

## The Effect of Tilt Angle on the Solar Panel Output تأثير زاوية الميلان على قدرة إنتاج اللوح الشمسي

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### Abstract

In this project we study how the effect of changing tilt angulations of the solar panel and (1) the variations in the incident sunlight affects the amount of electrical output from the (2) on the efficiency of solar panels in Baghdad location. The correct installation position will allow solar panels to be exposed to direct, unobstructed sunshine from 7am to 4pm every day ,this study determined that the optimum tilt angle for a PV panel changes throughout the year, we installed solar panels in four angles ( $20^{\circ}$ , $35^{\circ}$ , $45^{\circ}$ , $55^{\circ}$ ) as a fixed solar panel in august 2009 and in January 2010 . The results showed that the gains in the amount of solar radiation throughout the year received by the PV panel mounted at  $35^{\circ}$  for fixed solar panel to Baghdad location for all days year.

### الخلاصة :

في هذا البحث تم ملاحظة كيف يكون تأثير تغيير زاوية ميلان اللوح الشمسي وعلاقته مع تغير شدة الإشعاع الشمسي الساقط عليه وتأثيرها على كفاءة وكمية القدرة الخارجة من اللوح الشمسي في موقع بغداد , وعملية التنصيب الصحيحة للوح الشمسي تسمح له بان يكون بالاتجاه المقابل إلى ضوء الشمس من الساعة السابعة صباحا إلى الرابعة مساء . في هذه الدراسة أفضل زاوية ميلان للوح الشمسي خلال وعلى طول أيام السنة وتم تنصيب ألواح بأربع زوايا ( $20^{\circ}$ , $35^{\circ}$ , $45^{\circ}$ , $55^{\circ}$ ) وبتقنية اللوح الثابت في شهري آب 2009 وفي كانون الثاني 2010 ومن النتائج كانت أفضل ربح لكمية الإشعاع الشمسي والواصل إلى اللوح الشمسي هو بزواوية 35 درجة للوح الثابت ولموقع بغداد وعلى مدار السنة

**Keywords:** Tilt angle, Solar radiation, Optimum tilt angle , solar panel

### 1- Introduction

Installing photovoltaic(pv) panels in the right orientation and tilt angle is the most important thought we can do. The optimal position helps photovoltaic panels receive the most sunshine throughout the day and across different seasons of the year. This helps reduce the payback period. If panels are sited in the northern hemisphere, then will have to orientate solar panels southward,also we need to tilt them to the correct angle, depending on the latitude of photovoltaic panel site tilt plays a key role in solar output fluctuation, since the amount of solar radiation received by solar panels varies by tilt and time of year

A solar cell's short circuit current is proportional to the number of photons were absorbed by the cell.

The sun delivers an average of  $1,353 \text{ W/m}^2$  to the edge of earth's atmosphere. This is known as the *solar constant*. Since the atmosphere reflects and absorbs some of this energy, the solar intensity at sea level is less—about  $1,000 \text{ W/m}^2$  in the summer. The solar intensity at earth's surface varies with the seasons. This variation is caused by the changing tilt of locations on earth with respect to the sun. Solar intensity at earth's surface also varies with atmospheric conditions such as cloud cover and humidity.

It is obvious that the solar panel exists to convert solar light energy into electric power for use by some form of load, output voltage from a solar panel will vary depending upon the solar panel design (6V, 12V, 24V, etc.), the attached load, and the amount of light striking the surface. Most panels are rated in watts of power that can theoretically be produced on a high intensity day<sup>[1,2,3,4,5]</sup>

To optimize the generation of electricity, system has been optimized for the location, we must rotate the panels from the horizontal to the optimal angle. Tilt the solar panels until they are at this angle.<sup>[3,4,6,7,8]</sup>

Positioning of the solar panel face should always be due south for all locations north of the equator, and vice-versa if south of the equator. Solar panel tilt angle will vary depending upon the latitude of the installation location. The angles are calculated to provide optimum energy production during the winter months when solar radiation is at its weakest<sup>[1,2,10,11]</sup>

The direct component, of solar radiation falling on any surface can be calculated with knowledge of basic solar angles as follows in table (1) and figure (1) .

Table 1:show some of basic solar angles.

Angle	Symbol	Description
zenith	$\psi$	angle between beam radiation and the vertical
altitude	$\beta$	angle between beam radiation and the horizontal
solar azimuth angle	$\gamma_s$	angle between N-S and the solar beam
incidence angle	$\theta$	angle between the beam radiation on a surface and the normal to that surface
the surface-azimuth	$\gamma$	angle between the surface normal and N-S
the surface-solar azimuth angle	$\alpha$	angle between the incident beam and the surface normal
the tilt angle	$\phi$	angle of the surface above the horizontal

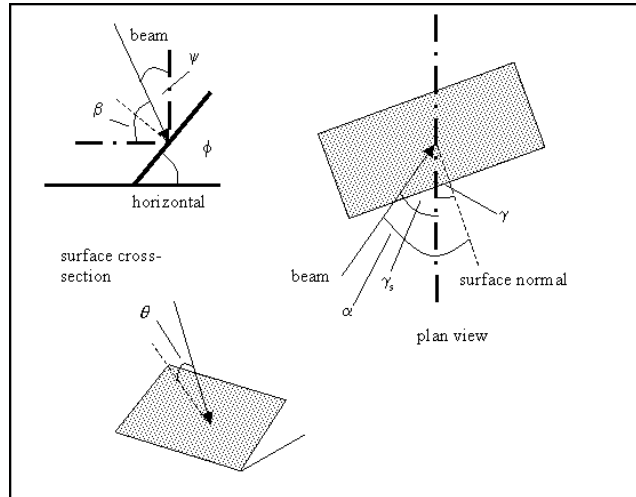


Figure 1:represent basic solar angles.

When installing or positioning a solar module it is critical to consider many factors related to the location ,the position and its path through the sky . Because of the daily rotation of the earth around its axis and the earths revolution around the sun the solar radiation striking the surface of solar module constantly change .The intensity of solar radiation and the angle at which this radiation hits the solar panel determines the amount of electricity it generates ,to optimize the output the solar module should be at a tilt angle equal to the latitude of the location plus 15 during the winter and latitude minus 15 during the summer .A solar module also could be mounted on a sun tracker to follow the sun as it travels through the sky [1,2,4,6,12,13]

**2- Procedure**

**2-1 – experimental equipment :-**

- 1- We amounted the solar panels in a sunny area ,the solar modules numbers contains (4) panels all of which have same power (80 watt) it mounted in (4) difference tilt angles (20,35,45,55)
- 2- To make the sun’s rays perpendicular to the panel, we need to make tilt the panel by Tilt  $\phi = 90 - \beta$  as show in figure (2) ) ,the  $\phi$  and  $\beta$  depicted in fig (1)

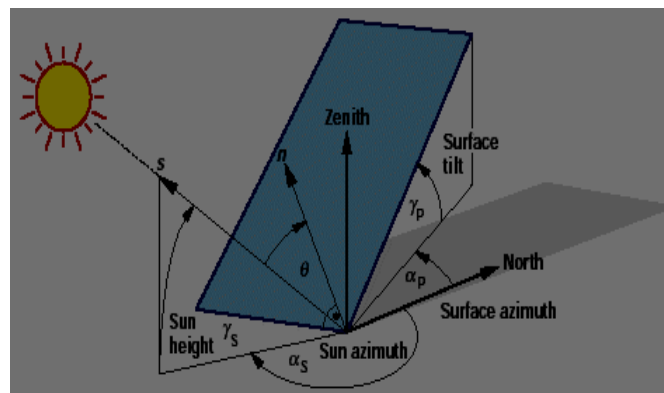


Figure (2) show the tilt angle

The panels are mounted in roof of the building to reach the maximum solar radiation without any shadow like that show in figure (3)



Figure (3) show the panels in roof building

- 3- We read solar radiation from weather station in ( $\text{w/m}^2$ ) using watch dog type which is included silicon sensor calibrated to read solar radiation by data logger show in figure (4), the solar radiation reading for every reading solar panel output with the duration hours day.



Figure (4) show weather station watch dog type

- 4- By multimeter show in figure (5) we measure the current to short circuit for all modules and recoded the reading for every panels against the hours day with solar radiation



Figure (5) show the multimeter fluok type

**3- Steps of the experiment and the results**

- a- Begging read data from 7 a.m. we read measurements every half hour to the long day to 4 p.m.
- b- We read solar radiation from the weather station every half hour to long day
- c- Connect the every solar module to the multimeter to Read the current in short circuit for all modules on measurements time
- d- We recorded the measurements in table (2)

Table (2) show the columns measurements

Time	Solar radiation	Current module(1) angle- 20	Current module(2) angle- 35	Current module(3) angle- 45	Current module(4) angle- 55
7 am -4 pm	w/m <sup>2</sup>	Amp	Amp	Amp	Amp

- e- Plot the curve between (Current module in(Amp) ) with time in (h) to long day the figure (6) show the relationship between the output panels with every half hour for four tilt angles in august month

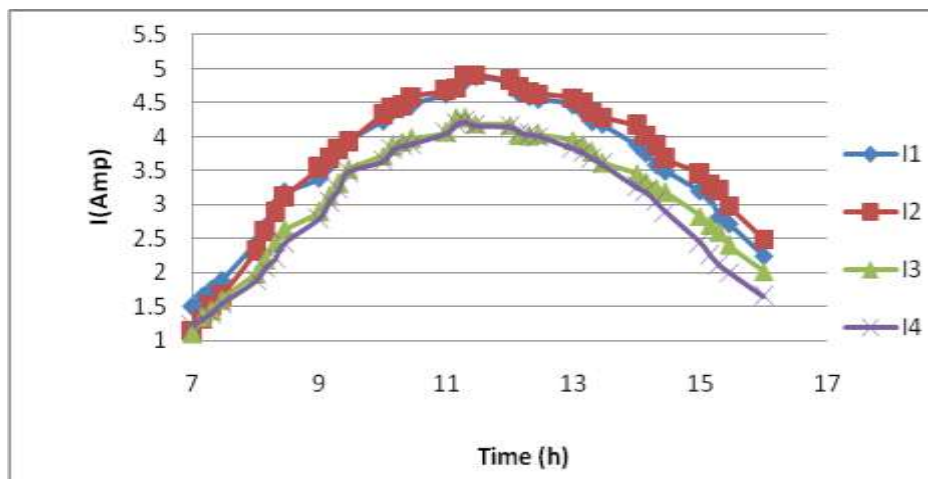


Figure (6) varies the current with the time for four tilt angles to day in august 2009

From the data which read from the weather station we plot the relationship between the solar radiation with time every half hour show in figure (7) to notice the change solar radiation with time in long day to compare the change output for solar panels with time for long day because changing the position for sun and change the amount of incident power on the panel surface

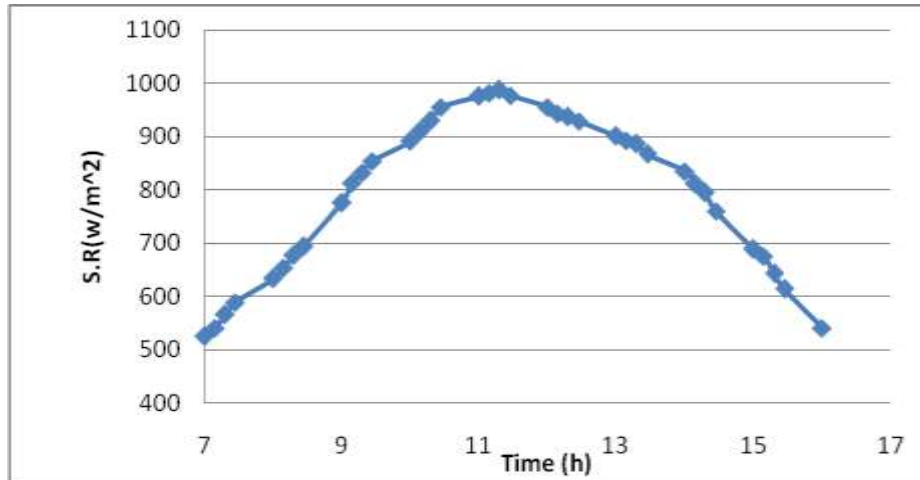


Figure (7) varies solar radiation with time for at half hour to long day in August 2009

- f- Repeat the preview steps in one day in January 2010 to notice the best tilt angle for solar panel and recoded the data in winter and comparator with the data it we obtain in summer the figures (8) and (9) show the data it we obtain in winter in January.

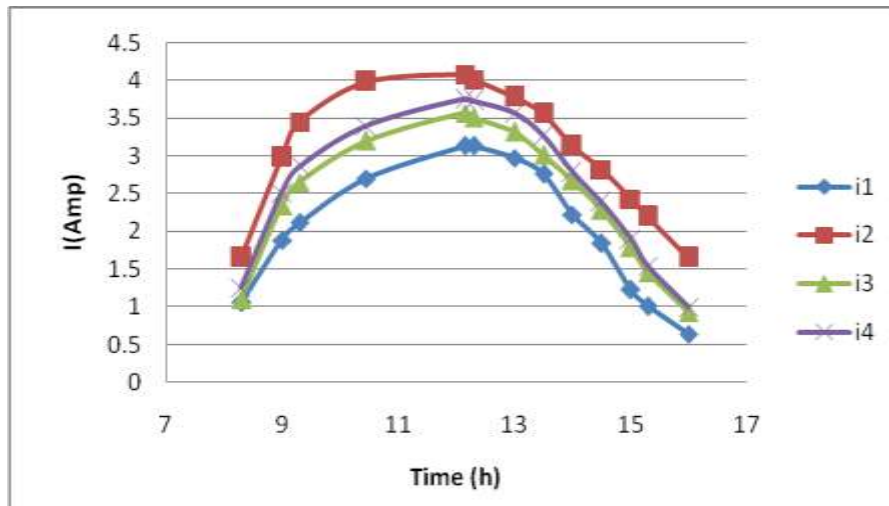


Figure (8) varies the current with the time for four tilt angles to day in January 2010

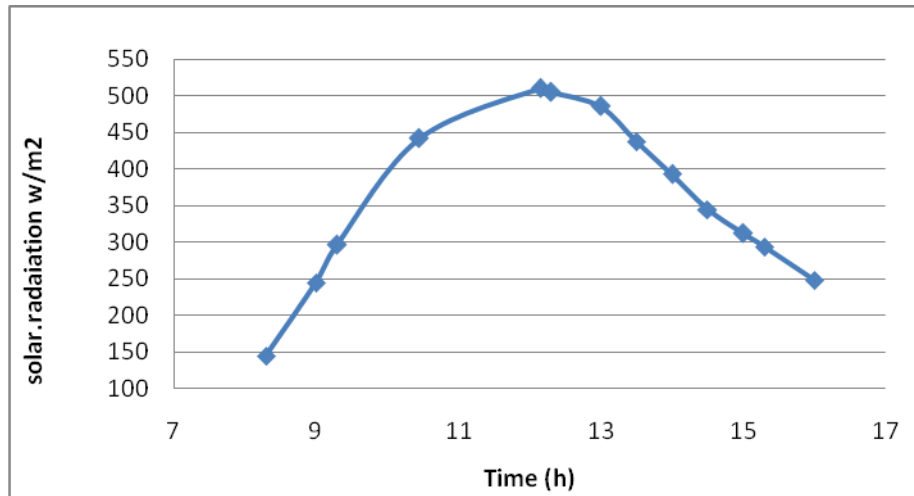


Figure (9) varies solar radiation with time for at half hour to long day in January 2010

From all steps experiments the amount of solar radiation change from the 7a.m. to the 4 p.m. depended on the sun position which limited by the factor air mass and the peak amount of solar radiation in afternoon because the sun position perpendicular to panel surface the amount of air mass equal to one and too the peak output of power to solar panel in afternoon and we notice different the output to all panels depended on tilt angle and the panel which be best perpendicular to the sun position will be more output power .

#### **4- Conclusion**

Tilt plays a key role in solar output fluctuation ,since the amount of solar radiation received by solar panels varies by tilt and time of year from this experiment we conclude

- 1- More solar radiation in the summer especially in Iraq will give more electricity energy production by solar panel and vice in the winter .
- 2- Fixed modules to maximize energy absorption over a year unless they are to be manually adjusted (perhaps once a quarter)
- 3- More energy is produced by the solar panels with a 20 and 35 it is be suitable in summer in Baghdad locations and the best angle to the fixed panel to all time of year is 35
- 4- The angles 45, 55 it is be suitable to winter condations and give to solar panel more solar radaition .
- 5- Big particles like dirt and dust travel short distances and adversely impact the output of solar panels closest to these particle sources and small particles settle on solar panels surfaces over time, and have higher concentrations in the summer than winter and the solar panel in 55 will by cleaner than solar panel in 20 becues the tilt angle and rain will cleans them quite well and Horizontal, non-tilted solar panels 20 rain does not clean them well, since rain does not drain well due to the solar panel's frame structure

**Refrances**

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