Investigation of light intensity and temperature dependency of solar cells electric parameters

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Abstract – In this paper, the performance and overview use of solar cells is expressed. The role of temperature, sunlight intensity on the solar cells electric parameters has been studied. Experimental results the amount of solar cell output parameters variations such as maximum output power, open circuit voltage, short circuit current, and fill factor in terms of temperature and light intensity shows. the most significant is the temperature dependence of the voltage which decreases with increasing temperature. Also output current of solar cells is directly proportional to the light intensity. The best performance of solar panels in sunny and cold day has been suggested. Obtained results could lead to optimal use of solar cells.

Key words – solar cells, temperature, light intensity, open circuit voltage, short sicut current, output power

I. Introduction

Nowadays we get approximately 80% of our energy from non-renewable energy sources, e.g. fossil fuels. Pollutants and greenhouse gases increase when fossil fuels are converted into electricity or heat. Therefore atmosphere is damaged and global warming developed. Fortunately, as the resources are limited, our dependence on fossil is close to its end. Presently, the world annual energy consumption is 10 terawatts (TW) and by 2050 this amount will be about 30 TW. The world will need about 20 TW of non-CO2 energy to stabilize CO2 in the atmosphere by mid-century. The simplest scenario to stabilize CO2 by mid-century is one in which photovoltaics (PV) and other renewable are used for electricity (10 TW), hydrogen for transportation (10 TW), and fossil fuels for residential and industrial heating (10 TW) [1]. Thus, PV systems will a significant role in the world energy supply in the future.

Photovoltaic systems have been installed to provide electricity to the billions of people that do not have access to mains electricity. Power supply to remoter houses or villages, irrigation and water supply are important application of photovoltaics for many years to come. In the last decade, PV solar energy system has shown its huge potential. The amount of installed PV power has rapidly increased. Nowadays, nearly 70 GW of PV power are installed worldwide. Perhaps the most exciting new application has been the integration of solar cells into the roofs and facades of buildings during the last decade.

Solar cells are based on semiconductor materials. semiconductor are materials from either group IV of the periodic table, or from a combination of group III and group V, or of combinations from group II and group VI. The sun radiates in all regions of spectrum, ranging from radio waves to gamma ray. Our eyes are sensitive to wavelengths ranging from 400-700 nm. In this narrow range, called visible range, the sun emits about 45% of total radiated energy. Nearly 80% of cells on the market are crystalline silicon based cells. The characteristics of silicon solar cells are affected on changing the environment. In this paper, some of the environmental effects that degrade the properties of solar cells are discussed. The presence of dust on the surface of the solar cells deteriorates their performance [3]. Concentration of dust and velocity of wind and cloudy days also reduces the current and power of solar cells. Solar cells are exposed to temperatures changing from 5 to 50 ^{0}c. The output parameters such as open circuit voltage, fill factor, short circuit current and efficiency of the solar cells are temperature dependent.

II. Solar cells operation

The photovoltaic (PV) effect is the direct conversion of light into electricity in solar cells. When solar cells are exposed to sunlight, electrons excite from the valence band to the conduction band creating charged particles called holes. In one PV cell, the upper or n-type layer is crystalline silicon doped with phosphorus with 5 valence electrons while the lower or p-type layer is doped with boron, which has 3 valence electrons. By bringing N and P type silicon (semiconductors) together, a p-n junction serves for creating an electric field within the solar cells, which is able to separate electrons and hole and if the incident photon is energetic enough to dislodge a valance electron, the electron will jump to the conduction band and initiate a current coming out from the solar cells through the contacts [2]. Figure 1 shows this process.

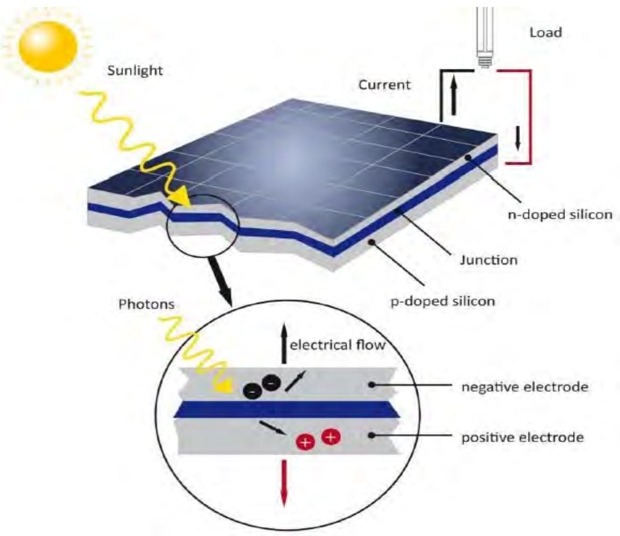

Fig. 1. Solar cells working principle

I-V Characteristics of Solar Cells

The equivalent circuit of the solar cells is combination of a current source (light generated current) and a diode. Solar cells behave similarly to diodes and thus the electrical characteristics of solar cells represented by using current-voltage curves (I-V curve). Figure 2 shows the I-V characteristics and the equivalent circuit of solar cells.

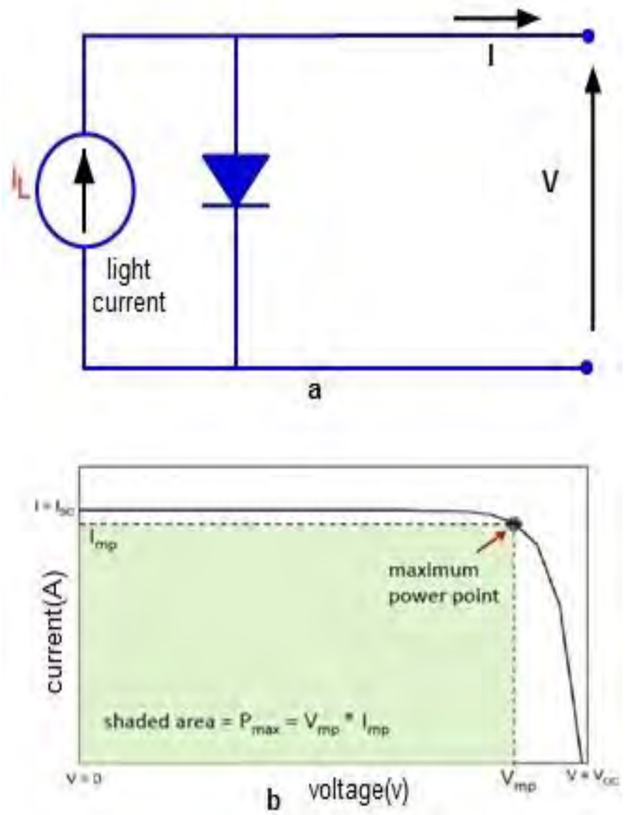

Fig. 2. (a). equivalent circuit,
(b). I-V curve of solar cells

I_{sc} represents the short circuit current, at which the current is at maximum and where voltage is zero. V_{oc} is open circuit voltage, at which the voltage is maximum and where current is zero. The maximum power P_{max} produced by a solar cell is reached when the product I-V is maximum. This can be shown graphically (fig. 2.b) where the maximum output power represents the largest rectangle area under the I-V curve [3].

$$I = I_L - I_0\left(e^{\frac{qv}{nkT}} - 1\right) \quad (1)$$

$$V_{OC} = \frac{nkT}{q}\ln\left(\frac{I_L}{I_0}\right) \quad (2)$$

Where k is the Boltzmann constant, T is the temperature in terms of Kelvin, q is Electric charge, V is output voltage of solar cell, I_L is light generated current, and I_0 is the reverse saturation current.

III. Effect of temperature and light intensity on solar cells

A. Effect of Temperature

The one sample of the commercially solar cells is used for experimental measurements. The solar cell was fabricated mono-crystalline structure with using phosphorus diffusion into a p-type silicon wafer.

Voltage-current (I-V) characteristics and output parameters of solar cell was measured. To obtain of solar cell I-V characteristics, sample was illuminated by reflective lamp with Light intensity equal 1000 W/m2. The measurements were performed at 15, 25, and 50 ^{0}c temperature with highly accurate measuring equipment at the institute of Radiation Problems of Azerbaijan National Academy of science. Voltage-current characteristics of sample have been showed in figure 3. Increases in temperature reduce the band gap of a solar cell, whereby effecting the solar cell output parameters [4, 5].

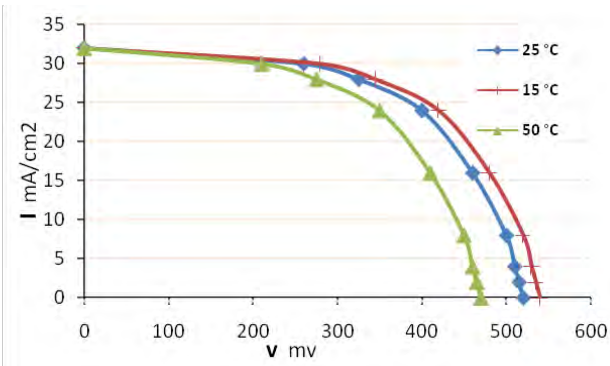

Fig. 3. V-I characteristics of solar
cell affected by temperature

The parameter most affected by temperature is V_{oc}. The open-circuit voltage decreases with temperature due to the temperature dependence of the reverse saturation current.

$$I_0 = qA\frac{Dn_i^{\,2}}{LN_D} \quad (3)$$

In the above equation, the most significant effect is due to the intrinsic carrier concentration (n_i). lower band gaps giving a higher intrinsic carrier concentration so higher temperatures results the higher n_i.

From figure 3, output and fundamental parameters of solar cells like maximum output power (P_m), fill factor (ff), short circuit current (I_{sc}), and open circuit voltage (V_{oc}), can be extracted. Table 1 shows the output parameters of solar cell sample at different temperature.

TABLE 1

OUTPUT PARAMETERS OF SOLAR CELL SAMPLE IN DIFFERENT TEMPERATURE

temperature (^{o}C)	V_{OC} [mv]	I_{SC} [mA/cm^2]	P_m [mw]	FF
15	540	31.99	8.05	0.575
25	520	32	8	0.56
50	470	32.01	7.87	0.545

According to results, for silicon solar cells reduction in the open-circuit voltage is about 2.2 mV/°C. The short-circuit current increases slightly with temperature, for silicon solar cell this is about 0.0006 mA/°C. FF decreases with increasing temperature, for silicon solar cells this is approximated by 0.0015 per centigrade e. Also the effect of temperature on the maximum output power is menus 0.005 mw/°C. In Figure 4, the maximum output power of solar panels in terms of temperature is shown.

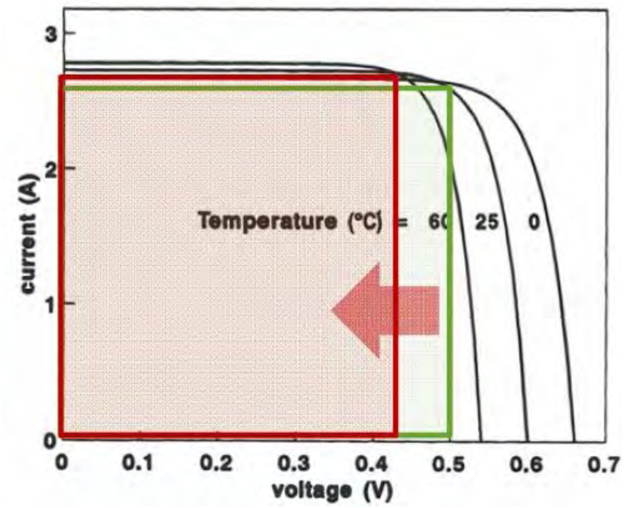

Fig. 4. Temperature dependence of maximum output power

B. Effect of Light Intensity

In the figure 5, the V-I characteristics of previous sample at light intensities 1000, 800, and 500 w/m2 have been shown. As can be seen, V-I characteristics of solar cell vary under different levels of illumination.

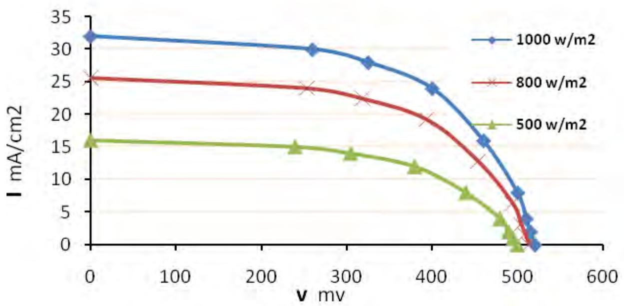

Fig. 5. V-I characteristics of solar cell affected by temperature

Variation of the light intensity incident on a solar cell changes all solar cells parameters. The light generated current is proportional to the flux of photons therefore I_{sc} is directly proportional to the light intensity [6-7], While, open circuit voltage increases logarithmically with light intensity, as shown in the equation below;

$$V'_{OC} = V_{OC} + \frac{nkT}{q} \ln X \quad (4)$$

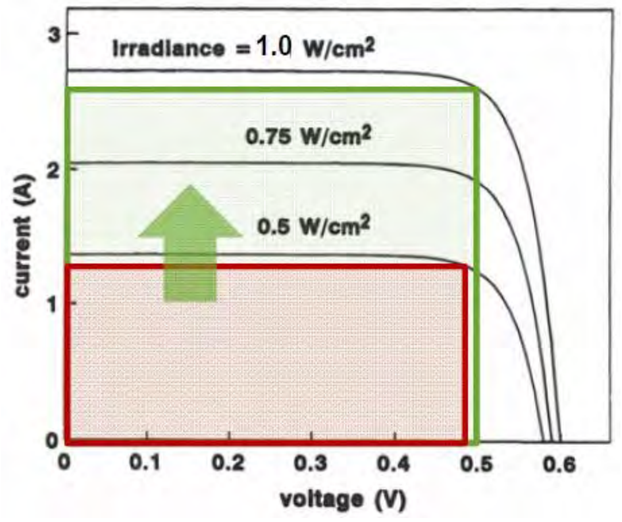

Fig. 6. Light intensity dependence of maximum output power

Where V_{oc} is open circuit voltage at light intensity equal to 1000 w/m2, X is the concentration of sunlight, for example, when solar cells illuminated under 800 w/m2, X equal to 0.8. In Figure 6, the maximum output power of solar panels in terms of light intensity is shown.

Conclusion

Performance of solar cells is dependent on environmental conditions and their output parameters such as output voltage, current, power, and fill factor vary with changes in temperature and light intensity. Experimental results showed that reduction in the open-circuit voltage for silicon solar cells is about 2.2mV/°C. The short-circuit current increases slightly with temperature, for silicon solar cell this is about 0.0006 mA/°C. FF decreases with increasing temperature this is approximated by 0.0015 per centigrade. Also the effect of temperature on the maximum power output is menus 0.005 mw/°C.

According to results, the most significant is the temperature dependence of the voltage which decreases with increasing temperature. output current of solar cells is directly proportional to the light intensity.

The best performance of solar panels in sunny and cold day has been suggested. To increase the efficiency of solar panels, it is better the solar panels are installed on a tracking system that follows the position of the sun for to get a more light intensity.

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