

Check Solar Cells and the Factors Affecting It

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Abstract

Regarding the increasing need for electrical power in today human life on the one hand, and on the other hand the difficulties of using traditional resources, it is inevitable and necessary to replace the sources of this valuable energy. The solar energy is in the center of attentions as it is always available and compatible with the environment. Using solar cells is one way of using solar energy to generate electricity. The study examines the factors affecting solar cells in order to improve the exploitation of solar cells.

Keywords: Solar Cells, Photovoltaic Modeling, Short Circuit Current, Open Circuit Voltage

Introduction:

Increasing need for electrical energy and reducing the sources of producing this energy, mainly fossil fuels, as well as the ecological problems and obstacles of using fossil fuels have led us to use new, renewable, and clean energies like solar energy. Solar cells are semiconductor devices that convert sun light energy into electrical energy. But the devices already has low efficiency and their efficiency is greatly influenced by environmental factors.

1. Review of the literature and relevant background

French physicist Alexandre Edmond Becquerel discovered the photovoltaic impact in 1839 that he observed the battery voltage increased when the silver panels placed under sunlight, (Peter Gyorkeane 2007). In 1877, Adams and Dye, two scientists from the University of Cambridge, explained photovoltaic effect on a solid matter (changes of the electrical properties of selenium under UV light) to Royal Society in a paper (Peter Gyorkeane 2007). In 1904, Halvats discovered a combination of copper and photosensitive copper oxide. Also, Einstein published his paper on the photoelectric effect in this year (Peter Gyorkeane 2007). Russell Ahel invented the first silicon solar cell with an efficiency of less than 1% for the first time in 1941 (Peter Gyorkeane 2007). In 1954 at Bell's Labs, the first practical sample of applicable solar cells with efficiency of around 6 per cent were made by Mr. Bell and his colleagues (FrederickSiv et al 2004). In the same year, strategies were presented by Prince Em.bye to increase efficiency by reducing the resistance of the series (Frederick Siv et al 2004). In 1958, solar cell with low weight, and the efficiency of about 9 percent was designed and built by Hoffman Electronic Company in order to be installed on Vanguard satellite (FrederickSiv et al 2004). In 1980, the first solar cell was designed and built by using organic materials (polymer). It should be noted that after the first Persian Gulf War and the energy crisis, many enterprises, institutions and scientists have worked on the solar cells and the use of different materials to improve efficiency and to increase the effectiveness of this valuable product, additionally, there are scholars who have widely investigated the exploiting conditions of this product in order to increase its lifetime and efficiency. Including the temperature dependence of the open circuit voltage and short circuit current in amorphous silicon solar cells by Mr. Yang et al in 2005, the effect of temperature on the electrical performance of solar cells by E. Apoclacki in 2011, the effect of temperature on sensitive pigmented solar cells by Francisco et al in 2013 and etc.

2. The need for the use of Renewable Energy

According to the recorded data in the recent years, the world's energy needs has significantly increased. In 1960, world energy consumption is equivalent to 3.3 billion tons per year. In 1990, this figure rose to 8.8 billion tons per year, with an average annual growth of 3.3 per cent and in 2020 this figure is expected to rise to 14 billion tons per year (C. Julian Chen, 2012). These figures show that the world's energy consumption is high in this century, so fossil energy sources cannot obviate the world's energy needs for survival, evolution and development, so it is necessary to replace fossil fuels with new energy sources.

3. Solar energy

3.1. The sun

The sun is one of the stars of the Milky Way and only star in the center of the solar system. It can be said that the sun is a perfect sphere made of hot plasma, and there is a strong magnetic field in the center. It has a diameter of nearly 1392000 km that is the main source of light, warmth and life on earth. The diameter of Sun is as nearly 109 times as the diameter of the earth and its mass is as 330 million times as the mass of the earth and it is equal to 1030×10^{24} kg, approximately 99.86% of the total mass of the solar system is from the sun (C. Julian Chen, 2011).

3.2. Solar energy

The sun is one of the main sources of renewable energies that can be used as a useful source of energy supply in most places. According to the latest official estimates, its life is more than 14 billion years. Every second 4.2 million tons of the Sun's mass is converted into energy. Regarding the mass of the sun, which is about as 330 thousand times as the mass of Earth, it can be considered as a great source of energy to next 5 billion year (C. Julian Chen, 2011).

4. The photoelectric effect

It is an electron quantum phenomenon in which an electron is emitted from the matter after absorbing the energy of electromagnetic radiation like X-rays or a visible strip.

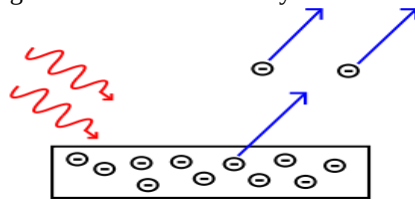


Figure 1: Display photoelectric effect

Photoelectric Effect has greatly help to advance the concept of the dual nature of light, showing the light of waves and particles at different conditions. This phenomenon could not be comprehended by the classic description of light as a wave, because the energy of the emitted electrons did not depend on the intensity of radiation. The classical theory predicted that the electrons could accumulate the received energy over a certain period of time and then it would be emitted (Hassan Katoozian 1384).

5. The electronic model of the solar cell

In fact, the solar cells are P-N connections on a larger scale, which are inactive tools in the absence of light and darkness and behave like a common diode. In this state, a number of electrons are in the conduction band by intrinsic stimulators such as ambient temperature, as they infuse spontaneously into valence band, very little current flows that is known as the reverse saturation current, but regarding the emitted photons, a usable electric current can be taken from them when light radiates to it. Usually a solar cell is shown by an electrical equivalent circuit of a diode.

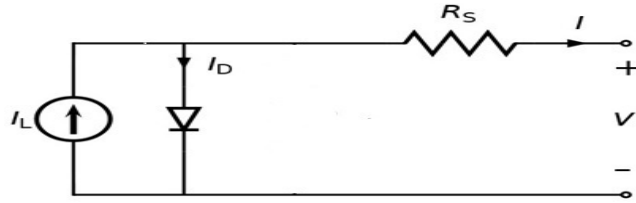


Figure 2: an equivalent circuit or the electrical model of a photovoltaic cell

This model consists of a current source, a diode and series and parallel resistances showing the internal resistance of each cell and communicative resistance between cells. The pure current is equal to the difference between the photocurrent (I_L) and common diode current (I_D), and we have the following equation from the circuit equivalent to the photovoltaic cell.

$$I_D = I_0 \left(\exp\left(\frac{qV}{kT}\right) - 1 \right)$$

$$I = I_L - I_D = I_L - I_0 \left(\exp\left(\frac{q(V + IR_c)}{nkT}\right) - 1 \right)$$

In this equation, n is idealization factor, R_c is internal resistance of the cell, k is Boltzmann's constant, T is the temperature of the cell, q is the electron charge, and v is the voltage created in two ends of the cell. I_0 is the reverse saturation current, and its size depends on the temperature (S.M.Z 1985).

6. Several terms related to solar cells:

6.1. Short-circuit current (I_{sc}): the current for short-circuit output of a solar cell is exposed to sunlight (S.M.Z 1985). In this case, we have:

$$I = I_L - I_D = I_L - I_0 \left(\exp\left(\frac{qV}{nkT_c}\right) - 1 \right), V = 0 \rightarrow I_D \approx 0 \rightarrow I = I_L = I_{sc}$$

6.2. Open circuit voltage (V_{oc}): The output voltage of a solar cell is exposed to sunlight while it is not connected to any charge (S.M.Z 1985). In this case, we have:

$$I = 0 \rightarrow I_L - I_0 \left(\exp\left(\frac{qV}{nkT_c}\right) - 1 \right) = 0 \rightarrow V = V_{oc} \approx \frac{nkT_c}{q} \ln\left(\frac{I_L}{I_0}\right)$$

6.3. Output power (P_{out}): electrical output power of a solar cell is exposed to sunlight (S.M.Z 1985). In this case, we have:

$$P = V I, P_{Max} = V_{Max} I_{Max}, V_{Max} = V_{oc}, I_{Max} = I_{sc} \rightarrow P_{Max} = V_{oc} I_{sc}$$

6.4. Efficiency (η): it is defined as the ratio of output power of solar cell or the delivery electrical power to the input power or radiated solar energy on the solar cell surface (S.M.Z).

$$\eta = \frac{P_{out}}{P_{in}}$$

P_{in} is radiation sun power.

7. The factors effecting on the efficiency of photovoltaic cells.

7.1. Factors affecting the efficiency of photovoltaic cells can be divided into two main categories, structural factors and natural factors or environmental factors.

7.1.1. Structural factors (physical) affecting the efficiency of photovoltaic cells

Structural factors are factors that regarding the material used in construction, construction mechanism, etc. can significantly affect the efficiency of these components material. The most important of which can be noted as follows:

- Lifetime of recombination or minority carrier: constructing the recombination centers during the preparation of materials and construction of cells should be avoided in order to achieve long lives.
- Surface recombination speed: the low speed of surface recombination helps to increase the current and to improve efficiency.
- Impurity density: the impurity density is an important factor in efficacy. It is an important factor in the electrical conductivity and the determination of band gap.
- The type of band gap: that is the band gap is direct or indirect. If the band gap of intended material is direct, the thickness of cells will be smaller as well as examining the efficacy of collection for diffusion length would be effective.
- Mobility: The more mobility is, the more efficiently of collection will be.
- The height of the Schottky barrier: the height of the Schottky barrier is also effective in the efficiency of photovoltaic cells.

- Absorption coefficient: in the cell thickness and determination of the required material is effective.
- The cladding material refractive index of cells: it should be considered to obtain suitable material as an anti-reflective coating.
- Surface properties: it effects on lifetime carriers.
- Series and parallel resistances (that is Ohm connection, series and parallel cause cells).

7.1.2. Natural factors (environmental) impact on the efficiency of photovoltaic cells

The most important environmental factors affecting the efficiency of photovoltaic cells can be noted as follows.

- Temperature
- Angle of installing photovoltaic cells
- surface angle on which photovoltaic cells installed
- the latitude where photovoltaic cells are installed
- changes in solar radiation during the year
- radiation changes during the day
- the concentration of air pollution
- the number of cloudy, rainy days during the year

8. Conclusion

As we know, the traditional sources of energy are finite and coming to end, on the other hand, using them causes a lot of issues and problems in the current quantity. That all of these factors direct us towards the use of clean, accessible, and renewable sources like the sun. Power supply by solar panels is one way of using solar energy. Despite abundant primary resources to produce these devices, these devices are still expensive due to the need for new technologies, and although a lot of work has been done to improve the efficiency of these devices, still it remains so much to achieve optimal efficiency, but less or more these devices can be economically used by proper utilization and right understanding of exploitation environment. For example, if you plan to use this equipment for mass production, you should have comprehensive knowledge about the install location of the horizontal gradient direction, latitude, the ambient temperature of installation, the number of sunny days, the amount of pollutants in the air, and other factors affecting the efficiency. Maximum sunlight can be received by always orderly planning of dusting off the surfaces, and changing the angle of installation, so despite the high installation cost, it is affordable and economical by large-scale use of these devices.

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