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The Effect of Temperature on Electrical Parameters of Solar Cells

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ABSTRACT: In this paper, the performance and overview use of solar cells is expressed. The role of temperature on the electric parameters of solar cells has been studied. Experimental results shows that all electrical parameters of solar cell such as maximum output power, open circuit voltage, short circuit current, and fill factor Have changed with temperature variation. As well as the amount of changes in these parameters in terms of temperature value have been obtained. According to results, the most significant is the temperature dependence of the voltage which decreases with increasing temperature while the current of cells slightly increases by temperature.

Keywords: maximum output power, open circuit voltage, short circuit current, solar cells, temperature

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.

Solar cell properties can be altered by changes in environmental conditions such as temperature. Typically solar cells are used at the temperature range between 5 to 50 °c .In this paper, temperature dependency of solar cells electric parameters such as open circuit voltage, fill factor, short circuit current and efficiency is investigated.

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

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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.

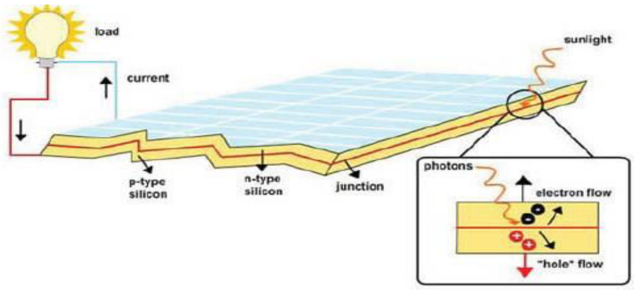

Fig.1 solar cells working principle

A. 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.

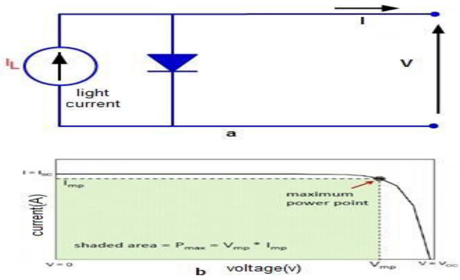

Fig.2 (a). equivalent circuit, (b). I-V curve of solar cells

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. The basic equation for solar cells is follow:

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

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

Where k is the Boltzman 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[3-5].

III. EXPERIMENTAL METHODS

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 to1000 W/m2 (AM 1.5). The measurements were performed at 15, 25, 30, 40, and 50 ^{0}c temperatures by highly accurate measuring equipment at the institute of Radiation Problems of Azerbaijan National Academy of science.

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IV. RESULTS AND DISCUSSION

Voltage-current characteristics of solar cell sample at 15, 25, 30, 40, and 50 ^{0}c temperatures have been shown in figure 3. As can be seen, V-I characteristics of solar cell vary under different temperature. Increases in temperature reduce the band gap of a solar cell, whereby effecting the solar cell electrical parameters [4, 5].

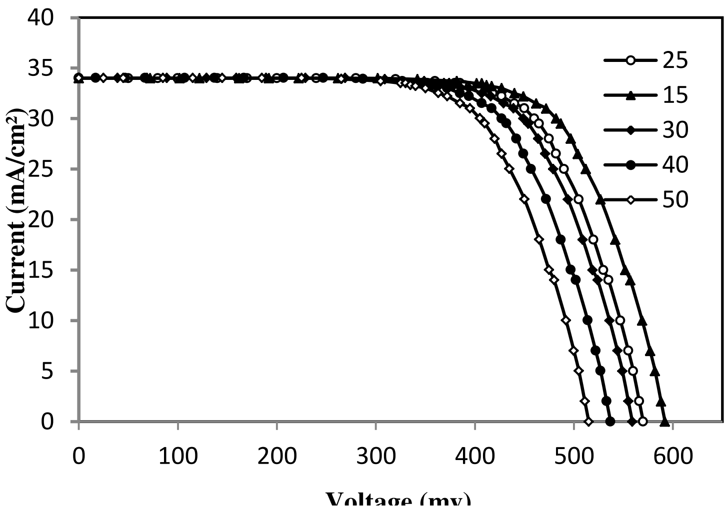

Fig.3 V-I characteristics of solar cell under different temperature

The parameter that most affected by temperature is V_{oc}. According to equation 2, the open-circuit voltage decreases with temperature due to the temperature dependence of the reverse saturation current (I_0).

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

Where:
D is the diffusivity of the minority carrier given;
L is the diffusion length of the minority carrier;
N_D is the doping;
q is the electronic charge;

In the above equation, intrinsic carrier concentration (n_i) has most significant on I_0 due to the lower band gaps giving a higher intrinsic carrier concentration so higher temperatures results the higher n_i.

From figure 3, fundamental parameters of solar cells like open circuit voltage (V_{oc}), short circuit current (I_{sc}), fill factor (ff) and efficiency (η) could be extracted [6, 7]. Table 1 shows the output parameters of solar cell simple under different temperature.

The fill factor (FF) parameter for solar cells can be expressed as

$$FF = \frac{V_{mp}.I_{mp}}{V_{oc}.I_{sc}} \quad (4)$$

Where Voc and Isc are the open circuit voltage and short circuit current, Vmp and Imp are the voltage and the current at a maximum power point respectively.

The efficiency (η) for a solar cell is given by

$$\eta = \frac{V_{oc}I_{sc}FF}{P_{in}} \quad (5)$$

Where, P_{in} is the incident light power

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TABLE1
OUTPUT PARAMETERS OF SOLAR CELL SIMPLE UNDER DIFFERENT TEMPERATURE

Sample	Temperature [^{0}c]	V_{OC} [mv]	I_{SC} [mA/cm^2]	V_{mp} [mv]	I_{mp} [mA/cm^2]	FF	η [%]
Mono-crystalline silicon solar cell	15	570	33.99	450	30.99	0.727	14.63
	25	563	34	443	31	0.72	13.95
	30	559	34	439	31	0.716	13.61
	40	554	34.01	434	31.01	0.714	12.93
	50	549	34.02	429	31.02	0.712	12.25

Notes: The solar cell forms an n-p junction very close to the front surface by diffusing 1-2-µm-thick n-type doping into approximately 0.4-mm-thick p-type silicon.

V. CONCLUSION

The Performance of solar cells is dependent on environmental conditions and their output parameters such as output voltage, current, power, and fill factor vary by temperature. Experimental results showed that the most significant changed by temperature is voltage which decreases with increasing temperature while output current slightly increase by temperature. Reduction in the open-circuit voltage for silicon solar cells is about 2mV/°C. As well as the effect of temperature on the maximum power output is menus 0.005 mw/°C. The best performance of solar panels in sunny and cold day has been suggested.

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BIOGRAPHY

Davud Mostafa Tobnaghi was born in Parsabad moghan, Iran, 1978. He has B.Sc & M.Sc. degree in field of electrical engineering from azad university, Tehran, Iran, 2006. Currently, he is faculty member of department of Electrical engineering of Parsabad mughan branch, azad university, iran. He is Ph.d student in field of solar cells in Azerbaijan National Academy of Science, Baku, Azerbaijan. He has published some paper in field of solar cells and electrical engineering.

Rahim Madatov was born in Shaki, Azerbaijan, 1949. He received M.Sc. and then Ph.D. degree in field of solar cells from Moscow State University, Russian, 1992. He has many published paper about solar cells. Currently he is the academic member of institute of Radiation Problem of Azerbaijan National Academy of Science, Baku, Azerbaijan.