The effect of Tilt Angle, Surface Azimuth and Mirror in Solar Cell Panel Output in Baghdad.

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Abstract:

In this research (100* 40* 4 cm) solar cell panel was used in Baghdad at autumn season (2010), to get best solar cell panel angles experimentally, and then a mirror (40*50 cm) is use to concentrate incident sunlight intensity on a panel. At first case we get (Tilt angle γ_P =60°and Surface Azimuth angle α_P =36°E) is the best angles and other case, we add a mirror at angle = 120° at bottom of panel, then we get output power (27.48watt) is bigger than without using a mirror (25.16watt). We can benefit from these cases in variety applications.

Key words: Solar cell, Tilt Angle, Surface Azimuth, plane Mirror

Introduction:

Visible light can be converted directly to electricity by photovoltaic cell or solar cell. Most photovoltaic cells are made from a crystalline substance called silicon, one of the Earth's most common materials. Solar cells are typically made by slicing a large crystal of silicon into wafers and putting two separate wafers with different electrical properties together, along with wires to enable electrons to travel between layers [1].When sunlight strikes the solar cell, electrons naturally travel from one layer to the other through the wire because of different properties of the two silicon wafers.

Solar cells are composed of various semiconducting materials. Semiconductors are materials, which become electrically conductive when supplied with light or heat, but which operate as insulators at low temperatures. Over 95% of all the solar cells produced worldwide are composed of the semiconductor material Silicon (Si). As the second most abundant element in earth`s crust, silicon has the advantage, of being available in sufficient quantities, and additionally processing the material does not burden the environment. To produce a solar cell, the semiconductor is contaminated or "doped". "Doping" is the intentional introduction of chemical elements, with which one can obtain a surplus of either positive charge carriers (p-conducting semiconductor layer) or negative charge carriers (n-conducting semiconductor layer) from the semiconductor material. If two differently contaminated semiconductor layers are combined, then a so-called p-n-junction results on the boundary of the layers.[2]

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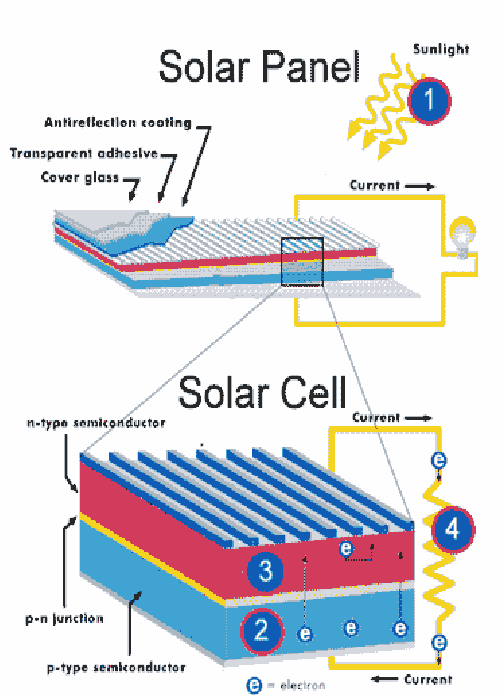

Fig.1 model of a crystalline solar cell panel. [2]

At this junction, an interior electric field is built up which leads to the separation of the charge carriers that are released by light. Through metal contacts, an electric charge can be tapped. If the outer circuit is closed, meaning a consumer is connected, then direct current flows.
Silicon cells are approximately 10 cm by 10 cm large (recently also 15 cm by 15 cm). A transparent anti-reflection film protects the cell and decreases reflective loss on the cell surface.
A PV module (panel) made up of a group of solar cells assembled in a commercial unit, ready for installation. Voltage for a solar cell is about 0.6 volt and the maximum short circuit is over 3 A. As the voltage is insufficient for many loads, the solar cells have to be connected in series. One PV panel has typically 36 cells and panels are connected in series as a string and depending on the application also in parallel to the array. Thus a solar generator consists of several strings (panels in series) connected in parallel.

A PV panel normally has a specified power rating and given a performance warranty by the manufacturer for 20 to 30 years.

Characteristics of a Solar Cell

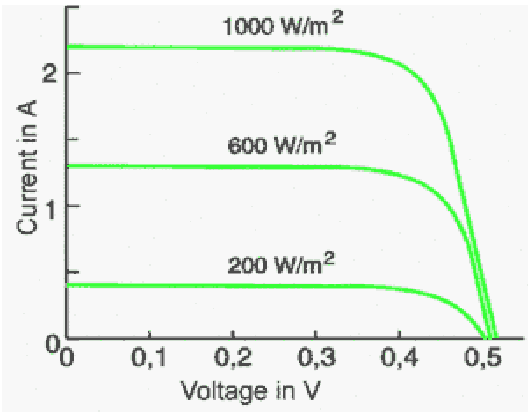

Fig.2 Current-Voltage line of a Si-solar cell.[2]

The usable voltage from solar cells depends on the semiconductor material. In silicon it amounts to approximately 0.5 V. Terminal voltage is only weakly dependent on light radiation, while the current intensity increases with higher luminosity.[3] A 100 cm² silicon cell, for example, reaches a maximum current intensity of approximately 2 A when radiated by 1000 W/m²as shown in Fig-3-. The output (product of electricity and voltage) of a solar cell is temperature dependent. Higher cell temperatures lead to lower output, and hence to lower efficiency. The level of efficiency indicates how much of the radiated quantity of light is converted into useable electrical energy. [4]

Optimal solar panel angles

This solar angle calculator tells you the optimum angle to get the best out of your system. To get the best out of your photovoltaic panels, you need to angle them towards the sun. The optimum angle varies throughout the year, depending on the seasons and your location and this calculator shows the difference in sun height on a month-by-month basis. Of course, the sun is continually moving throughout the day and to get the very best from your photovoltaic system we would need to angle your panels to track the sun minute by minute.[5] We can buy an automated solar tracker to do this. Unfortunately, the expense of a tracker means that for most applications they are more expensive than buying additional panels to compensate. The amount of power a solar tracker uses in order to track the sun also negates much of its benefits. The sun is at its highest at solar noon each day (this occurs exactly half way between sunrise and sunset) and this calculator shows the angle at that time of day. At solar noon, the irradiance from the sun is at its very high and we can generate the most power. In the northern hemisphere, the sun is due south at solar noon.[6] Therefore, to get the very best out of our photovoltaic panels, we would typically face them due south at the optimum angle so that the panel is receiving as much sunlight as possible at this time. The correct angle for your project will depend very much as to when we want to get the best out of your photovoltaic system. If we want to get the best performance during the summer months, you would angle your photovoltaic panels according to the height of the sun in the sky during these months. If we want to improve your winter performance, we would angle your photovoltaic panels towards the winter months in order to get the best performance at that time of year. If we have the opportunity to adjust the angle of your photovoltaic panels throughout the year, we will benefit from having the optimum performance from your solar system all of the time. This solar angle calculator allows us to calculate the optimum angle on a month-by-month basis. Surface tilt (γ_P) and surface azimuth (α_p) are illustrate in figure -3-.where (α_p) is represent the angle between a north line and the projection of the site to the sun line on the horizontal plane, as we shown in fig-6-. [7]

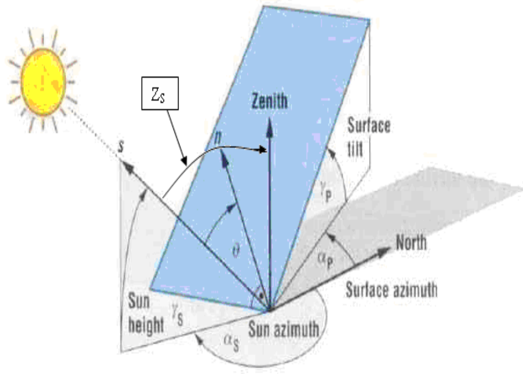

Fig.3 PV panels position. [7]

in order to simplify calculation, it will be assumed that the earth is fixed and the sun's apparent motion is described in coordinate system fixed to the earth with the origin being at the site of interest it allows for the position of the sun to be described at any time by the altitude and azimuth angles. The altitude angle A, is the angle between the central rays from the sun and the horizontal plane, and can be calculated by use of the following equation:

$$\sin(A) = \sin(L)\sin(\delta_S) + \cos(L)\cos(\delta_S)\cos(h_S) \quad \ldots(1)$$

where L is the latitude of site, δ_S is the declination angle of sun and h_S is the hour angle. The angle between the site to the sun line and the vertical at site is the zenith angle, Z_S , which is found by subtracting the altitude angle from ninety degrees as in the following equation [7]:

$$Z_S = 90 - A \quad \ldots.. (2)$$

The monthly averaged solar altitude and zenith angles for Baghdad

(Latitude: 33, Longitude: 44) are listed in table (1).

Table (1) monthly averages solar angles at mid noon (degrees) [5].

Mon.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
A	36.2	44.6	55.1	66.7	75.8	80	78.2	70.7	60	48.5	38.8	34.1
Z_S	53.8	45.4	34.9	23.3	14.2	10	11.8	19.8	30	41.5	51.2	55.9

The azimuth angle of Sun AZ_S, is the angle between a south line and the projection of the site to the sun line on the horizontal plane. For the azimuth angle, the sign convention used is positive if west of south and negative if east of south. The azimuth angle is found by using the following equation. [3]

$$\cos(AZ_S) = \sin(A)\sin(L) - \sin(\delta_S) / \cos(A)\cos(L) \quad \ldots(3)$$

<u>The plane mirror</u>: A **plane mirror** is a **planar** reflecting surface, on which specular (regular) reflection is observed. A **virtual image** is formed by a plane mirror. The rays reflecting from the mirror appear to have originated from the location of the virtual image. On a diagram, a virtual image is usually depicted by a broken (dotted) arrow. A **real image** (formed by other kinds of optical devices) can be focused on a screen, whereas a virtual image can not. On a diagram, a real image is usually depicted by a solid arrow. The image in a plane mirror is located as far behind the mirror as the object forming it is in front of the mirror. It is the same size as the object. (magnification = +1)

$$\text{magnification } (m) = \frac{\text{height of image}}{\text{height of object}} = H_i / H_o = -d_i / d_o \quad \ldots (4)$$

Where d_i is the distance from the image to the mirror, and d_o is the distance from the object to the mirror. *(Note that some resources use the symbols **p** and **q** instead of d_o and d_i respectively)*The mirror equation, for a plane mirror, $R = \infty$ *and* $f = \infty$ *, so*

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{\infty} = 0, \quad d_i = -d_o \text{ and } m = +1 \quad \ldots (5)$$

R is the radius of curvature and ***f*** is the focal length.

<u>Experimental work</u> :

In this research fixed system was used, which contain (panel of solar cell (AL-MANSOUR manufactory made in Iraq , two multimeter (MULTIMETER M 2006 AVO made in w.germany and DT830 B DIGITAL MULTIMETER made in china), RESISTANCE = 4.7 ohm , CAMPASS, plane mirror (40 * 50 cm) and metric ruler.

Fig.4 Experimental system

At first three angles of surface azimuth wer examined (α_p =20W, 25E, 70E), and then four angles of Surface tilt are examine (γ_P = 15, 30, 45 and 60 degree).to concentrate the amount of light falling on the surface of panel plane mirror (40 * 50 cm) was used, after choosing optimal solar panel angles.

Result and Discussion:

SURFACE AZIMUTH

At first we need to find azimuth surface angle, to do this (I-V) characteristic was found for three angles (9°W,36°E,81°E degree) then the relation between power and time at (8:00am to 4:30 pm) is find which is illustrate in figure (6). In this figure we get (α_p =36°E) is the optimal angle because its represent approximately stable power region at several hours approximately .

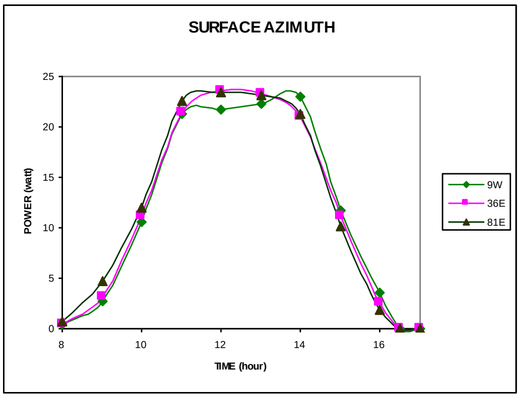

Fig.5 Surface azimuth

SURFACE TILT

After limit of optimal surface azimuth,four angles of surface tilt (15°, 30°,45°,60°) were chosen and meager current and voltage with time for each angle, Then the relation between power and time (8:00am-4:30pm) is draw.

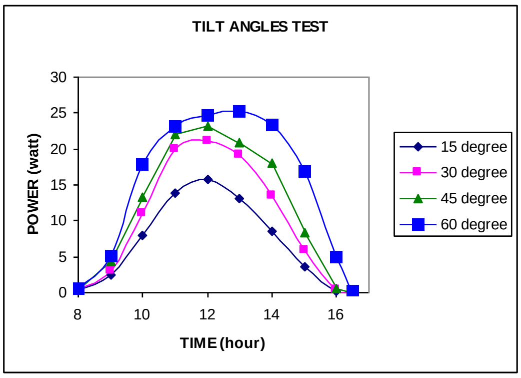

Fig.6 Surface tilt

From figure (6) and table.2 we see that the surface tilt **(60°)** is the optimal angle, where we note the increasing of power along work time, and we reach to the maximum value of power **(25.16 watt)** at mid noon.

Table (2) the relation between (γ_P) and power at mid noon .

AT MID NOON				
TILT ANGLE	15°	30°	45°	60°
POWER(watt)	13.184	19.22	20.94	25.16

Solar cell and mirrors

To find the effect of mirror on output power of panel, two angle (90° and 120°) were chosen between panel and plane mirror, from figure (8) we see that at angle=**120°,** we reach to high value of power **(27.48 watt)** at mid noon, and from same figure we note the increasing of power along the time (8 o'clock a:m to 4:30 o'clock p:m). If we use a big mirror we can get upper power, but it difficult mater, because, that it may be broken, specially, if we put system at height place.

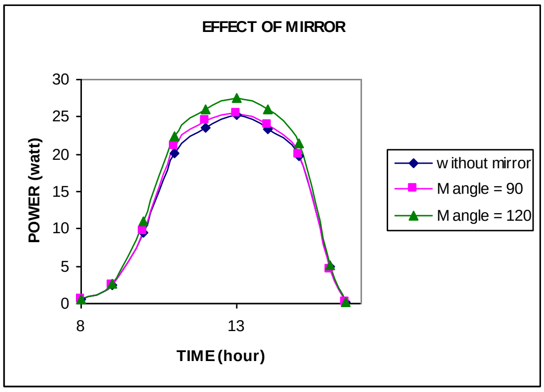

Fig.7 Effect of plane mirror

Conclusion :

The best **Surface azimuth** angle is 36°E.
The optimal **Surface tilt** angle is 60°.
We can increase **Output power** if we use a Mirror with angle 120° at bottom of solar cell panel.

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تأثير زاوية الميل وزاوية السمت السطحية والمرايا في القدرة الخارجة للوح الخلايا الشمسية في بغداد

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الخلاصة

في هذا البحث تم استخدام لوح خلايا شمسية (4*40*100 سم) في مدينة بغداد في فصل الخريف (2010)م ,وذلك للحصول على أفضل زوايا للوح الخلايا الشمسية تجريبيا, وبعدها استخدمنا مراة مستوية (40 * 50 سم) لزيادة شدة ضوء الشمس الساقط على اللوح . في الحالة الأولى حصلنا على افضل الزوايا وهي (زاوية ميل اللوح $\gamma_P = 60°$,وزاوية السمت السطحية $\alpha_P = 36°E$). ومن جانب اخر عند اضافة مراة بزاوية 120° عند اسفل اللوح حصلنا على قدرة خارجة(27.48 وات) اكبر من عدم استخدام المراة (25.16 وات). ويمكن الاستفادة من كلا الحالتين في التطبيقات المختلفة.