American Scientific Research Journal for Engineering, Technology, and Sciences (ASRJETS)

ISSN (Print) 2313-4410, ISSN (Online) 2313-4402

http://asrjetsjournal.org/

Significant Parameters Affecting the Performance of Si Based Solar Cells

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Abstract

Photovoltaic cell has become the most utilized renewable energy resource for the production of power directly from the sun radiations but it has comparatively lower efficiency than other power producing sources and is expensive too. Out of many reasons of lower efficiency of PV cells; some factors are studied in this work i.e. temperature of the module, maximum power point tracking (MPPT) and the efficiency of energy transformation. From the experimentation it was concluded that the rise in the temperature of solar cell, after an optimum level, declines its efficiency by 0.5% for each unit rise in temperature (/°C). So an appropriate method should be adopted to control the temperature of the panel. The energy conversion efficiency was increased with the reduction in the reflection of the incident rays coming from the sun, so that more photons are absorbed by the cell thus achieving increment in energy conversion and MPPT adjust the working point of PV cell under varying intensity of sunrays which is achieved when the tracker changes the solar cell's equivalent load.

Keywords: Module Temperature; Maximum Power point tracking; Energy conversion efficiency.

1. Introduction

In late 1900s, as the journal "**Solar Energy Materials"** was issued, PV cells have been exceptionally enhanced.

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Global industries have been offered ascend by PV technology, these industries can generate numerous Giga watts (GW) of yearly additional nominal capacity [1]. The usage and supply of energy is hindered by many factors including the environmental ones like global warming, polluted air, acid precipitation, damage to forests and harmful substances emitting radioactive rays. Enhanced efficiency in “Energy conservation”, less usage of fossil fuels and increased usage of biodegradable energy resources, combination of these things can help in devising feasible ideas for solving and prevent the above mentioned energy issues.

Power production by solar cell system has proved to be very helpful in solving many ecological problems thus it has gotten extraordinary consideration from researchers [2]. Energy coming from sun is the solar energy and by converting this energy in using PV cell we get DC electricity. Different semiconductor materials are used for making PV cells. The materials which conduct electricity as it is exposed to heat energy or light energy are known as semiconductor materials. And when temperature is low, they act as an insulators. Solar cells transform the light energy to charge transporters once light strikes the cell. The separation of charge carriers that are positive i.e., holes and negative called electrons (produced by photons of sun light) is been done by the Electrical field which is present over the junction. In this manner, when the circuit is closed on an outer load, electric current is deduced or squeezed out. The efficiency of PV cells depends on certain parameters. This paper refers to the analysis of the parameters influencing the productivity of solar cells in accordance with the scientific literature. These parameters include variation in temperature of solar cell and utilizing MPPT along PV cell and energy.

2. Description of Solar cell

It is for the most part characterized as the electric voltage’s presence between two electrodes appended to strong fluid framework after bright light fallen on to this framework. Voltage in this case called photo-voltage is produced over a p-n junction in a semiconductor which is a part of every PV panel. These photovoltaic cells are also named as solar cells. In **Figure 1** a traverse area through a PV cell is appeared. To consume most part of the solar spectrum, semiconductor materials should own this ability. Light absorbed by PV cell depends upon the absorption properties of the material and the area near the surface, more or less, would absorb the light. Electron hole pairs are created at the point when light quanta are integrated and they can achieve the junction if their recombination is counteracted where electric field causes isolation between them [3]. In 1839, a French physicist, Edmund Bequerel, initially noticed the photoelectric phenomenon, he came to know that a little measure of electric current would be created by the specific materials when exposed to Sunlight [4, 5].

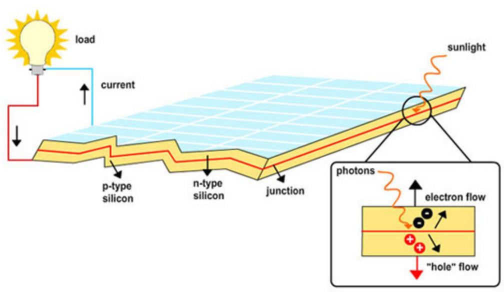

Figure 1: Schematic typical Solar cell

The Sun based impact of semiconductor material is the hypothesis of the PV cell. The process in which energy is absorbed by the semiconductor materials, after which electron hole pair comes in excited state producing electromotive form (emf) which is created by the bombardment of photons on the cell, is called solar effect. With the intensity of sunlight, variations occur in PV cell's current-voltage (IV) characteristics and cell temperature (^oC) is I=f (V, S, t). The equivalence PV cell circuit, as shown in **Figure 2**, which hypothesis of gadgets indicates, when the pure resistance is load [6].

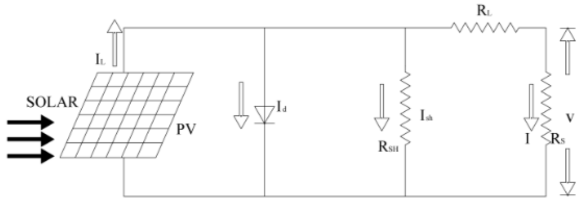

Figure 2: Equivalent circuit of **PV** cell

Solar cell supplied I_L and:

$$I = I_L - I_0[exp\left(\frac{q(V+IR_S)}{AkT}\right) - 1] \quad (1)$$

Where $$I_d = I_0[exp\{q(V + IR_S)/AkT\} - 1] \quad (2)$$

I_d is the junction current of diode.

Here, I is the load current, I_L the PV current, I_0 is the reverse saturation current, q is the electronic charge, k is Boltzmann constant, T is absolute temperature, A is the diode quality factor, R_S is the resistance in series, R_{SH} is the resistance in parallel and V_{oc} is the voltage in an open circuit;

$$V_{OC} = \frac{kT}{q} ln\left(\frac{I_L}{I_0} + 1\right) \approx \frac{kT}{q} ln\left(\frac{I_L}{I_0}\right) \quad (3)$$

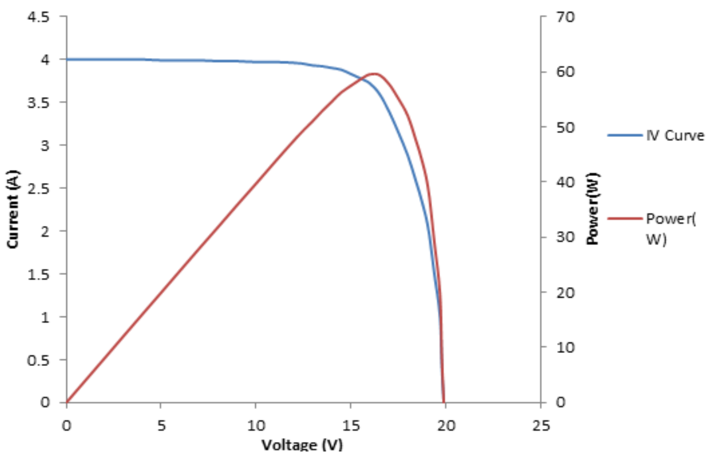

Figure 3: IV and PV curves of a silicon module

A current-voltage curve and PV curve is shown in **Figure 3** which demonstrates the point of maximum power [7].

3. Efficiency factors of PV cell

3.1. Temperature of PV Cell

Due to increment in temperature the intrinsic semi conductor's band width contract and the voltage of open circuit (V_{OC}) diminishes taking after the voltage temperature of p-n junction that dependents on diode component q/kT .In this manner the temperature coefficient of PV cell is negative of V_{OC} (β).In addition the same photocurrent in light is given at the result of lower yield power because of the fact that the lower potential is required to free the charge carriers. Lower hypothetical maximum power $P_{max} = I_{SC} \times V_{OC}$ is a result of decrease in V_{OC} which is found by utilizing the tradition presented with the calculation of fill factor. Same short out current (I_{SC}) is given by the $P_{max}=I_{SC}\times V_{OC}$ [8].As the temperature expands the intrinsic semiconductor's band gap shrivels which means that the more incident energy is assimilated in light of the fact that a more noteworthy rate of occurrence light will have sufficient energy for the electrons of the valence band to travel towards conduction band (producing electrical energy). I_{sc} increments for given shielding, is a result of bigger photocurrent and the temperature coefficient of PV cell is positive of I_{sc} (α) [8].

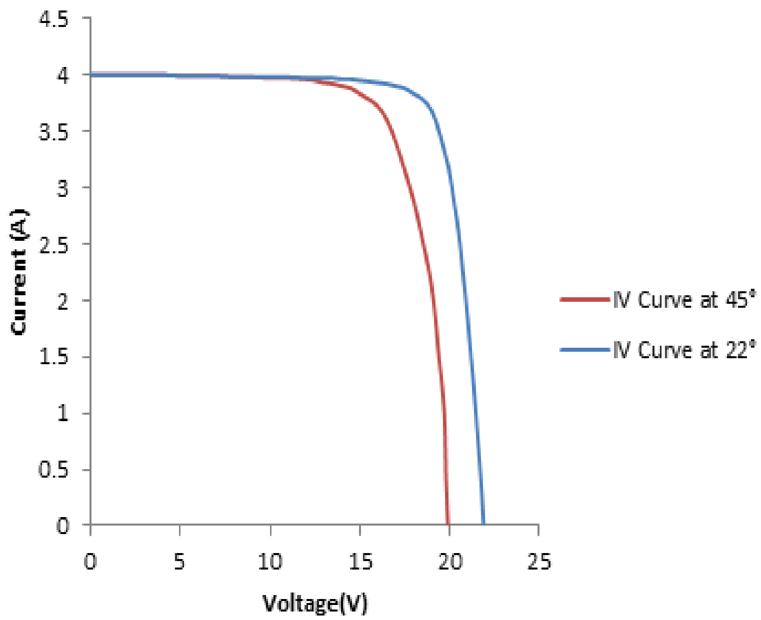

Figure 4: IV characteristic curve of PV module at different Temperatures

IV and power curves with the variation of temperature is been shown in **Figure 4** and **Figure 5** respectively [9]. Crystalline silicon cell-based modules have the temperature impacts that are the aftereffect of intrinsic characteristics. They tend to drop the voltage by creating high voltage, also on the other hand in high temperatures, voltage decrease. Any solar system lower in count should include this change in temperature's impact [10].

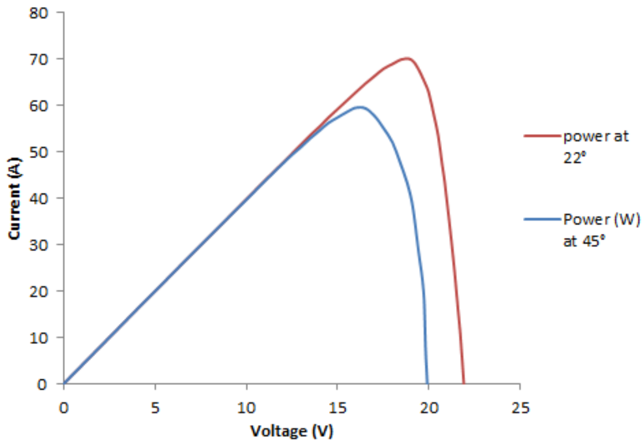

Figure 5: PV curve of solar cell at different temperatures

3.2. Efficiency of Energy Conversion of PV Cell

Efficiency (η, eta) of PV cell to convert energy depends upon output power that been achieved (in the form of percentage) by the taking the energy from photons and converting it into electrical one by connecting it in an electrical circuit and then storing it. This term is computed utilizing the proportion of the positive extreme point of power denoted by "$\mathbf{P_m}$", separated by the product of the surface region (**Ac** in m2) of the solar cell and solar irradiance denoted by "**E"** measured under standardized test conditions (taken as input measured in units watt per square meter, W/m^2). It can be expressed in the form of equation as:

$$\eta = \frac{P_m}{E \times Ac} \tag{4}$$

But the efficiency of PV cell in energy conversion is low which demands two things, first one is the need of extensive areas for adequate insulated protection and the second one is our considerations about inimical proportions of required energies for cell generation in comparison to that of gathered energy(energy that's been collected) [12]. By the reduction in the reflection of incoming solar radiations, the efficiency of the solar cell can be improved in terms of energy conversion and this reduction in light reflection can be achieved by these two strategies:

1. To use a type of optical coating known as AR (antireflection) covering to lessen the deviation of light.
2. To finish the surface of the cell with such texture that confines the incoming light coinciding with it.

It's been demonstrated that the ability to sense the spectrum of light of a SILICONE PHOTO DIODE could be improved fundamentally and expand its range having profound UV at its one end and covering the majority of visible light region of spectrum, this enhancement occurs when the light has any change or transformation in its wave-length [13]. Based on its type solar module has an alternate spectral reaction. Along these lines, any variation in the input irradiance spectrum would impact the production of solar power [14]. The estimation of solar spectrum is being done by using a black body of 5900K which turned out to be an expansive spectrum range with ultraviolet on its on end and near infrared at its other. The function of a semiconductor, then again, is to just convert the energy of small energy packets called photons from the incoming sunlight (having the energy equal to the band gap of semiconductor) into electrical one and achieve great efficiency. Energy of the photons should be equal to that of band gap, in case of high energy photons (having higher energy than that of the required amount) get their energies lessened to that of the gap energy by thermalization and in case of low energy photons, they are of no use as they don't get retained or absorbed. **Figure 6** shows the graph between band gap and efficiency going through maximum [3].

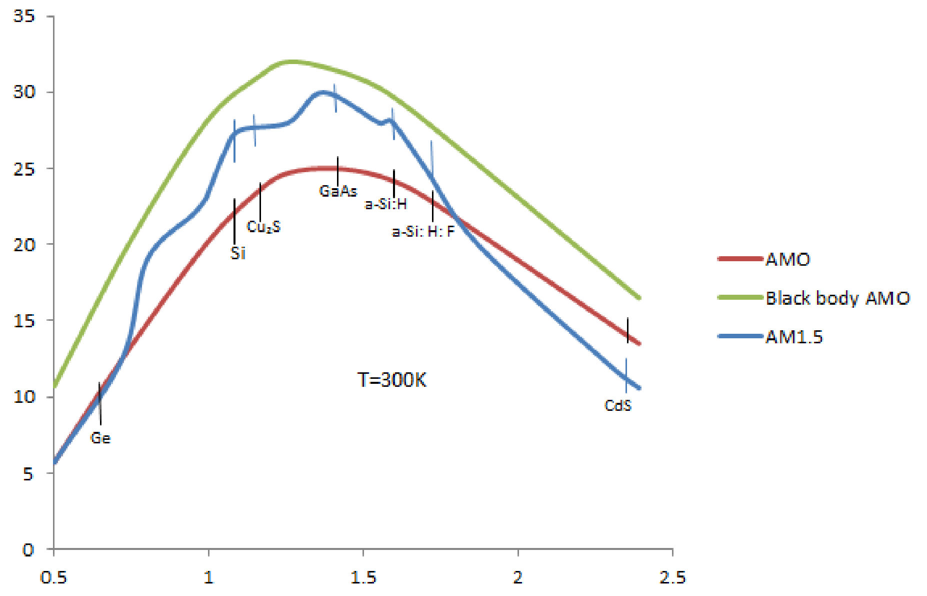

Figure 6: Relation between conversion efficiency and semiconductor band gap

3.3. Tracking of Maximum Power Point (MPPT)

Right now, PV cell efficiency span around **39.9%** which is comparatively low and it ought to be enhanced ought to be enhanced with different strategies. The critical technique which is used for this purpose is MPPT which is maximum power point tracking. The DC to DC high efficiency converter works in the combination with MPPT, representing a favorable yield power. The cell generated current at short circuit (where voltage is zero) is equivalent to that of produced by the photons symbolically represented as I_L. The V_{OC} , is the voltage in an open circuit where current is zero, could be calculated without much of a stretch. In case of open or short circuit no power is obtained [15]. The energy conversion device produce maximum power "P_{max}" shown as a point in the figure of IV characteristic curve and its position speaks to the biggest range of the rectangle appeared. Fill-factor ***"ff"*** can be represented in the form of equation as [15]:

$$ff = \frac{Pmax}{VOC} = \frac{Vm \times Im}{VOC \times Il} \qquad (5)$$

Here, V_m= maximum point voltage

I_m= maximum point current

At the point when there is less yield voltage of array of PV cells, there would be little variation of yield current accordingly to voltage, hence in this case we can say that PV cell is a source that provides constant current. But if the voltage value of a PV cell is over significant value and keeps up its increment while the value of current declining rapidly at the same time then in this case the PV cell would be in resemblance to that of constant voltage source. With the continuous increment in the voltage values there would be a maximum power point in the yield or output power. The maximum power point tracker works in a way that the PV array or solar cell gives maximum output power by working on its maximum power point while the temperature and solar irradiance or intensity of sun radiations are varying which is achieved when the tracker varies the solar cell's equivalent load [6].

4. Conclusion

The elements influencing the efficiency of a PV cell are inspected in this paper. These elements include variation in temperature of cell, utilizing MPPT along PV cell and energy transformation efficiency of the cell. Inherent characteristics of a PV cell results in the form of temperature impacts. When temperature is low, high voltage is produced, and high temperature causes voltage to decline. Energy conversion efficiency can be increased as a result of decreased reflection of incident light. To make variations in PV cells arrangement's taken load is the functionality of MPPT which in result enhance the output power by allowing PV modules to work at their optimum point (maximum power point).For the enhancement of PV cell efficiency it's very important to have positive variations in these factors. It is economical to achieve immense advantages of the electrical power produced by PV modules when these cells work at favorable conditions. The optimum conditions for the working of PV cells that's been deduced from this paper are:

1. To decrease the cell temperature by using some cooling method either by using a Thermoelectric module or floating of panel into a liquid.
2. To use anti-reflection covering to decrease the reflection of sunlight causing increased energy conversion efficiency.
3. MPPT would make the PV cell to work at its maximum power point.

Working of PV cells on the combination of these optimum conditions would cause an increase in its efficiency.

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