.21	9.73
White	390 – 780	3.09	45.1	139.566	11.56

A. Power output variation

The voltages, current and power variation of the module with different filters are presented in Figure 3. And for a crystalline solar cell, the electrical output voltage is a function of the temperature, Intensity and colour of the incident light. Due to filters, the module power was significantly reduced in comparison with the module without filters. A greater amount of current was generated when light of a longer wavelength fell upon the photovoltaic cell. However, the wavelengths of violet and orange light did not follow the trend. This signifies that a relationship between wavelength and current may not be completely linear. Outside factors may have also influenced the result. We assumed that blue light shining on a solar panel would give off the higher volt reading because it has the shortest wavelength and the highest energy, but it was actually the lowest.

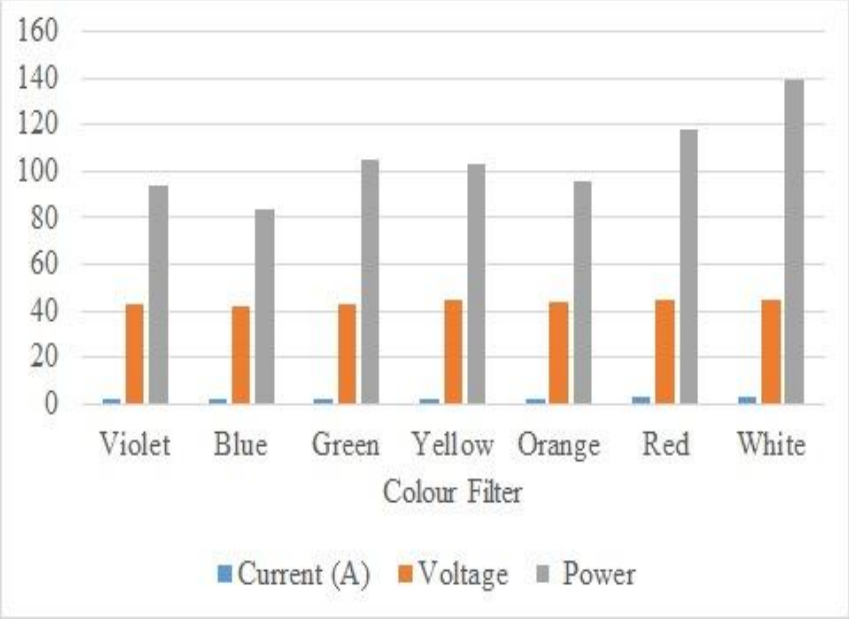

Figure 3. Variation of Voltage, Current and power output of solar module with filters.

B. Efficiency variation

This is due to the reason that module without filter was receiving all the photons of solar radiation compared to the module with filters. The best efficiency obtained was when no filter was used. The photovoltaic conversion efficiency of the modules with different filters is estimated and shown in Figure 4.

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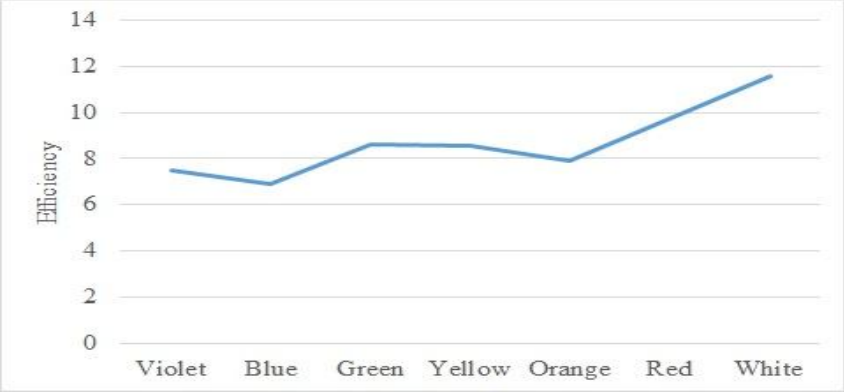

Figure 4. Variation of efficiency of solar module with different filters.

C. Spectral response.

The ability of solar cell to capture energy is not just determined by the strength of the energy, but by the ability to catch or 'detect' light. This is most often related to the energy's frequency/wavelength. The types of energy (color, frequency, wavelength) a device can detect is called its 'spectral response'. This is often given as a numerical range of wavelengths (frequencies, or colors), But the wavelength/color that corresponds to the highest peak of the spectral response graph, will be the type of light that particular panel can best convert to electricity

IV. DISCUSSION

The data was analysed and it was found that the output of the 300W solar panel under sun light was significantly higher than that of any of the other colour light. This is almost certainly due to the loss of light intensity inherent to the tint of the colour filters. The output of 300W solar panel under blue colour filter is lower than that of all the other colour filters. This proves that the spectral response of the solar panel for the blue light is the lowest. The spectral response of panel for green light is slightly higher than that of yellow and orange. Red and blue all had outputs significantly higher than green, which is concurrent with the intensity readings: Blue s intensity fell short of the next lowest, violet, by more than 11%. By this study, it is once again proved that visible portion of the Solar Spectrum influences the performance of the Solar panel than the Infra Red light

V. CONCLUSION

This study was carried out in Poornima University, Jaipur to determine the wavelength and the effect of various colour filters on the performance characteristics of Solar module. From the experimental results, it was concluded that the colour of filter and wavelengths of light falling on solar module affects the performance of solar module. Wavelength of red light generates electrical output than other colours wavelength. The solar module output efficiency can be improved by exposure to red light. Future studies might examine the material properties of solar cells that make solar module more responsive to red light wavelength. The electrical efficiency of solar module can also be improved by reducing the loss of radiation intensity due to tinting.

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BIOGRAPHIES

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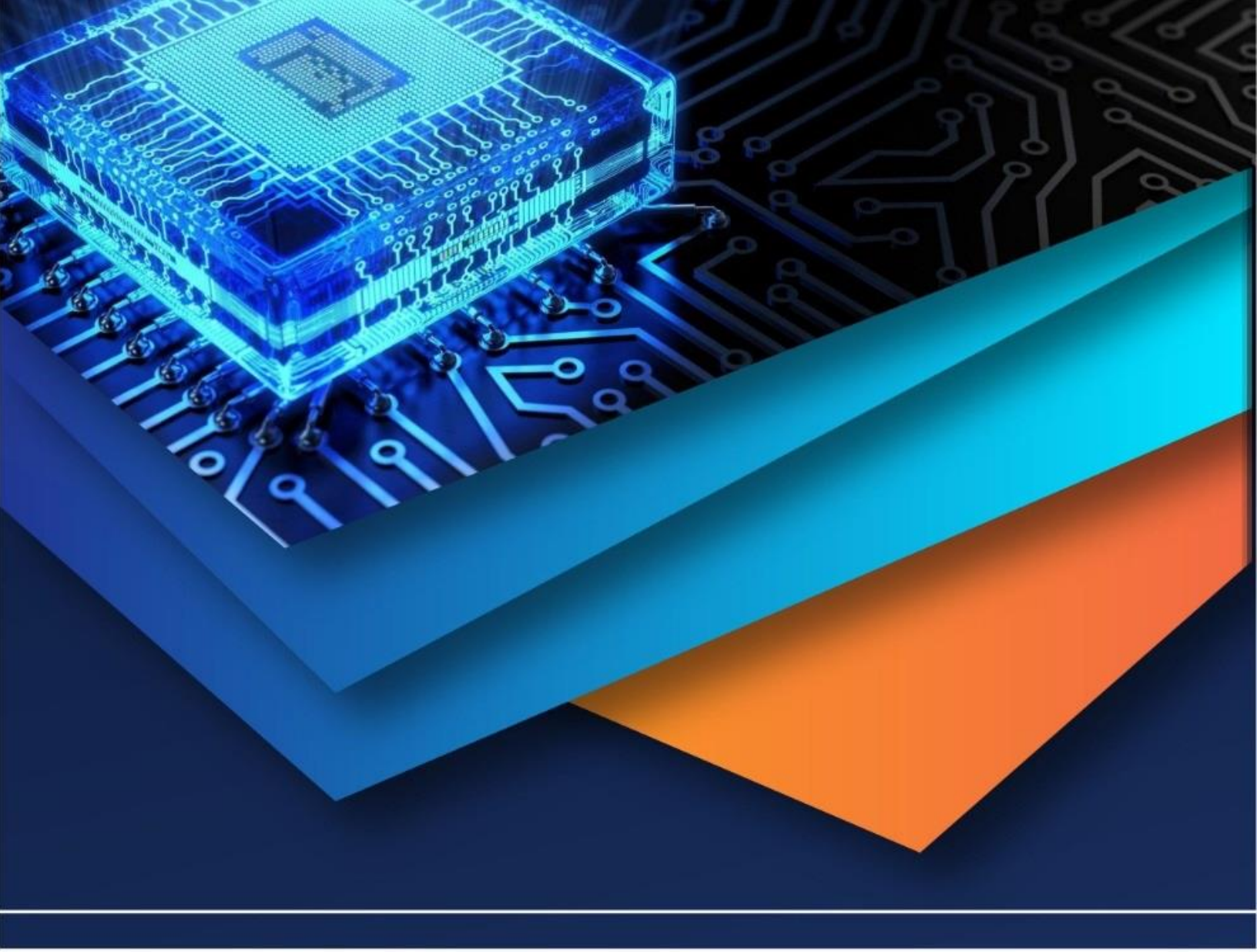

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