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Effect of Angle Orientation of Flat Mirror Concentrator on Solar Panel System Output

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Abstract: *In this research two flat glass mirrors is used as concentrator of solar panel system. The mirrors increase's the concentration of sun light ray on the solar module. Anew model of solar panel system is designed by mean of software Zemax in order to find best possible inclination angle of the concentrator that improves the performance of the solar panel. So the efficiency is 59.5% for designed system with inclination angle 60° of the concentrator. Then a practical design for the solar panel system with concentrators is established. The outdoor measurements for the practical design indicated that the output power and efficiency is increasing by increasing the inclination angle of the concentrator and reaches its maximum value at 60^o at different times of the date 5-2-2014. Also the results showed that the maximum value of efficiency is 0.85 at 11 o'clock at 60^o. While the maximum value of the output power is 72.8w at 12 o'clock of the same day.*

***Keywords**: solar panel, concentrators, flat mirror concentrator. .*

I. Introduction

The need for energy from renewable sources has become a pressing issue in recent years. Renewable energy is the essential development for the secure future. Among various natural resources, solar energy is a radiant energy that produced by the sun. The solar energy that is incident on the earth surface can be converted directly to electricity by photovoltaic (PV) or into thermal energy by solar collectors.

A PV module consists of individual solar cells electrically connected together to increase their power output. They are packaged so that they are protected from the environment and so that the user is protected from electrical shock. However, several aspects of PV module design which may reduce either the power output of the module or its lifetime need to be identified. A final structural component of the module is the edging or framing of the module. A conventional PV module frame is typically made of aluminum. The frame structure should be free of projections which could result in the lodgment of water, dust or other matter [1].

The using of solar energy in Iraq faces real problems which indicated as accumulation of dust on solar panels and the high ambient temperatures. The accumulation comes from the increasing of activity of dust storm after the year of 2000 due to the global climate change, enlarging the desertification and the shortage in water resources. The input optical power, that reaches to the solar cells, decrease with period time and reached to about 50% for one month under the effect of natural deposition of dust [1].

Over the last few decades, there has been an increasing effort from governments, industry and academic institutions to find useful way to improve the solar cell or photovoltaic cell efficiency. One of these ways is concentrator photovoltaic systems, which use a limited number of small, specialized, efficient solar cells and concentrating optics to increase the intensity of sunlight striking the cells such as [2-6**].**

II. Solar Module Characteristic

A solar Module is a set of solar cells connected in series. Solar panels are referred to by the industry as solar cell modules or PV modules. Module or panel is flat arrangement of series connected silicon solar cells. There are generally 30 to 36 solar cells per module. The modules can be wired as series or parallel arrays to produce higher voltage and currents as illustrated in Figure (1).

Figure (1): The image of solar array [7].

The equivalent circuit of a solar Moduleis the sum of the solar cells equivalent circuits connected in series. These circuits are shown in Figure (2). With sunlight on the Module and no external load, all the current from the source is through the series diodes, but the output voltage of the Module is the sum of the voltages across the diodes [8].

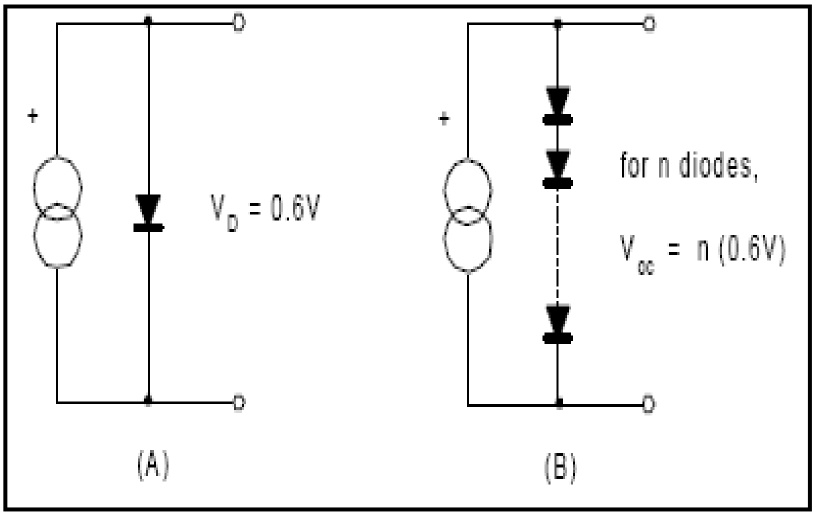


Figure (2)**:** (A) Solar cell equivalent circuit and (B) solar module equivalent circuit [9].

The open circuit voltage (V_{OC}) is the maximum voltage available from a solar cell, and this occurs at zero current. The open circuit voltage corresponds to the amount of forward bias on the solar cell due to the bias of the solar cell junction with the light – generated current. The V_{OC} is shown on the IV curve in Figure (2) [9,10] .

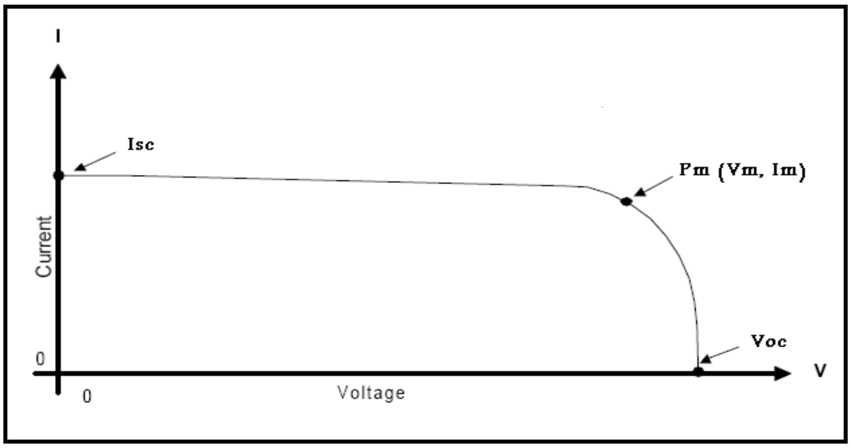


Figure (3): Solar Module Characteristic Curve under Standard Test Conditions (STC) [9].

The V_{OC} can be calculated from the relation [8]:

$$V_{oc} = \frac{kT}{q} ln\left(\frac{I_L}{I_o} + 1\right) \quad \text{(1)}$$

Where kT/q, is the equivalent thermal voltage, I_L is photocurrent (light generated current) and I_o is reverse saturation current [11].

With sunlight on the Module and a short- circuit load, the entire current source is through the short. This is the solar Module short-circuit current from the current source is through the short which is denoted (I_{sc}) [8]. I_{sc} occurs on a point of the curve where the voltage is zero as shown in Figure (2). At this point, the power output of the solar cell is zero. The series resistance (R_{si}) of the solar cell contributes highly on power loss as the current reaches its maximum limits. Ideally the I_{sc} is equal to the light generated current (I_L) which is countered by all wavelengths less than (λ_g), numerically expressed as follows [12]:

$$I_L = \int_0^{\lambda g} \varphi(\lambda)\psi(\lambda)d\lambda \quad \text{(2)}$$

Where(λ_g) is the maximum wavelength causing generation of carriers, $\psi(\lambda)$ is the external quantum efficiency which represents the ratio of Photo- generated current to the number of incident photons and $\varphi(\lambda)$ is the incident photon flux. The I_{SC} is due to the generation and collection of light – generated carriers. For an ideal solar cell at most moderate resistive loss mechanisms , the I_{SC} maximum when the V_{OC} is zero and the light generated current are identical .Therefore, the (Isc) is the largest current which may be drawn from the solar cell. It depends on a number of factors like the area of the solar cell, the number of photons, the spectrum of the incident light, the optical properties (absorption and reflection) of the solar cell, the collection probability of the solar cell, which depends chiefly on the surface passivation and the minority carrier lifetime in the base [10].

The point (P_m) on the knee of the curve, marks the value of current and voltage at which the module delivers the greatest power for a given level of sunlight. Under standard test conditions (Irradiance 1000 W/m², air mass (AM=1.5 at θ= 60°), angle of incidence (AOI=0°) and temperature (25°C), the maximum current (I_m) and maximum voltage (V_m) at maximum output power (P_m) defined the rated power of the module. The other characteristics of solar module are conversion efficiency (η) and Fill factor (FF). The conversion efficiency is defined as the ratio of output electrical power to incident optical power.
The efficiencies equation can be written as [13].

$$\eta = \frac{P_m}{P_{in}} \times 100\% = \frac{I_m V_m}{P_{in}} \times 100\% \quad \text{(3)}$$

$$P_m = V_{OC}\, I_{SC}\, FF \quad \text{(4)}$$

$$P_{in} = I \times A \quad \text{(5)}$$

Where P_{in} is the incident power of the sun and can be calculated from multiplying the (I) solar irradiance in (W/m²) by the area of the solar cell or module (A) in square meter unit.
Since the (Isc) is proportional to the irradiation, it is important to measure the incident irradiation during the measurements. The irradiation can be measured using a pyranometer or solar meter device. The surface of the solar meter is mounted normal to the sun [14].

And FF is the ratio of the maximum output power to the product $I_{SC}.V_{OC}$ [13]

$$FF = \frac{I_m V_m}{I_{SC} V_{OC}} \quad \ldots\ldots (6)$$

If all the solar cells in a module have identical electrical characteristics, and they all experience the same insolation and temperature, then all the cells will be operating at exactly the same current and voltage. In this case, the IV curve of the PV module has the same shape as that of the individual cells, except that the voltage and current are increased [1]. The overall IV curve of a set of identical connected solar cells is shown Figure (4) [1].

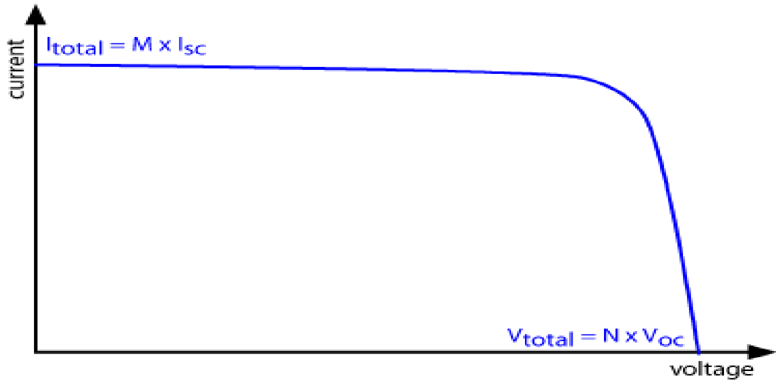


Figure (4): I-V curve for *N* cells in series × *M* cells in parallel [1].

The equation for the circuit is [1]:

$$I_T = M \cdot I_L - I_o \left[exp\left(\frac{q\frac{V_T}{N}}{nkT} \right) - 1 \right] \quad \ldots\ldots (7)$$

where:
N is the number of cells in series.
M is the number of cells in parallel.
I_T is the total current from the circuit.
V_T is the total voltage from the circuit.
I_o is the saturation current from a single solar cell.
I_L is the short-circuit current from a single solar cell.
n is the ideality factor of a single solar cell.
q, *k*, and *T* are constants

The total current is simply the current of an individual cell multiplied by the number of cells in parallel. Such that:

$I_{SC\ total} = I_{SC} \times M$ ……………………………………………… (8)
$I_{MP\ total} = I_{MP} \times M$ ……………………………………………… (9)
$V_{OC\ total} = V_{OC} \times N$ ……………………………………………… (10)
$V_{MP\ total} = V_{MP} \times N$ ……………………………………………… (11)

III. Solar Panel Model Design Using Software Zemax

A theoretical model has been designed by using software Zemax to determine the best angle of inclination of the flat mirror concentrator (FMC) which is fixed on the solar panel module and then its inclination angle is changed from 10^o to 90^o by steps of 10^o in order to get optimum angle that gives higher efficiency. The input parameters in Zemax window includes:

1-The object distances (for the sun i.e infinity distance).
2- The radius of curvature of the concentrator mirror (∞ i.e plane).
3-The coated material of the concentrator (Ag), (refraction index of the reflection coating).
4-The inclination angle between the concentrator mirror and the solar panel.
5- The dimension of solar concentrator and solar panel (length 146 cm – width 68cm).
6- The wavelength of the incident light (UV wavelength 0-380) nm, (visible wavelength380-780) nm.
7- Entrance pupil diameter of the system 150cm.
8- Filed of view of the total system 0.25
9- The angle of the incident light with the system 45°.

Table (1) shows the change in the inclination angles of the concentrator with the solar panel using the Zemax and the values of η at each angle.

Table (1): The efficiency of the each angle by Zemax software

	x-position	z-position	tilt y(θ)	Efficiency η %
mir 1	610	-60	10	28%
mir2	-610	-60	-10	
mir 1	600	-120	20	28%
mir2	-600	-120	-20	
mir 1	590	-180	30	28%
mir2	-590	-180	-30	
mir 1	550	-220	40	29.40%
mir2	-550	-220	-40	
mir 1	500	-240	50	44.30%
mir2	-500	-240	-50	
mir 1	480	-280	60	59.50%
mir2	-480	-280	-60	
mir 1	440	-320	70	52%
mir2	-440	-320	-70	
mir 1	370	-350	80	38%
mir2	-370	-350	-80	
mir 1	320	-360	90	28%
mir2	-320	-360	-90	

Table (1) shows that the maximum efficiency is 59.90% at angle 60^{o}.

The output result after optimaization include:
1-The irradiance distribution on the solar panel.
2-The collection efficiency by the solar panel.

IV. Practical design

The designed system (Figure 5) consist of two concentrator (flat mirrors that made of glass) with length 146 cm and width 68 cm for each one of the mirrors enclosed by aluminum frame and connected with a solar panel tilted at 45° from the horizon in the direction of the sun to concentrate light on the solar panel in order to make the sun light covering a largest area of it. The length of the solar panel is 147cm, width 68cm and consists of 36 solar cell peak power 110W ,peak voltage 17.5V, peak current 6.29Amp, V_{OC} = 22 V and the I_{SC} =6.85 Amp ,weight 12.5 kg, maximum system voltage 1000V ,temperature T=25ºC, Solar radiation 1000W/m².

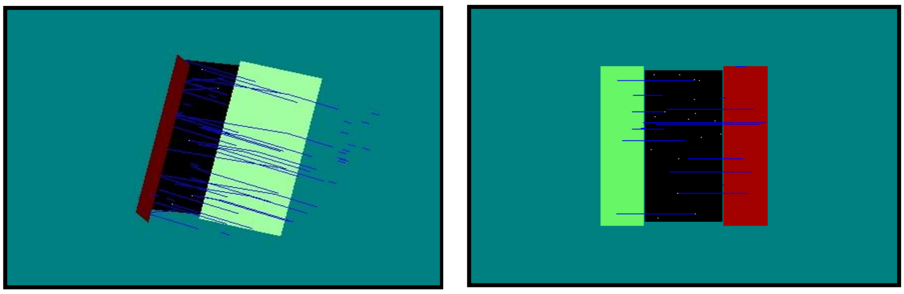
(a) (b)

Figure (5): (a) The static solar panel with inclination angle 45 ° with horizon
(b) The concentrator inclined with angle 60°.

The inclination angle of the concentrator on the solar panel has changed with different values from 30°to 80° with step by 5° during every 55 minutes once for several times a day.

V. Results

The Figure (6-a -b) show the designed system with inclination angle 60° at which the efficiency is (59.5%) that constructed from software Zemax. The two plates (red and green), represents the concentrator and the black one represent the solar panel. The blue lines represent the incident light. The intensity of solar radiation on the solar panel system is shown in figure (7). While figure (8) show the spectrum of the illumination intensity of the solar panel system at inclination angle 60°.



(b) (a)

Figure (6-a-b): Designed solar panel system using software Zemax with a FM concentrator.

Figure (7): The intensity of solar radiation on the solar panel system.

Figure (8): The spectrum of the illumination intensity of the solar panel system at 60°

The out dower measurements of I_{SC} , V_{OC} , P , T , FF and η for the solar panel system at different times of the date 5-2-2015 are illustrated in tables (2), (3), (4) and (5).

The results showed the optimum angle that gives the best efficiency for the designed system is 60^o and this is in a good agreement with the result that is constructed from software Zemax.

Table (2): The characteristics for the static solar panel at different inclination angles of the concentrator at 9 am on 5-2-2014.

Angle (degree)	V_{OC} (V)	I_{SC} (amp)	P (W)	T (h.m)	FF	η %	Solar radiation Intensity (W/cm²)
80	20.9	1.1	22.9	9	1.6	0.42	150
75	20.9	1.4	29.2	9.2	1.2	0.54	150
70	20.9	1.5	31.3	9.5	1.1	0.57	150
65	20.8	1.6	33.2	9.8	1.1	0.61	150
60	20.7	1.8	37.2	9.11	1	0.68	150
55	20.7	1.7	35.1	9.13	1.0	0.65	150
50	20.7	1.6	33.1	9.16	1.1	0.61	150
45	20.6	1.4	28.8	9.19	1.2	0.53	150
40	20.8	1.2	24.9	9.22	1.4	0.46	150
35	20.8	1	20.8	9.24	1.7	0.38	150
30	20.8	1	20.8	9.27	1.7	0.38	150

Table (3): The characteristics for the static solar panel at different inclination angles of the concentrator at 10 am on 5-2-2014.

Angle (degree)	V_{OC} (V)	I_{SC} (amp)	P (W)	T (h.m)	FF	η %	Solar radiation Intensity (W/cm²)
80	20.8	0.83	17.2	10	2.5	0.31	150
75	20.8	1	20.8	10.2	2.1	0.38	150
70	21	1.1	23.1	10.4	1.9	0.42	150
65	21	1.5	31.5	10.6	1.4	0.58	150
60	21.1	2	44.3	10.9	1	0.82	150
55	21	2	42	10.11	1.0	0.77	150
50	20.9	2	41.8	10.14	1.0	0.77	150
45	20.8	1.9	39.5	10.17	1.1	0.73	150
40	20.7	1.7	35.1	10.19	1.2	0.65	150
35	20.8	1.4	29.1	10.22	1.5	0.53	150
30	20.8	1	20.8	10.25	2.1	0.38	150

Table (4): The characteristics for the static solar panel at different inclination angles of the concentrator at 11 am on 5-2-2014 .

Angle (degree)	V_{OC} (V)	I_{SC} (amp)	P (W)	T (h.m)	FF	η %	Solar radiation Intensity (W/cm²)
80	20.7	1.7	35.1	11	1.7	0.48	200
75	20.8	1.9	39.5	11.4	1.5	0.54	200
70	20.7	2.1	43.4	11.6	1.4	0.60	200
65	20.6	2.4	49.4	11.8	1.2	0.68	200
60	20.6	3	61.8	11.11	1	0.85	200
55	20.6	0.9	59.7	11.13	1.0	0.82	200
50	20.7	2.9	60	11.15	1.0	0.83	200
45	20.7	2.8	57.9	11.17	1.0	0.80	200
40	20.6	2.8	57.6	11.19	1.0	0.80	200
35	20.6	2.7	55.6	11.21	1.1	0.77	200
30	20.6	2.7	55.6	1123	1.1	0.77	200

Table (5): The characteristics for the static solar panel at different inclination angles of the concentrator at 12 on 5-2-2014.

Angle (degree)	V_{OC} (V)	I_{SC} (amp)	P (W)	T (h.m)	FF	η %	Solar radiation Intensity (W/cm²)
80	20.6	2.5	51.5	12	1.4	0.57	250
75	20.7	2.7	55.8	12.2	1.3	0.62	250
70	20.9	3	62.7	12.5	1.1	0.69	250
65	20.8	3.3	68.6	12.7	1.0	0.76	250
60	20.8	3.5	72.8	12.11	1	0.80	250
55	20.7	3.5	72.4	12.13	1.0	0.80	250
50	20.7	3.7	68.3	12.16	1.0	0.75	250
45	20.8	3.2	66.5	12.19	1.0	0.73	250
40	20.7	3.2	66.2	12.21	1.0	0.73	250
35	20.7	3	62.1	12.24	1.1	0.69	250
30	20.6	3	61.8	12.27	1.1	0.68	250

VI. Conclusion

The results showed that the output power of the designed system and its efficiency is increasing by increasing the inclination angle of the concentrator. It reaches its maximum value at 60^o at different times of the date 5-2-2014. Also the results showed that the maximum value of efficiency is 0.85 at 11 o'clock with inclination angle 60^o of the concentrating mirror with solar panel. While the maximum value of the output power is 72.8w at 12 o'clock of the same day.

References:

[1]. Ahmed F. Atwan, Naseer K. Kasim, Ala'a H. Shnieshil, "PV Solar Panel Performance under the Effect of Dust in Baghdad", RONCHI, Italy, N.3, PP.379-388, 2012.

[2]. Karvelas .E, Papadopoulos A., Dousis D., Markopoulos Y. P., Mathioulakis E., Panaras G., Vamvakas V. and Davazoglou D., " Mirrors Based on Total Reflection for Concentration PV Panels", 4th International Conference on Solar Concentrators for the Generation of Electricity or Hydrogen, pp 165-168, Attiki, Greece, 2002.

[3]. Maria B., "Optical Efficiency of Low – Concentrating Solar Energy Systems With Parabolic Reflectors", 2004.

[4]. David N. W., "Improved boost mirror for low concentration photovoltaic solar power systems", Silver Spring, Maryland, e-mail: davidnelsonwells@yahoo.com, 2009.

[5]. Alaa M. A., "Solar Energy the Suitable Energy Alternative for Iraq Beyond Oil", International Conference on Petroleum and Sustainable Development IPCBEE , IACSIT Press, Singapore, vol. 26 , 2011.

[6]. Abdilmoutalib H. A. Al- Shareefy, "Study The Performance of Fresnel – Based Photovoltaic Concentrator", MSc Thesis, Al-Mustansiriyah University, Education College, Physics Dep., [2012].

[7]. Science and technology ministry, 2008.

[8]. Horowitz, Paul and Hill, "The Art of Electronics", 2nd Edition", University of Cambridge, Winfield, P. 932-933, 1989.

[9]. Chesney Mc. P. J., "Solar Electric Power for Instruments at Remote Sites", University of Washington Geophysics Program, Science for a Changing World (USGS), Open File Report 00-128, 2000.

[10]. Sinton R.A., Cuevas A., "Contactless determination of current – voltage characteristics and minority – carrier lifetimes in semiconductors from quasi – steady – state photoconductance data ", journal of Applied physics Letters, vol. 69, p.p. 2510-2512, 1996.

[11]. Edward S. Y., "Microelectronic Devices", McGraw-Hill, 1988.

[12]. Hovel H. J., "Semiconductor and Semimetals, Solar Cells", Vol.11, Academic Press, 1975.

[13]. Ashok S. and Pand K. P., "Photovoltaic Measurements ", Solar Cells, Vol. 14, 1985.

[14]. Nilsson, J., "Optical Design and characterization of Solar Concentrators for photovoltaics", Division of Energy and Building Design Department of architecture and built Environment Lund University, p.p. 43-53, 2005.