Analysis of colour spectrum on the performance of photovoltaic cell

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ABSTRACT

With the fossil fuels are getting limited solar energy is emerging as the renewable energy source that could change the future. It is easily available and its usage does not harm the environment with greenhouse gas emissions. By using solar tracking and maximum power point tracking, engineers are working to meet the main challenge of improving the efficiency of solar energy systems. The total electrical power generated by a photovoltaic system depends on solar irradiance (solar energy per unit area of the solar panel's surface) and other conditions such as temperature and cloud cover. With the change of the light intensity incident on a solar cell all solar cell parameters, including the short-circuit current, the open-circuit voltage, the FF, the efficiency and the impact of series and shunt resistances changes. The current and voltage at which a solar module generates the maximum power is known as the maximum power point. In this paper, experiments are carried out using various films (photoconduction) to evaluate the effect of colors of light on the photovoltaic cell performance.

Keywords: *Illumination, irradiance, concentrators, fill factor*

1. Introduction

The light intensity on a solar cell is known as the number of suns, where 1 sun corresponds to standard illumination at AM1.5, or 1 kW/m^2. For example a system with 10 kW/m^2 incident on the solar cell would be operating at 10 suns, or at 10X. A PV module designed to operate under 1 sun conditions is called a "flat plate" module while those using concentrated sunlight are called "concentrators". Cell series resistance is: 1 ohm cm^2, cell shunt resistance is: 100 ohm cm^2 and concentration: 1 suns real. The series resistance has a greater effect on performance at high intensity and the shunt resistance has a greater effect on cell performance at low light intensity.

2. I-V curve

Photovoltaic cells have a complex relationship between their operating environment and the maximum power they can produce. The fill factor gives an idea of the non-linear electrical behavior of the solar cell. Fill factor is the ratio of the maximum power from the solar cell to the product of V_{oc} and I_{sc}. In the mentioned data it is often used to estimate the maximum power that a cell can provide with an optimal load under given conditions, $P=FF*V_{oc}*I_{sc}$. For many purposes, FF, V_{oc}, and I_{sc} are enough information to give a useful approximate model of the electrical behavior of a photovoltaic cell under typical conditions. For any set of operational conditions, cells have one single operating point where the values of the current (I) and Voltage (V) of the cell result in a maximum power output. These values correspond to a particular value load resistance, which is equal to V / I as specified by Ohm's Law. The power P is given by $P=V*I$. A photovoltaic cell shows approximately exponential relationship between current and voltage. From basic circuit theory, the power delivered from or to a device is optimized where the derivative (graphically, the slope) dI/dV of the I-V curve is equal and opposite to the I/V ratio (where dP/dV=0). This is called as the maximum power point (MPP) and corresponds to the "knee" point of the curve. A load with resistance $R=V/I$ equals to the reciprocal of this value draws the maximum power from the device. This is sometimes called as the characteristic resistance of the cell. This is a dynamic quantity changing on the level of illumination, as well as other factors like temperature and the age of the cell. If the resistance is less or higher than this value, the power drawn will be less than the maximum available, and thus the cell will not be used as efficiently as it could be. Maximum power point trackers utilize different types of control circuit or logic to search for this point and thus allow the converter circuit to extract the maximum power available from a cell.

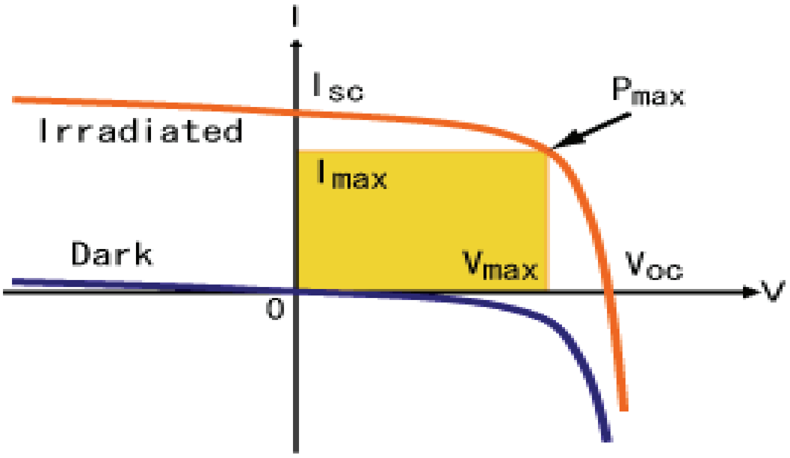

Figure 1 shows I-V characteristics of solar cell both on irradiated and dark condition

3. P-V curve

In one of the method, the controller adjusts the voltage by a small amount from the array and measures power; if the power rises, further adjustments in that direction are tried until power no longer increases. This is known as the perturb and observe method and is most common, although this method can result in oscillations of power output. It is also called hill climbing method, as it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method because of its ease of implementation. Perturb and observe method results in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is used.

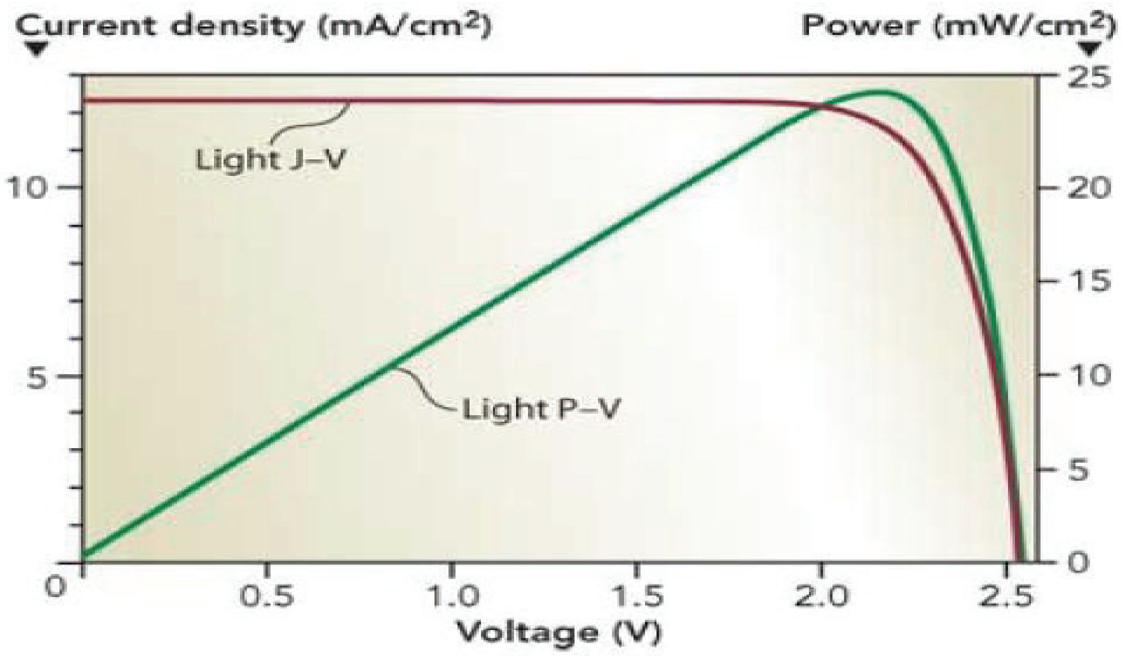

Figure 2 shows power versus voltage curve

4. Concentrators

A concentrator is a solar cell designed to operate under illumination greater than 1 sun. The incident sunlight is focused or guided by optical elements such that a high intensity light beam shines on a small solar cell. Concentrators have several potential advantages, including a higher efficiency potential than a one-sun solar cell and the possibility of lower cost. The short-circuit current from a solar cell based linearly on light intensity, such that a device operating under 10 suns would have 10 times the short-circuit current as the same device under one sun operation. However, this effect does not provide an efficiency increase, since the incident power also increases linearly with concentration. Instead, the efficiency benefits arise from the logarithmic dependence of the open-circuit voltage on short circuit. Therefore, under concentration, V_{oc} increases logarithmically with light intensity, as shown in the equation below;

$$V'_{OC} = \frac{nkT}{q}\ln(\frac{XI_{SC}}{I_o}) = \frac{nkT}{q}[In(\frac{I_{SC}}{I_0}) + InX] = V_{OC} + \frac{nkT}{q}InX$$

where X is the concentration of sunlight.

From the equation above, a doubling of the light intensity (X=2) causes a 18 mV rise in V_{OC} . The cost of a concentrating PV system may be lower than a corresponding flat-plate PV system since only a small area of solar cells is needed. The efficiency benefits of concentration are reduced by increased losses in series resistance as the short-circuit current increases and also by the increased temperature operation of the solar cell. As losses due to short-circuit current depends on the square of the current, the power loss due to series resistance increases as the square of the concentration.

5. Low light intensity

Solar cells experience changes in light intensity, with the incident power from the sun varying between 0 and 1 kW/m^2. At low light levels i.e 0 to 0.4 kW/m^2, the effect of the shunt resistance becomes increasingly important. As the light intensity reduces, the bias point and current through the solar cell also decreases and the equivalent resistance of the solar cell may begin to approach the shunt resistance. When these two resistances are similar, the fraction of the total current flowing through the shunt resistance increases, thereby increasing the fractional power loss due to shunt resistance. Consequently, under cloudy conditions, a solar cell with a high shunt resistance retains a greater fraction of its original power than a solar cell with a low shunt resistance.

Fill Factor = (Vm*Im) / (Voc*Isc)
Solar efficiency = (Vm*Im)/ Solar Power.

We can see the effects of more and less light and different wavelengths of light on the PV cell and of the cells temperature. Current readings will be larger when more light is absorbed. We can see the effects of more and less light and different wavelengths of light on the PV cell and of the cell's temperature. Current readings will be larger when more light is absorbed. Open circuit voltage readings should be smaller when the PV cell is cold, though this temperature effect may be too minor to observe on a small scale. The decreasing angles from the sun (light source) result in lower current readings Current times Voltage equals Power. Short circuit current (the current when the voltage is zero) increases in proportion to the incident energy (sunlight). Because of Ohm's Law (and the equation Power = Voltage x Current), the result of reduced voltage is reduced power output. The ideal position on any I-V curve—the sweet spot where we can collect the most power from the module—is at the "knee". That's the *maximum power point* (MPP), and you can see that its position changes with temperature and irradiance. The best position on any I-V curve-the sweet spot where we are able to collect the most power from the module-is at the "knee". That is the maximum power point (MPP), and you can see that its position changes with temperature and irradiance.

For red colour:
Fill Factor = (Vm*Im) / (Voc*Isc) = 0.6941
Solar efficiency = 22.98%

The Fill factor values for other colours are calculated and shown in the observation table below along with the graph.

6. Experimental data

RED				
SL NO	VOLTAGE(VOLTS)	CURRENT(mAmp)	Power (watts)	
1	0	238	0	
2	13.25	200	2.65	
3	14.25	160	2.28	
4	15.25	120	1.83	**Fill factor=0.6941**
5	15.5	100	1.55	
6	16	80	1.28	
7	16.25	70	1.1375	
8	16.6	0	0	

GREEN				
SL NO	VOLTAGE(VOLTS)	CURRENT(mAmp)	Power (watts)	
1	0	238	0	
2	13.25	200	2.65	
3	14.5	160	2.32	
4	15.5	120	1.86	Fill factor=0.5413
5	16	100	1.6	
6	16.25	80	1.3	
7	16.5	70	1.155	
8	16	0	0	

VIOLET				
SL NO	VOLTAGE(VOLTS)	CURRENT(mAmp)	Power (watts)	
1	0	200	0	
2	12	200	2.4	
3	13.75	160	2.2	
4	14.75	120	1.77	Fill factor =0.553
5	15.5	100	1.55	
6	15.75	80	1.26	
7	16	70	1.12	
8	16	0	0	

PINK				
SL NO	VOLTAGE(VOLTS)	CURRENT(mAmp)	Power (watts)	
1	0	240	0	
2	13.25	200	2.65	
3	14.5	160	2.32	
4	15.5	120	1.86	Fill factor =0.6495
5	15.75	100	1.575	
6	16.25	80	1.3	
7	16.5	70	1.155	
8	17	0	0	

7. Results

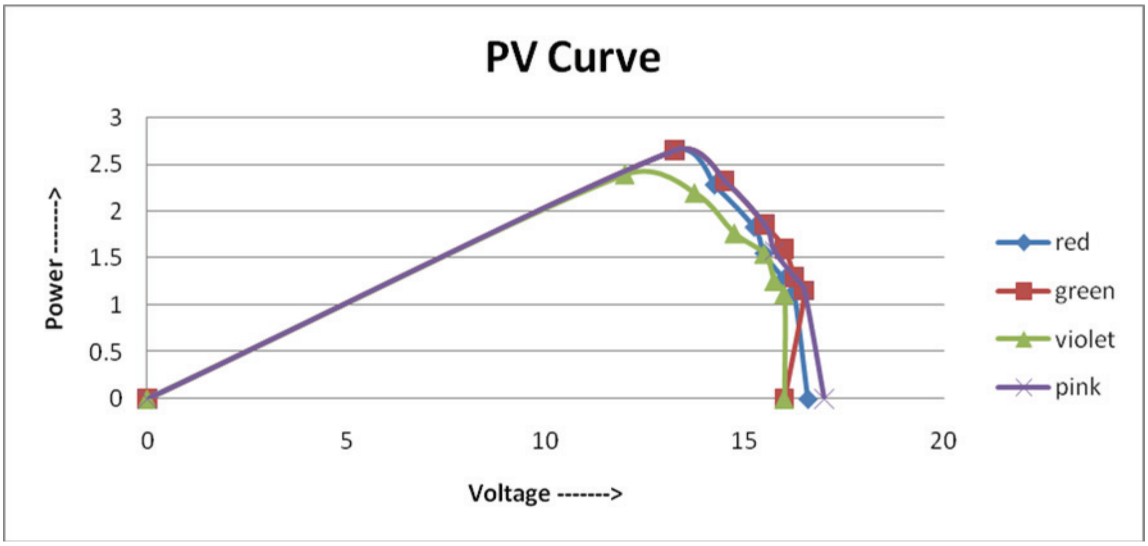

Figure 3 shows P-V curve for solar photovoltaic cell for various colour spectrum

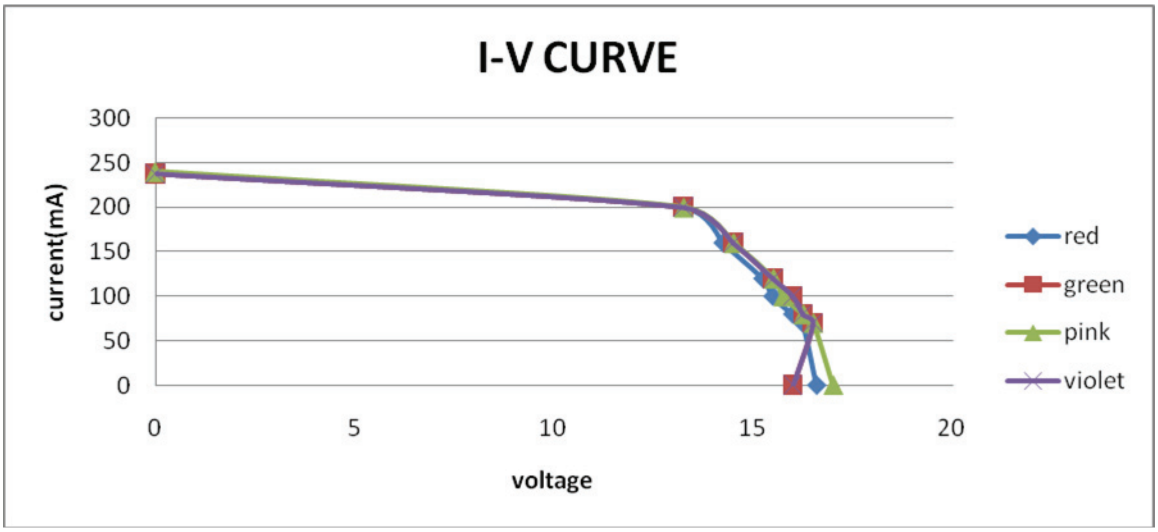

Figure 4 shows I-V curve for solar photovoltaic cell for various colour spectrum.

8. Conclusion

The results show that the present day PV technology is influenced by the red color of light. In other words, the energy available on the PV surface lies between the wavelengths of orange and red colors whereas the energy of the system lies between yellow and green colors of light The visible light spectrum spectrum runs from approx 450*10^12 Hz (red) through to 750*10^12 Hz (blue). So red photons have the least energy, and violet photons have the most energy. Green is in between the two at about 600*10^12 Hz. So, when no color, all the photons can hit the solar cell, and you get the best efficiency. When the red color is used, we are losing only the low energy red photons, but still keeping the medium energy green, and the high energy violet photons.

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