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Parameter Analysis Method for Enhancing Efficiency of Photovoltaic Cells

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Abstract: A Photovoltaic(PV) cell is a device which generates electricity directly from visible light. Their efficiency is fairly low due to environmental changes and nature of material. So, the PV cells are expensive according to other energy resources products. Several parameters affect solar cell efficiency. This paper presents the most important parameters that affect efficiency of PV cells. These are cell temperature, Irradiation, MPPT (maximum power point tracking) and energy conversion efficiency. PV cell efficiency is improved by changing these parameters.

Keywords: PV Cell, Efficiency, PV Cell Factor, PV Cell Temperature, Irradiation.

Introduction

Solar Energy is energy that comes from the sun. The energy uses by PV cells that convert sunlight into direct current electricity. PV cells are composed of various semi conducting materials. Semiconductors are materials, which become electrically conductive when supplied with light or heat, but which operate as insulators at low temperatures. When photons of light fall on the cell, they transfer their energy to the charge carriers. The electric field across the junction separates photo-generated positive charge carriers (holes) from their negative counterpart (electrons). In this way an electrical current is extracted once the circuit is closed on an external load.

The PV field has given rise to a global industry capable of producing many gigawatts (GW) of additional installed capacity per year [1]. The problems with energy supply and use are related not only to global warming but also to such environmental concerns as air pollution, acid precipitation, ozone depletion, forest destruction, and radioactive substance emissions. To prevent these effects, some potential solutions have evolved including energy conservation through improved energy efficiency, a reduction in fossil fuel use and an increase in environmentally friendly energy supplies. Among them, the power generation with PV cells system has received great attention in research because it appears to be one of the possible solutions to the environmental problem [2].

Several factors affect PV cell efficiency. This paper examines the factors that affecting efficiency of PV cells according to scientific literature. These factors are changing of cell temperature, using the MPPT with PV cell and energy conversion efficiency for PV cell.

Characterization of PV Cells

It is quite generally defined as the emergence of an electric voltage between two electrodes attached to a solid or liquid system upon shining light onto this system. Practically all photovoltaic devices incorporate a PN junction in a semiconductor across which the photovoltage is developed. These devices are also known as PV cells. A cross-section through a typical PV cell is shown in Figure 1. The semiconductor material has to be able to absorb a large part of the solar spectrum. Dependent on the absorption properties of the material the light is absorbed in a region more or less close to the surface. When light quanta are absorbed, electron hole pairs are generated and if their recombination is prevented they can reach the junction where they are separated by an electric field [3].

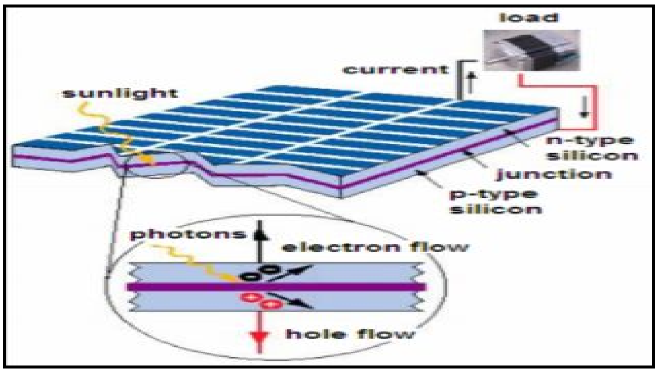

Figure 1. A schematic of the layers of a typical PV cell

The photoelectric effect was first noted by a French physicist, Edmund Bequerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light [4,5]. The theory of the PV cell is the PV effect of semiconductor material. The solar effect is a phenomenon that the semiconductor material absorbs the solar energy, and then the electron-hole excited by the photon separates and produces electromotive force. The *I-V* characteristic of the PV cell changes with the Irradiation G (W/m^2) and cell temperature T (°C), that is I = f (V, G, T). According to the theory of electronics, when the load is purely resistive , the actual equivalent circuit of the PV cell is as Figure 2 . The current to the load can be given as:

$$I = I_L - I_o\left(e^{\frac{qV_d}{nK_bT}} - 1\right) - \frac{V_d}{R_{sh}} \qquad (1)$$

where $V_d = V_{PV} + I_{PV}R_{se}$

In above equation (1) R_{se} is series resistance R_{sh} is parallel resistance, q electronic charge 1.602X10^{-19} C , V_T is thermal generated voltage, K_b is Boltzmann constant 1.38X10^{-23} J/K,T is temperature , n is diode ideality factor,I_o is diode reverse saturation current.

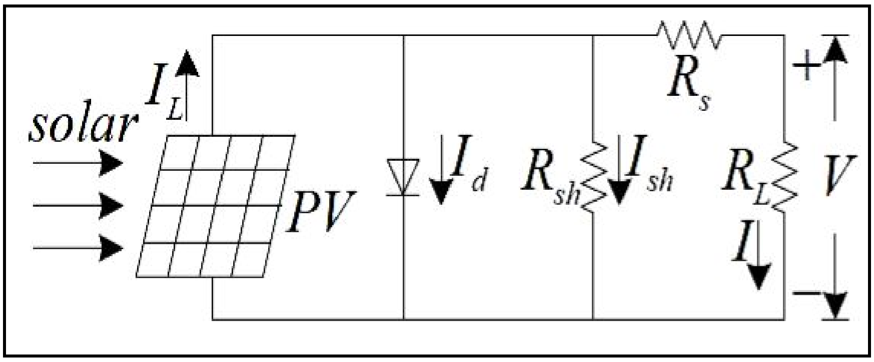

Figure 2. The equivalent circuit of the PV cell

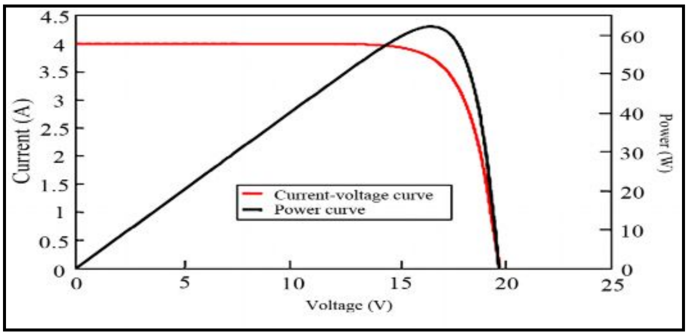

Figure 3. Typical I-V characteristic of a polycrystalline silicon module with the variation of power

Figure 3 shows an I-V characteristic together with the power curve, to illustrate the position of the Maximum power point(MPP) [6].

PV Cells Efficiency Factors

Cell Temperature

As temperature increases, the band gap of the intrinsic semiconductor shrinks, and the open circuit voltage (V_{oc}) decreases following the PN junction voltage temperature dependency of seen in the diode factor nKT. PV cells therefore have a negative temperature coefficient of V_{oc}. Moreover, a lower output power results given the same photocurrent because the charge carriers are liberated at a lower potential. Using the convention introduced with the Fill Factor calculation, a reduction in OCV results in a smaller theoretical maximum power $P_{max}=I_{sc}*V_{oc}$

given the same short-circuit current I_{sc} .

As temperature increases, again the band gap of the intrinsic semiconductor shrinks meaning more incident energy is absorbed because a greater percentage of the incident light has enough energy to raise charge carriers from the valence band to the conduction band. A larger photocurrent results; therefore, Isc increases for a given insolation, and PV cells have a positive temperature coefficient of I_{sc} [7].

Figure 4 shows the I-V and P-V characteristics at the constant illumination when the temperature changes [8]. Temperature effects are the result of an inherent characteristic of crystalline silicon cell-based modules. They tend to produce higher voltage as the temperature drops and, conversely, to lose voltage in high temperatures. Any PV panel or system derating calculation must include adjustment for this temperature effect [9].

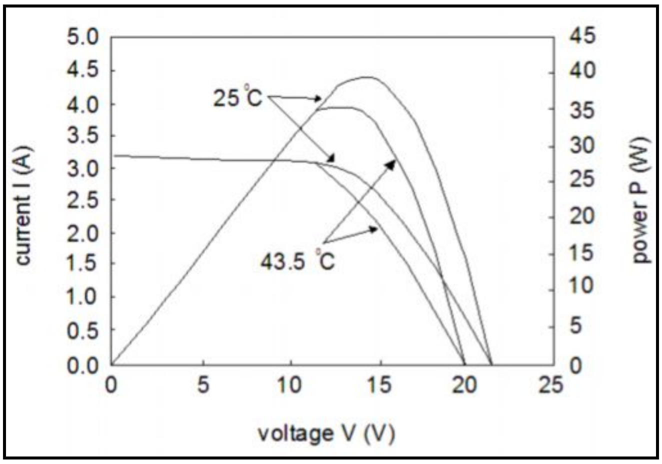

Figure 4. I-V and P-V characteristics of PV cell module

Energy Conversion Efficiency

A PV cell's energy conversion efficiency (η), the percentage of power converted (from absorbed light to electrical energy) and collected, when a PV cell is connected to an electrical circuit. This term is calculated using the ratio of the maximum power point, P_m, divided by the input light irradiance (G, in W/m^2) under standard test conditions and the surface area of the PV cell (A_c in m^2) .

$$\eta = \frac{P_m}{GA_c} \tag{2}$$

The efficiency of energy conversion is still low, thus requiring large areas for sufficient insulation and raising concern about unfavorable ratios of energies required for cell production versus energy collected . In order to increase the energy conversion efficiency of the PV cell by reducing the reflection of incident light, two methods are widely used. One is reduction of the reflection of incident light with an antireflection coating, and the other is optical confinements of incident light with textured surfaces. They showed that the transformation of the wavelength of light could significantly enhance the spectral sensitivity of a silicon photodiode from the deep UV and through most of the visible region.

The PV module has a different spectral response depending on the kind of the module. Therefore, the change of the spectral irradiance influences the PV power generation . The solar spectrum can be approximated by a black body of 5900 K which results in a very broad spectrum ranging from the ultraviolet to the near infrared. A semiconductor, on the other hand can only convert photons with the energy of the band gap with good efficiency.

Photons with lower energy are not absorbed and those with higher energy are reduced to gap energy by thermalization of the photo generated carriers. Therefore, the curve of efficiency versus band gap goes through a maximum as seen from Figure 5 .

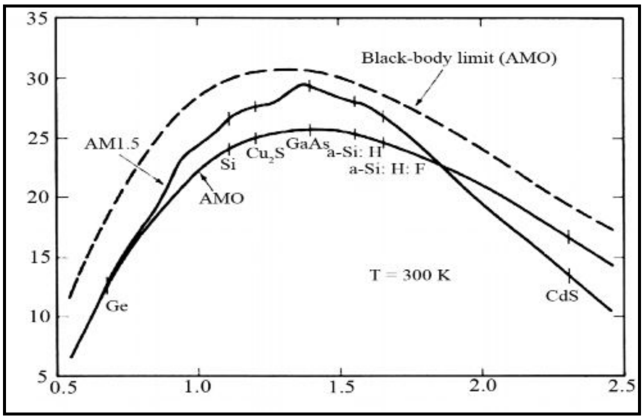

Figure 5. Dependency of the conversion efficiency on the semiconductor band gap

Maximum Power Point Tracking

Currently, the electricity transformation efficiency of the PV cells is very low that reach about 14%. The efficiency of PV cells should be improved with various methods. One of them is maximum power point tracking (MPPT) which is an important method. The MPPT operates with DC to DC high efficiency converter that presents an optimal and suitable output power.

The resulting I-V characteristic is shown in Figure 5. The photo generated current I_L is equal to the current produced by the cell at short circuit (V = 0). The open circuit Voltage V_{OC} (when I = 0) can easily be obtained.

No power is generated under short or open circuit. The maximum power P produced by the conversion device is reached at a point on the characteristic. This is shown graphically in Figure 6 where the position of the MPP represents the largest area of the rectangle shown. One usually defines the fill-factor ff by

$$ff = \frac{P_{\max}}{V_{oc}} = \frac{V_m I_m}{V_{oc} I_L} \qquad (3)$$

where, V_m and I_m are the voltage and current at the MPP.

When the output voltage of the photovoltaic cell array is very low, the output current changes little as the voltage changes, so the PV cell array is similar to the constant current source; when the Voltage is over a critical value and keeps rising, the current will fall sharply, now the PV cell array is similar to the constant voltage source.

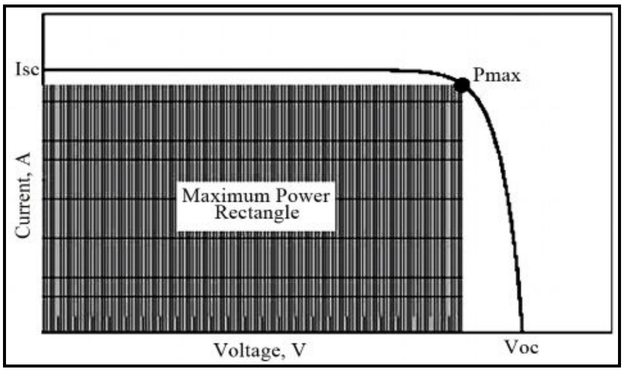

Figure 6. The I-V characteristic of an ideal PV cell

As the output voltage keeps rising, the output power has a maximum power point. The function of the maximum power tracker is to change the equivalent load take by PV cell array, and adjust the working point of the PV cell array, in order that the PV cell array can work on the MPP when the temperature and irradiation are both changing .

Conclusions

This paper examines the parameters thataffects efficiency of PV cells. These are changes in cell temperature, irradiation, operation of MPPT with PV cell and energy conversion efficiency for PV cell. Temperature effects are the result of an inherent characteristic of PV cells. They tend to produce higher voltage as the temperature drops and, conversely, to lose voltage in high temperatures. The energy conversion efficiency is increased by reducing the reflection of incident light. The function of the maximum power tracker is to change the equivalent load take by the PV cell array, and adjust the working point of the array, in order to improve the efficiency. These parameter changes are very critical for PV cell efficiency. The optimum parameters make it possible to get the great benefits of solar power at an affordable cost.

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