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Simulation models to change the values of solar radiation that affected by weather factors and their impact on the performance of solar cells over Egypt

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Abstract— Egypt has an intention for using further alternative resources of energy due to several economic reasons and more importantly other environmental protection goals. Solar energy is a type of renewable energies and it is most readily available source of energy. It is non polluting and maintenance free. Egypt has great advantageous position, belongs to the global sun-belt. To make best use of the solar PV systems the output is maximized either by mechanically tracking the sun and orienting the panel in such a direction so as to receive the maximum solar irradiance or by electrically tracking the maximum power point under changing the values of solar radiation that affected by weather factors. The overall performance of solar cell varies with varying Irradiance with the change in the time of the day the power received from the Sun by the PV panel changes. Not only solar radiation affects solar cell efficiency as well as corresponding Fill factor also changes. This paper gives an idea about how the solar cell performance changes with the change in above mentioned factors in reality with theoretical modelling and simulation and the result is shown by conducting a number of experiments.

Index Terms— Alternative resources of energy, Solar PV systems, Solar energy, Solar cell, Simulation models, Solar radiation, Weather factors, Egypt.

1 Introduction

Egypt has an intention for using further alternative resources of energy due to several economic reasons and more importantly other environmental protection goals. Solar energy is a type of renewable energies and it is most readily available source of energy. It is non-polluting and maintenance free. Egypt has great advantageous position, belongs to the global sun-belt. The effects of changes of irradiance and temperature on the current-voltage characteristic are shown in Figure 1 [1]. Changes of irradiance affect the short-circuit current proportionally but have little effect on the open-circuit voltage, because of the logarithmic relationship as equation (1).

$$V_{OC} = \ln [(I_G / I_O) + 1] \qquad (1)$$

In concentrated sunlight, the short-circuit current remains proportional to the irradiance up to extremely high levels, provided the temperature is controlled at a constant value. As the open-circuit voltage also increases, albeit only slightly, one would expect the conversion efficiency to rise as the concentration ratio is increased. So it does, up to a point, but the effect of series resistance as equation (2) progressively reduces the fill factor, offsetting the gain in efficiency and limiting the improvement that can be achieved.

$$I_L = I_G - Io \{\exp [q (V + I_L R_S)/A.K.T] - 1\} \qquad (2)$$

Where, The load current I_L is the difference between the generated current I_G and the junction current I_J ($I_L = I_G - I_J$), Io is the dark reverse saturation current of the diode and proportional to exp (-Eg/KT), q is the charge on an electron (1.6×10^{-19} C), k is the Boltzmann constant (1.38×10^{-23} J.K^{-1}), T is the absolute temperature of the cell (K), A is a constant between 1 and 2 (varies with type of cell) and V is the terminal voltage. In the short-circuit condition, when there is no voltage across the terminals of the cell, IJ is very small and practically all of the generated current passes through the external link. The short-circuit current is therefore a useful measure of the generated current and the two terms are normally interchangeable.

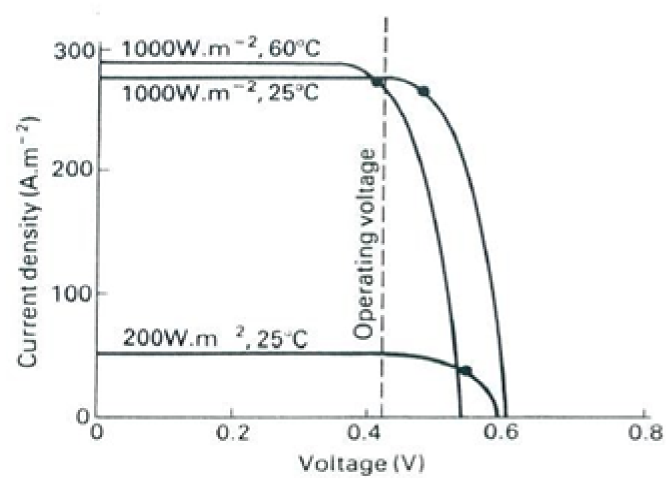

Fig 1 Effects of changes of irradiance and temperature

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The most important parameters that describe the operating condition of a solar cell are the total irradiance, the spectral distribution of the irradiance and the temperature. The solar irradiance at ground level varies in intensity and spectrum due to varying atmospheric parameters such as the temperature, cloud cover, the turbidity, the water vapor content and the zenith angle.

The main purpose of this research is to know how silicon solar cells perform under global solar irradiance variations due to the variation of the temperature, Relative humidity and extraterreial solar radiation using empirical models for three different sites at Egypt.

2 INSTRUMENTS AND PROCEDURE

2.1 Geographical Description

In this work, the measuring stations are located on three different sites in Egypt, Marsa Matrouh (coastal area) , the National Research Institute of Astronomy and Geophysics at Helwan (desert area) and South valley university station at Qena (an urban area).

The National Research Institute of Astronomy and Geophysics at Helwan (latitude 29°520 N and longitude 31°200 E) where it is located on a hilltop site about 30 km south of Cairo in desert surroundings. Marsa Matrouh (latitude 31° 21' 15.6348'' N and longitude 27° 14' 14.3376'' E) is locate at 240 km west of Alexandria and 222 km from Sallum, on the main highway from the Nile Delta to the Libyan border. Another highway leads south from the town, toward the Western Desert and the oases of Siwa and Bahariya. South valley university station at Qena (latitude 26.170 N and longitude 32.70 E) is located in the Upper Egypt about 600 Km south of Cairo and 60 Km north of Luxor and 260 Km west of Red Sea, which is one of the stations guide of the Egyptian Meteorological authority.

2.2 Data collection

Hourly data of global solar radiation and meteorological data were obtained from South valley university station at Qena, The National Research Institute of Astronomy and Geophysics at Helwan and MarsaMatrouh station. Data of radiation were recorded in units of W/m² while the temperature in units of ^{o}C, and relative humidity of %.

2.3 Methodology

In thispaper solar radiation has been calculated using various parameters by an empirical model. We calculate the daily and monthly average global solar radiation from three important parameters through year 2012. The parameters are Temperature, Relative humidity and Extraterrestrial solar radiation at three different sites in Egypt, Marsa-Matrouh (coastal area), Qena (urban area) and Helwan (desert area). For this aim, Multiple Linear Regression model was applied as follow.

$$V = a + b X + c Y + d Z$$

Where a, b, c and d are regression coefficients to be determined by regression analysis and depend on the location. Hence, the term V in the equation represent global solar radiation while the terms X, Y and Z stand for the extraterrestrial-radiation, temperature, and relative humidity respectively.

Multicrystalline silicon is an important and dominant material in photovoltaics due to its low production costs and readily abundance. Therefore, it is currently the dominant solar cell material for commercial applications [2], [3], [4], [5].

Our solar module consists of four similar back contacts multicrystalline silicon large area of 21 cm × 21 cm connected in series. The module is installed in a tilted position at the optimum tilt angle of the location of study [6], in the outdoor. Each cell current is collected by the fine finger grid which is led to the back side through 25 holes. On the back side there are 25 soldering pads for each polarity. The outdoor module electrical performance is studied by measuring both short circuit current and open circuit voltage in the tilted position. Multicrystalline silicon solar module in the outdoor located at optimum tilt angle with the radiation meter is shown in Figure (2-a) and the block diagram of the measuring system using current shunt is illustrated in Figure (2-b) [7].

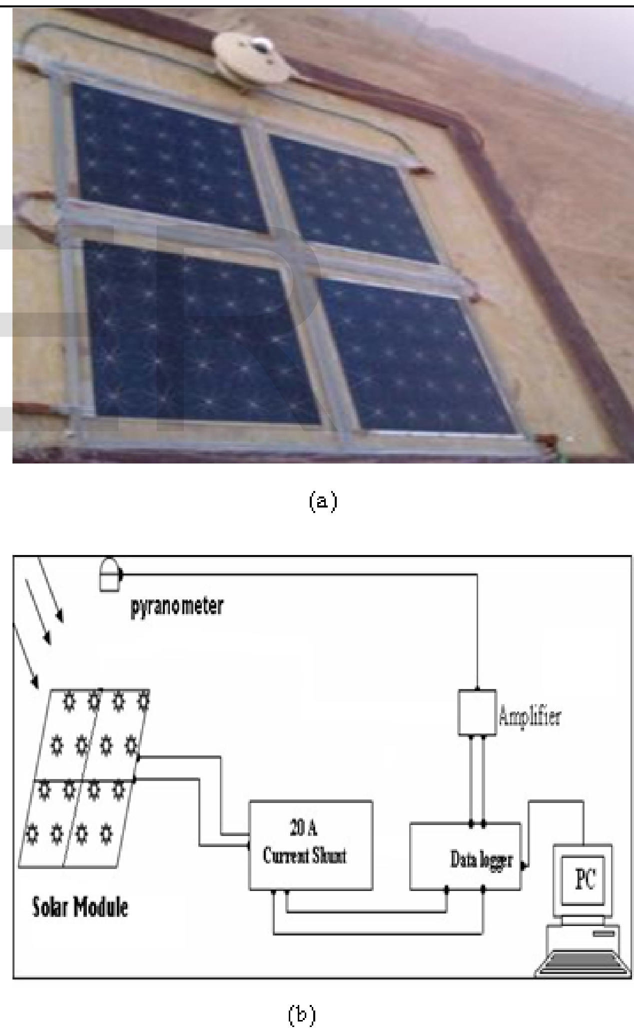

Fig. 2: (a) Multicrystalline silicon solar module in the outdoor located at optimum tilt angle with the radiation meter; (b) Block Diagram of the measuringsystem using the current shunt.

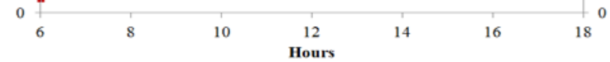
Fig. 3 The output current versus time under the global solar radiation effecting for monocrystalline silicon cell.

3 RESULTS AND DISCUSSIONS

3.1 Measured parameters trends.

To make best use of the solar PV systems the output is maximized either by mechanically tracking the sun and orienting the panel in such a direction so as to receive the maximum solar irradiance or by electrically tracking the maximum power point under changing the values of solar radiation that affected by weather factors. The overall performance of solar cell varies with varying Irradiance with the change in the time of the day the power received from the Sun by the PV panel changes. Not only solar radiation affect solar cell efficiency as well as corresponding Fill factor also changes. This section is specified for the measurements of the silicon solar cells performance with the change in above mentioned factors in reality with theoretical modeling and simulation.

The measurements of the output current of monocrystalline silicon solar cells versus the global solar radiation against the time is plotted in Figure 3 and the resultant power of the cell versus the output voltage against the time is illustrated in Figure 4 while Figure 5 illustrate the variation of the resultant power of the solar cell with the current during the day time.

From figure 3 we find that the output current is proportional to the irradiance, and will therefore vary during the day in the same manner. where the radiation and the output current reach to their maximum values of 536 W/m2 and 8.48 A respectively at the noon time.

While figure 4 shows the variation of resultant power of the cell versus the output voltage during the day time, we notice that the voltage will therefore vary less than the current. Their values vary between 2 to 2.17 volt and the resultant power of the cell has the maximum value of 18.1 W also at the noon time. It is obvious that that the power obtained per meter square increases with increasing the output current as seen Figure 5.

3.2 Current and Radiation models:

Figure 6 shows that the output current increases with increasing the global solar radiation. There are Three different models (Linear, Quadratic polynomial and Power relations) were used to calculate the output current from global solar radiation as follow:

Linear	I = a + b G	(3)
Quadratic polynomial	I = a + b G + c G2	(4)
Power	I = a Gb	(5)

Where a, b and c and are empirical constants. The correlation (R^2) of the three empirical models are illustrated in Figure 7 for Linear, Figure 8 for Quadratic polynomial and Figure 9 for Power relation. According to these figures, in view of the high values of the correlation coefficients, all these formulae can compute the output current of the solar cell with a good accuracy but the quadratic polynomial equation is the best. In this work the quadratic polynomial equation (4) is used to calculate output current of the solar cell. Detailed analysis of these three models are given using SPSS program and summarized in Table 1 for linear relation model and Table 2 for quadratic polynomial relation model and Table 3 for the power relation model.

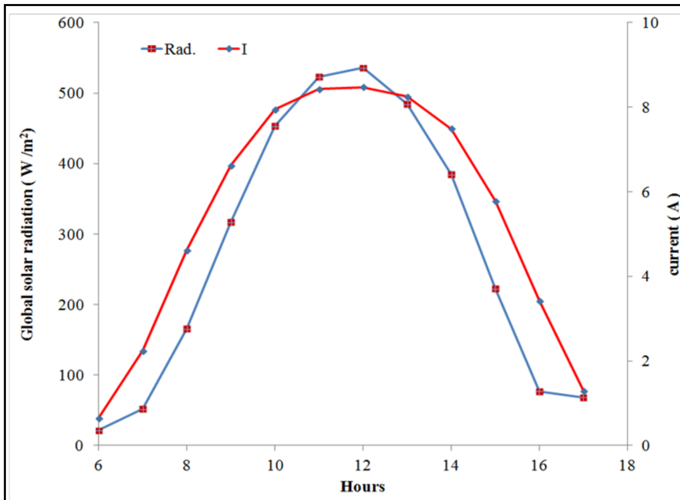

Fig. 3 The output current versus time under the global solar radiation effecting for monocrystalline silicon cell.

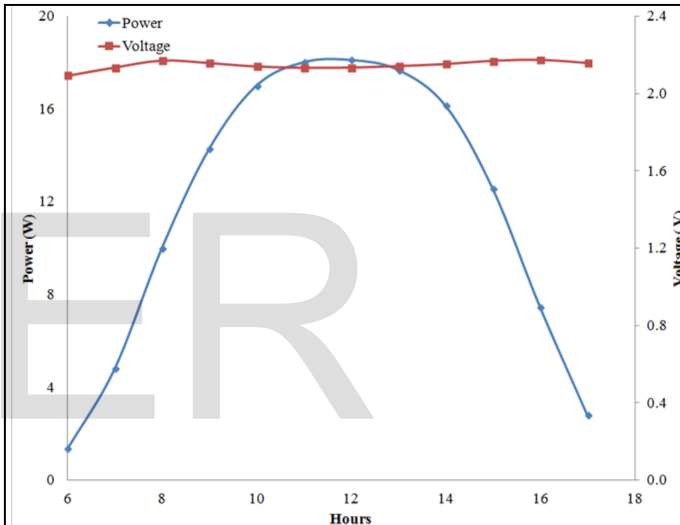

Fig. 4 The resultant power of the cell versus the output voltage against the time

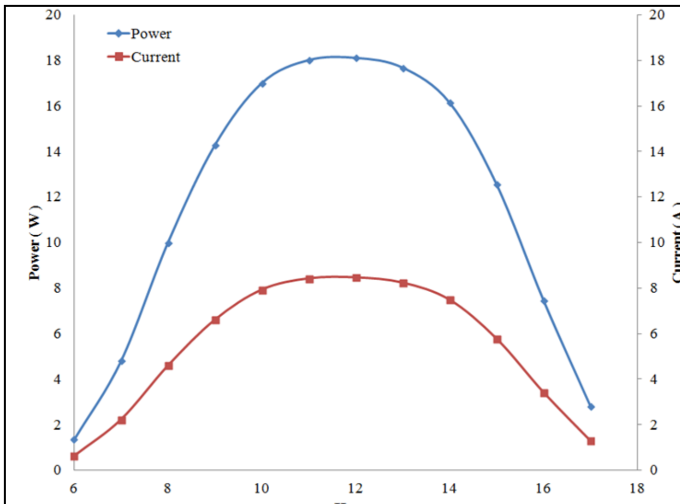

Fig. 5 The resultant power of the cell and the output current against the time.

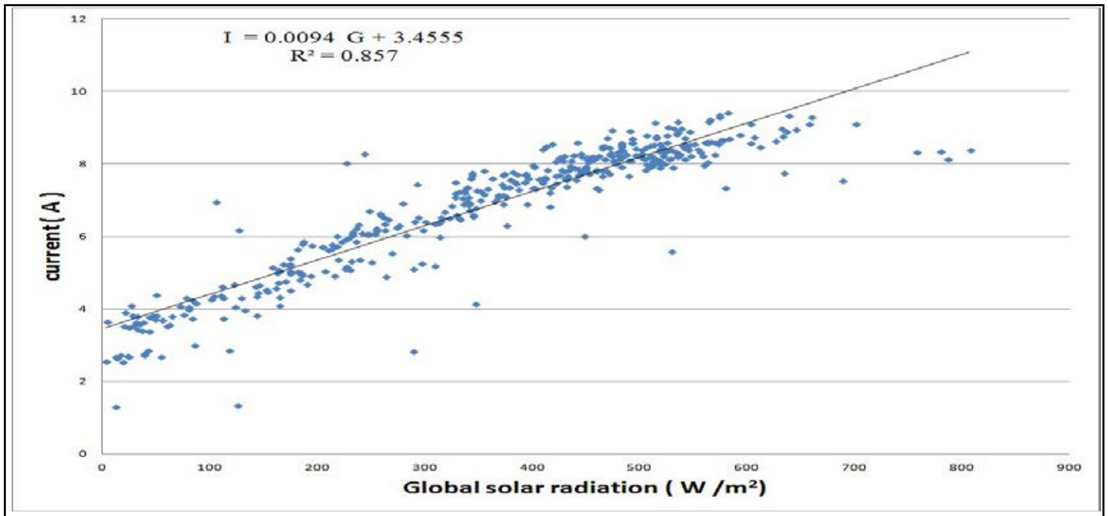

Fig. 7 Linear Variation of output current and incident radiation.

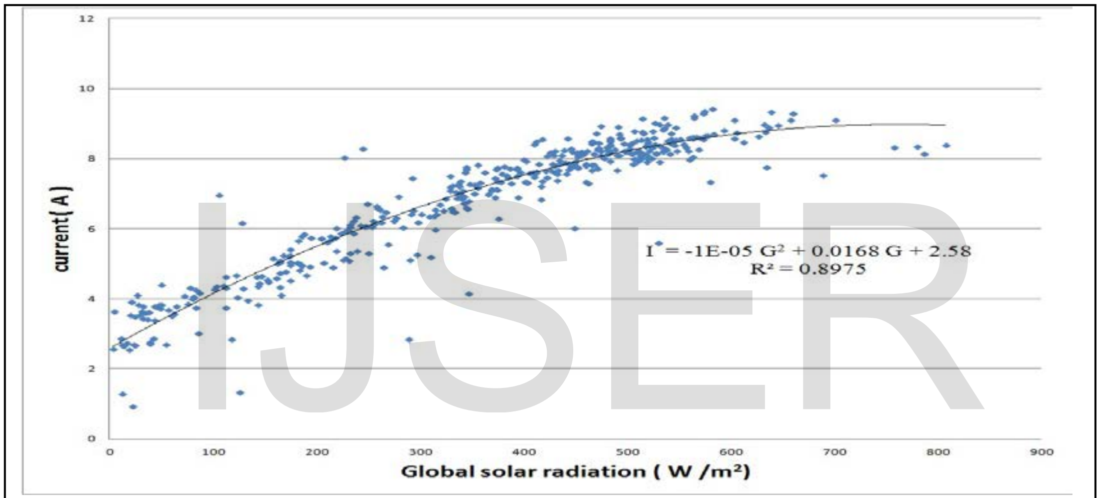

Fig. 8 quadratic polynomial Variation of output current and incident radiation.

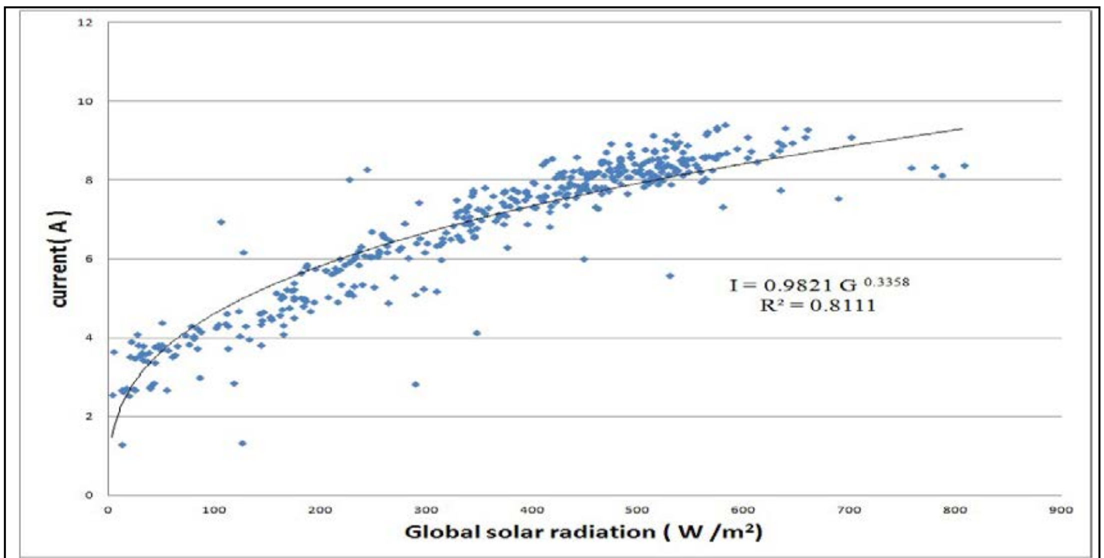

Fig. 9 Power Variation of output current and incident radiation.

Table 1: Statistical parameters for equation 3.

Model Summary					
Model	R	R Square	Adjusted R Square	F	Sig.
1	.925	.857	.857	2436.055	.000
Coefficients					
model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	3.45	0.077		44.631	.000
G	0.01	0.000	0.925	49.356	.000

Table 2: Statistical parameters for equation 4.

Model Summary					
Model	R	R Square	Adjusted R Square	F	Sig.
1	.947	.897	.897	1777.479	.000
Coefficients					
model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	2.577	0.093		27.739	.000
G	0.017	0.001	1.630	28.347	.000
G**2	-1.099E-5	0.000	-0.733	-12.756	.000

Table 3: Statistical parameters for equation 5.

Model Summary					
Model	R	R Square	Adjusted R Square	F	Sig.
1	0.896	.811	.811	1674.270	.000
Coefficients					
model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	0.982	0.045		20.840	.000
Ln (G)	0.344	0.008	0.896	40.918	.000

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