International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Effects of Low Photovoltaic Cell Efficiency: Theoretical approach

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Abstract:
A solar cell, also known as a photovoltaic cell, is a device that uses visible light to directly generate energy. They are not very efficient, though. Therefore, the cost of the solar cell is high in comparison to other energy related items. The efficiency of solar cells is influenced by several factors. The key elements influencing solar cell efficiency are discussed in this work. These consequences include energy conversion efficiency, cell temperature and maximum power point tracking.

Keywords: Photovoltaic cell, temperature, cell factor, efficiency, visible and solar cell.

Introduction:

Visible light is converted into direct current (DC) electric power by a solar cell. The amount of solar radiation that strikes the cell, the temperature of the air around the cell, the thickness of the cable that connects the solar panel, the wave length of the falling photons, the shading effect, the direct recombination of holes and electrons, radiation reflection, and the types of solar cell panels that use the least efficient inverters, batteries, and charger controllers are some of the factors that affect the efficiency of the solar cell. Any deviation from the reference level in any of these variables limits the maximum efficiency of the solar photovoltaic cells. The key elements affecting photovoltaic cell efficiency are described in this paper. Enhancements to the above stated elements will increase the solar cells' efficiency.

The cleanest and most abundant energy source is solar power. It generates electricity, heat, and brilliant light for homes and businesses using sunshine. Renewable energy sources must now be used to adequately fulfill future energy needs without endangering the environment by releasing greenhouse gases into the atmosphere, as traditional energy sources like coal and petroleum are running out. Despite the sun's enormous energy potential, drawing electricity from it is mostly challenging because of the cells' declining efficiency. Temperature, wind speed, and irradiance all affect how well a solar cell performs overall. One of the variables that depend on temperature is the open circuit.

Methodology:

1. Solar Cell Characterization:

It is often understood to be the appearance of an electric voltage between two electrodes connected to a solid or liquid system when light is shone on it. A p-n junction in a semiconductor, across which the photovoltaic voltage is developed, is a practical component of all photovoltaic devices. Another name for these gadgets is solar cells. A normal solar cell's cross-section is displayed in A French physicist named Edmund Bequerel discovered that some materials will generate little quantities of electric current

when exposed to light in 1839, which led him to discover the photoelectric effect [4,5]. The solar effect of semiconductor material is the basis for the solar cell theory. The solar effect occurs when solar energy is absorbed by semiconductor material, and the photon-excited electron-hole splits and creates electrically.

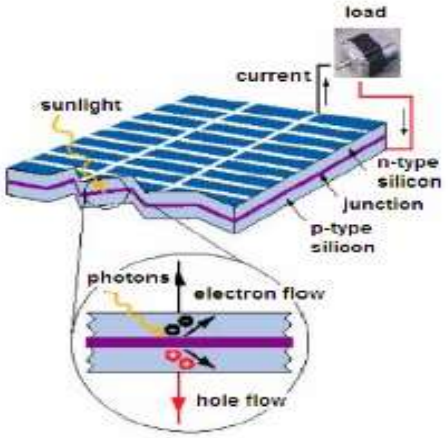

Figure: A schematic of the layers of a typical PV cell

Figure: The equivalent circuit of the solar cell

2. Efficiency Factors for Solar Cells:

1. Temperature

An important factor in solar panel efficiency is temperature. Even though solar panels are made to turn sunlight into power, temperature changes can have an impact on how well they work. The temperature coefficient of solar panels shows how their efficiency drops with increasing temperature. Due to the materials' sensitivity to temperature fluctuations, the majority of solar panels see a decrease in efficiency when the temperature rises. Generally, solar panel efficiency drops by a specific percentage for each degree Celsius that the temperature rises above the typical testing threshold of 25°C. Cooler temperatures increase the efficiency of solar panels. Nevertheless, solar panels absorb heat from their surroundings in addition to sunlight. Because a larger proportion of incident light has sufficient energy to raise charge carriers from the valence band to the conduction band, the intrinsic semiconductor's band gap again narrows with increasing temperature, absorbing more incident energy.

2. Energy Conversion Efficiency:

When a solar cell is connected to an electrical circuit, its energy conversion efficiency is the proportion of power that is gathered and transformed from absorbed light to electrical energy. This term is computed by dividing the maximum power point, Pm, by the surface area of the solar cell (Ac in ^{m2}) and the input light irradiance (E, in W/^{m2}) under normal test circumstances

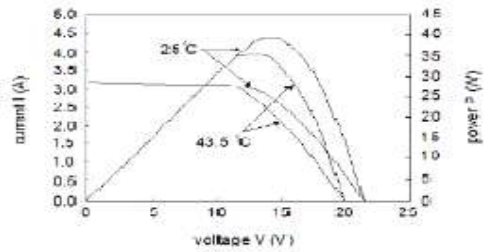

Figure 4. I-V and P-V characteristics of solar cell module

Concerns regarding negative ratios of energy received to energy needed for cell manufacturing are raised by the low energy conversion efficiency, which necessitates vast surfaces for adequate insulation. There are two common techniques for lowering incident light reflection in order to boost the solar cell's energy conversion efficiency. One involves using an antireflection coating to lessen incident light reflection, while the other involves using textured surfaces to optically restrict incident light. They demonstrated how altering the light's wavelength might greatly improve a silicon photodiode's spectral sensitivity from the deep ultraviolet to the majority of the visible spectrum.

Depending on its type, the solar module has a variable spectrum response. As a result, variations in spectrum irradiance have an impact on solar power generation. Conversely, only photons with the energy of the band gap can be efficiently converted by a semiconductor. Higher energy photons are reduced to gap energy by thermalization of the photo generated carriers while lower energy photons are not absorbed. As a result the efficiency versus band gap curve reaches its maximum.

3. Irradiance

1. Direct Connection When exposed to greater levels of irradiance, solar panels produce more electricity. More photons interacting with the photovoltaic cells from more sunlight results in a higher output of electricity
2. Optimal Performance Standard Test Conditions (STC) for irradiance and temperature are $1000W^{m2}$ and 25°C respectively under which solar panels are normally tested and certified. Solar panels operate at their peak efficiency in these perfect circumstances. The actual output of solar panels can be impacted by irradiance levels that fluctuate during the day and throughout the seasons in real-world situations

4. Tracking Maximum Power Point:

At the moment, solar cells' electricity transformation efficiency is about 14%, which is quite low. There are several ways to increase the efficiency of solar cells. Maximum power point tracking is one of them. In an open circuit or short circuit, no power is produced. There is a point on the characteristic where the conversion device's maximum power P is reached. The photovoltaic cell array is similar to a constant current source when the output voltage is very low because the output current changes very little as the voltage changes. When the voltage is over a critical value and continues to rise, the current will drop sharply, and the array is similar to a constant voltage source. The output power has a maximum power point when the output voltage continues to increase. The maximum power tracker's job is to adjust the photovoltaic cell array point's equivalent load.

Conclusion:

This paper discusses the factors affecting solar cell efficiency, including cell temperature maximum pow

er point tracking and energy conversion efficiency and how these factors can be adjusted to improve efficiency for more reliable applications. An intrinsic feature of solar cells is the cause of temperature effects. They often generate more voltage as the temperature drops and lose more when the temperature rises. By lowering incident light reflection, the energy conversion efficiency is raised. The purpose of the maximum power tracker is to modify the solar cell array's working point and the corresponding load it takes in order to increase efficiency. The efficiency of solar cells depends critically on these elements changing. The best conditions allow for the significant advantages of solar power at a much reduced cost.

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