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# Output Energy of Photovoltaic Module Directed at Optimum Slope Angle in Kuala Lumpur, Malaysia

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**Abstract:** This research analyzes the optimal choice of the tilt angle for (PV) module sequentially to collect the maximum power. The tilt and slope angles of a Photovoltaic (PV) array affect the amount of occurrence solar radiation exposed on the array. It based on the measured values of daily global and diffuse solar radiation on a horizontal surface which generate the maximum power. It had shown the different optimal angle of tilt (β) for each direction during sunny days per year. To allow to collected the maximum power energy for Kuala Lumpur site on yearly bases. The influences of PV roofing orientation on the power output of PV modules are also investigated. Annual optimum tilt angle is found to be approximately equal to latitude of the location was 15° at South direction. Compared with the different optimum tilt (β) and four directions. Results give implementation for the optimum tilt angles for BIPV applications.

**Key words:** Sequentially, implementation, applications, orientation, optimal angle, Malaysia

## INTRODUCTION

Protected since developing clean energy resources as alternative one of the important task assigned to modern science and technology. Among a wide variety of renewable energy project in progress, Photovoltaic (PV) cells is the most important one of as a future energy technology Research of BIPV optimal tilted angle, use of latitude concept for South orientated plans (Cheng *et al*., 2009).

The direct conversion of solar radiation to electricity by PV cells has a number of significant advantages as an electricity generator. One of the most promising applications of PV power generation is used for residential PV system addicted up to utility grid. This interconnection system permits the excess power produced by the PV system can be sold to the utility.

The grid itself constitutes the backup when the PV system's output is not sufficient to satisfy the load, event the array fails to operate (Cheng *et al*., 2009). Over recent years, the number of Building Integrated Photovoltaic (BIPV) installations for home systems have been increasing in the world as well as Malaysia. For the optimum design of BIPV systems, it is important to determine their performance at the site installation (Chang, 2010). Since the amount of power produced by a PV panel depends upon the amount of region's solar irradiation and temperature. For optimum design of PV system in certain region, the estimation of long term system performance is necessary.

One of the approaches to obtain this information is by experimental data taken at UKM Bangi. The analysis was undertaken using calculation and experimental data tools to optimize performance of BIPV system in Kuala Lumpur, Malaysia. In this study, the analysis was assumed for the system design to get the data n different direction with the same angle per day. Units in order to calculate factors which influence the performance of BIPV home system (Mondol *et al*., 2006) based on a 1 year recorded weather data for city of Kuala Lumpur.

**Climate data of Kuala Lumpur:** The researcher used PVSYS-50 software to simulated the climate data in Kuala Lumpur to compare between the real data obtained to the researcher and the range was not different between each other results as shown in Fig. 1 and 2 it agrees with (Mondol *et al*., 2006) where he found that the average monthly of solar irradiation and temperature is 131 kWh $m^{-2}$ and 25°C, respectively. Heavy rainfall,

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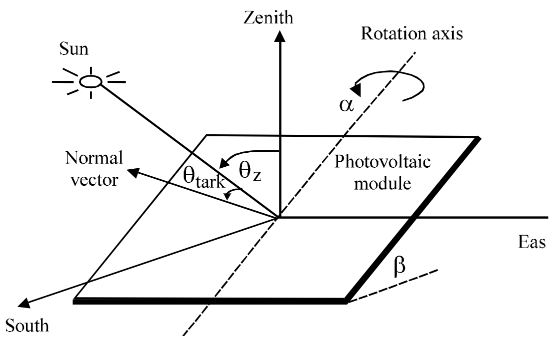


Fig. 1: Geometry of PV panel

Fig. 2: System modules into four direction slope angle (β) 30°

constantly high temperature and relative humidity characterize the Kuala Lumpur as well as Malaysian climate. In this research simulated the climate data in Kuala Lumpur and noticed that the result is not far from the real data which was obtained from the experiment (Eltbaakh *et al.*, 2011) in their result that the monthly average daily solar radiation in Malaysia is 4000-5000 kW h $m^{-2}$ with the monthly average daily sunshine duration ranging from 4-8 h.

Eltbaakh *et al.* (2011) found the average of maximum global solar radiation was 4800 kW h $m^{-2}$ which was recorded in march and the average of minimum solar radiation was 4400 kW h $m^{-2}$ which was recorded in December that obtained that the global solar radiation in Kuala Lumpur was partially static during the entire year. PVSYST 5.0 software is a practical tool for evaluation and calculation of a PV and BIPV system's performance and earlier versions of the software has been used to obtain data for BIPV systems with high accuracy rates (Van der Borg and Jansen, 2003; Chang, 2009a, b). Prior to conducting the calculation process the software offers two options according to the detail of the information provided for the system, Project design and Preliminary design. The latter was selected for the calculations in the present study.

## MATERIALS AND METHODS

This study examines a performance feature of PV systems is the relationship between power output and the slope angle (β) and radiation in which direction South or West or North or East. The objective of the experiment was to quantify this relationship by plotting power output against the slope angle (β) in suitable direction of the photovoltaic module as shown in Fig. 1. These experiments were done by four irradiating test modules as a system connected to the running software (adam view). This system was designed by (SERI) UKM to calculate the slope angle (β) and measure its temperature and solar radiation and power in different angle 15, 20 and 30° over a series of time steps as the solar radiation increased towards the maximum solar radiation (Mondol *et al.*, 2006) which will generate the maximum power in complete sunny days in Kuala Lumpur under the normal situation of climate and the data was taken in sunny days every second and at last the researcher collected the data to get the maximum power in different angles by using excel (Microsoft Office) (Yang and Lu, 2007). The research was carried out in the solar simulator located within the Mechanical Engineering Laboratories at Solar Institute, University Kebangsaan Malaysia.

**Modules requirement:** Modules used in the experiments had main specification. PV-UD185MF5 185 Watt high performance multi crystalline solar panels. Maximum power voltage 24.4 V. Maximum power current is 7.58 amps Cable with MC connectors. Dimensions 65.3×32.8×1.81 weight 37 LBS.

**System description:** The system used in this experiment was design by solar institute in University Kebangsaan Malaysia. It was used mainly to define the optimum solar angles, slope angles and azimuth angles which have a correlation with direct solar radiation and power (Yang and Lu, 2007). The main element of the system was 5 module are position to the steel skelton in a cube shape, those modules are fixed with screw to the Skelton with opportunity to move and change the angles of four direction which will be located to the main direction (North, South, East and West) to gather the solar radiation direct from modules. I-V readings through the panels were monitored by four digital millimeters under varying load resistances applied by two load resistors to have detailed information about PV panel power output

(Benghanem, 2011). The module are made in such a way that particular unit were in no contact to each other as shown in Fig. 2 analysis the solar radiation at located direction and conduct these data to main box of changer of the data using (Adam view software) to communicate with computer as output unit for all related data, to get the optimum angle and optimum direction with details of data on solar radiation, temperature, time and power at the same time.

**Experimental program:** The levels of irradiation used was different because it depends on normal condition of climate between 1000, 600 and 700-200 $Wm^{-2}$, this was in agreement (Eltbaakh *et al*., 2011) where they found in the result that the monthly average daily solar radiation in Malaysia is 4000-5000 Wh $m^{-2}$ with the monthly average daily sunshine duration ranging from 4-8 h. The researcher collected the data every second from 10 am to 4 pm. Benghanem (2011) and Reichart and Glass (2009) had done same experiment but it was different in controller condition of solar radiation and had all the variables fixed variables to get the difference of temperature. The study considered as how to produce the electricity from photovoltaic solar cells and there are experiment proving that and overview of techniques and principles of cell design and the main result of this study was that there is relationship between temperature irradiance G. Therefore, in Libya where the air temperature reaches 45°C in summer would result in a maximum surface temperature 95°C. This increase in temperature together with the lower intensities of irradiance experienced in practice would result in the module tested delivering 66% of its rated power when used in Libya. This experiment had same process but differ in climate condition, solar radiation which it is main requirement of this experiment that we were able to acquire different data of power depending on the location of longitude and latitude of a country, consequently the slope of angle will be changed depending on the circumstance (Asl-Soleimani *et al*., 2001; Mondol *et al*., 2007) from country to another and that will be a major influence on the architecture design of roof and orientation of the buildings, to hold most solar energy as it can.

**Optimization result using Matlab software:** The researcher took the average of the data obtained from the experiment, when the solar radiation was effected on the surface of four module in different direction for six selected angles as character for each angle as we seen in (Fig. 3). Matlab software optimized the whole data for angles and direction and compared each other and defined the addition of maximum power in the direction to find the optimum angle in many cases by the mathematically operated software (Mondol *et al*., 2006) which helped the researcher to get it as a single value.

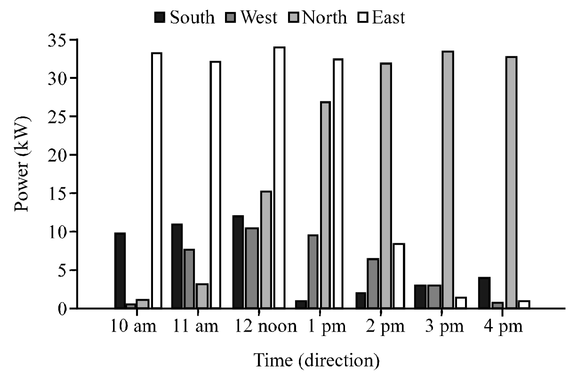


Fig. 3: Average of maximum power in different direction per sunny day at slope angle (β) 15°

**Examination of experiment work:** The analysis of the data was categorized into two main parts to identify the optimum slope angle for the motivation to generate maximum power to acquire maximum electricity with the photovoltaic module with the preferred specifications (Asl-Soleimani *et al*., 2001; Mondol *et al*., 2007) which was selected to integrate upon the roof. The two main parts are. The optimum slope angle (β) in different direction per sunny day plots. Which was obtains it from optimization process for data. It had fixed the direction (North South, East or West). The optimum direction of different slope angle (β) to get the optimal direction, to generate the maximum power. In this part was getting in the plots which were getting it in the optimization process for data. The angle was fixed to get the optimum angle in the four direction inaccessible and into four steps to get optimum four slope angle (β) to compare between these directions (Peippo and Lund, 1994). After verifying these two parts TO get the optimum slope angle (β) and optimum direction per clearly sunny day as an answer of one of the research question. Irradiance start between 1000-200 W $m^{-2}$ in the average of clearly sunny seven days, when we compare between (Al-Shamiry *et al*., 2007) study where their experiment requirement was a daily operation of 5 h (11:00-16:00) and 3 days autonomy. The total load demand is 217 Amps. It is diverse with the researcher in terms of the solar simulator process which was run for 6 h from 10 am to 4 pm noon for 7 sunny days and readings were evidenced at 1 sec interval that is contained in the result and is more credible for the reason that it took more time duration for 7 days. Slope angle (β) = 15-30° Modules temperature start from 13°.

## RESULTS AND DISCUSSION

**The optimum direction of 15° slope angles (β):** The maximum power generated in different slope angle in

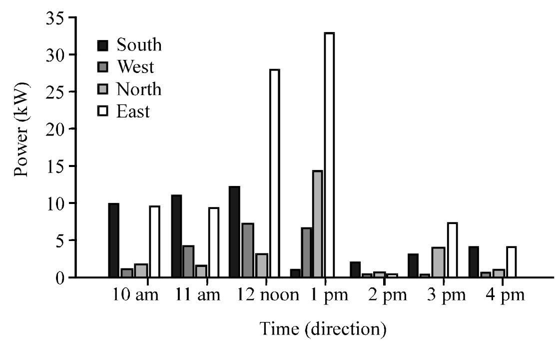


Fig. 4: Average of maximum power in different direction per sunny day at slope angle (β) 30°

different direction isolated to define this angle per hour of sunny day in Fig. 3, it take the two angles one by one. In this figure clearly that in slope angle (β) 15° all the different value and the whole variables of this angle influences to determined the optimum angle as the result of optimization of all input data to get this position of the maximum angle (Kacira *et al*., 2004; Chang, 2009a, b). And all this variables work together to get this value, it was obviously understood from this figure that direction and the time in deep analysis that they are analytical variables partial to each other to give the optimum angle in all direction (Mahmoud and Nabhan, 1990). At the same time, found that in slope angle (β) 15° at 10 am the power in South direction is 10 kW h m$^{-2}$ and in West direction is not influenced and it was small value, 0.899 10 kW h m$^{-2}$. In North it was 1.543 kW h m$^{-2}$ and in the East it was maximum at 10 am which proved as 31.234 kW h m$^{-2}$ so the optimum direction at this angle at 10 am is East, refer to Fig. 4. At 11 am found that in the South the power was 11.123 kW h m$^{-2}$ in the West it was 8.435 kW h m$^{-2}$ in North direction it was increased than that at 10 am and confirmed as 4.069 kW day$^{-1}$. Finally in the East direction the power was the highest at 11 am that is 31.098 kW h m$^{-2}$, so the optimum direction of this angle at 11am was East direction. At 12 noon found that in the South the power was 12.123 kW h m$^{-2}$ in the West it was 11.445 kW day$^{-1}$ in North direction it was increased than that at 11 am and it was confirmed to be 15.269 kW h m$^{-2}$. Finally in the East direction it was the uppermost at 11 am, that is 34.098 kW h m$^{-2}$ so the optimum direction of this angle at 11am was East direction.

At 1 pm found that in the South the power was 11.123 kW h m$^{-2}$ in the West it was 8.435 in North direction it was increased than that at 10 am it was evidenced as 3.869. Finally in the East direction it was the uppermost at 11 am that is 31.098 kW h m$^{-2}$ so the optimum direction of this angle at 1 pm was East direction. At 2 pm found that in the South the power was 3.12 kW h m$^{-2}$ in the West it was 6.035 kW h m$^{-2}$ in North direction it was increased than that at 1 pm which was documented as 26.869 kW h m$^{-2}$. Finally in the East direction it was the maximum at 1 pm that is 34.098 kW h m$^{-2}$ therefore, the optimum direction of this angle at 1pm was East direction. At 3 pm found that in the South the power was 3.22 kW h m$^{-2}$ in the West it was 3.05 kW h m$^{-2}$ in North direction it was increased than that at 2 pm which was documented as 33.099 kW h m$^{-2}$ which was the maximum at 2 pm as optimum direction. Finally in the East direction it was 2.098 kW h m$^{-2}$ so the optimum direction of this angle to arrange the slope of roof at 2 pm was North direction.

At 4 pm found that in the South the power was 4.303 kW h m$^{-2}$ in the West it was 3.435 kW h m$^{-2}$ in North direction it was increased than that at 10 am and it was recorded as 32.769 kW h m$^{-2}$ which was the extreme value at 4 pm and finally in the East direction it was 2.098 kW h m$^{-2}$, consequently the optimum direction of this angle at 3 pm was East direction.

**The optimum direction 30° slope angles (β):** In this Fig. 4 found obviously that in slope angle (β) 30° all different value and the whole variables of this angle that influences in determining the optimum angle as the result of optimization of all input data to get this point of the maximum angle and all this variables work together to get this value (Mahmoud and Nabhan, 1990; Chowdhury, 1992). Clearly in this figure that direction and the time as cavernous analysis. The researcher found that in azimuth angle 30° at 10 am the power in South direction is 10 kW h m$^{-2}$ and in West direction it is not influenced and was small value (1.099 kW h m$^{-2}$). In North it was 2.043 kW h m$^{-2}$ and in the East it was modest greater than East and North directions at 10 am which was recorded as 9.234 kW h m$^{-2}$. So the optimum direction at this angle was 30° at 10 am which is South as seen from figure to get suitable design at 10 am.

At 11 am found that in the South direction the power was 11.123 kW h m$^{-2}$. In the West it was 4.435 kW h m$^{-2}$. In the North direction it was less than that at 10 am and was evidence as 0.869 kW h m$^{-2}$ and finally in the East direction it was a less value than that at 10 am (9.098 kW h m$^{-2}$) therefore, the optimum direction of this angle at 11 am was South direction at that time 11 am. At 12 noon found that in the South the power was 12.123 kW h m$^{-2}$. In the West it was 6.435 kW h m$^{-2}$. In the North direction it was slightly increased than that at 10 and 11 am recorded as 4.869. In the East direction it was the topmost at 12 noon (28.098 kW h m$^{-2}$). So the optimum direction of this angle at 11am was East direction. Hence it will be easy to intend the design for the slope of roof to this direction when established 30° in building spatially for domestic use. At 1 pm found that in the South direction the power was 1.163 kW h m$^{-2}$. In the West was 7.435 kW h $m^{-2}$ and in the North direction it was increased than that at 12 noon recording to 13.869 kW h $m^{-2}$. In the East direction it was the maximum at 1 pm (34.00 kW h $m^{-2}$). The optimum direction of this slope angle (β) at 1 pm was East direction. It is the most suitable to arrange the roof at this angle. At 2 pm found that in the South the power was 2.123 kW h $m^{-2}$. In the West it was 1.405 kW h $m^{-2}$ and in the North direction it was decreased than that at 1 pm and recorded as 0.869 kW h $m^{-2}$. Finally in the East direction it was the much big difference in this range to 1.098 kW $day^{-1}$.

So the optimum direction of this angle at 1 pm was South direction but it was not enough of output of the power to integrate upon the roof. At 3 pm found that in the South the power was 11.123 kW h $m^{-2}$. In the West it was 8.435 kW h $m^{-2}$ and in the North direction it was increased than that at 2 pm and recorded as 3.869 kW h $m^{-2}$. Finally in the East direction it was the highest at 3 pm (31.098 kW h $m^{-2}$). The optimum direction of this angle at 3 pm was East direction. At 4 pm found that in the South the power was 4.123. In in the West it was 1.435 $KWday^{-1}$ and in the North direction it was increased than that at 10 am indicating 1.869 kW h $m^{-2}$. Finally in the East direction which was the highest at 3 pm (1.098 kW h $m^{-2}$). Hence the optimum direction of this angle at 11 am was South direction.

**Optimization of angle 15° to generate the maximum power:** The East direction it was 2.098 kW h $m^{-2}$ so the optimum direction of this angle to arrange the slope of roof, at 2 pm was North direction. At 4 pm found that in the South the power was 4.303 kW h $m^{-2}$ in the West it was 3.435 kW h $m^{-2}$ in North direction it was increased than that at 10 am and it was recorded as 32.769 kW h $m^{-2}$ which was the extreme value at 4 pm and finally in the East direction it was 2.098 kW h $m^{-2}$, consequently the optimum direction of this angle at 3 pm was East direction.

To summarize the results for maximum power in different direction per sunny day at angle 15° was established by (Seng *et al*., 2008) described the selection of the optimum angle to generate the maximum power to use as a solar energy for housing in Malaysia (Seng *et al*., 2008; Li and Lam, 2007) colleagues studied on how the load profile can be affected by PV systems of various sizes, the actual output profiles of a 5.25 kW PV system on a bungalow house were used. Moreover, Marcellus and Kyle (1998), Seng *et al*. (2008), Li and Lam (2007)and Vanier *et al*. (1998) determined that the racks typically orient the modules to face due South with a tilt angle of 20-30°. Parallel rows of rack mounted modules must be spaced to avoid shading the next row. For example, to limit shading to periods when the sun is <10° that indicated this slope angle (β) 15° was suitable to install the module upon the roof to generate the maximum power for domestic using as most angle was appropriate to generated the energy.

**Optimization of angle 30°:** The optimum direction of this angle at 3 pm was East direction. At 4 pm found that in the South the power was 4.123. In the West it was 1.435 kW $day^{-1}$ and in the North direction it was increased than that at 10 am indicating 1.869 kW h $m^{-2}$. In the East direction which was the highest at 3 pm (1.098 kW h $m^{-2}$). Hence the optimum direction of this angle at 11 am was South direction.

Also Al-Shamiry *et al*. (2007) and Al-Shamiry and Mohammed (2007) in their study done in Sarawak (Malaysia) had agreed that when the time progresses during sunny day the power increase rationally and that the result we obtained in the West and South direction in this experiment suggest that the PV system power was found to be 34.0 kW at 11:00 am. This value was increased to 400.81 at 13:00 pm and decreased to 27.5 kW at 16:00 pm. The total energy per day (from 8:00 am to 6:00 pm) given by the PV modules to the battery bank was 2.8 kWh. From the load data, consumption of energy per day was 2.6 kWh and (Cheng *et al*., 2009; Sanchez and Cheng, 2009) found that in tilt and the angle was ranging from 0-85 latitude in the Northern hemisphere.

## CONCLUSION

The calculation and experimental process of the optimal tilted angle show a pivotal role in the designing of a successful BIPV system. Designers who are aware of the correlation between β and υ can assume a highly efficient titled angle for PV panels without having to conduct additional calculations and only by knowing the site's latitude angle. The purpose of the validation of this theory as presented in the experimental results indicated that the best annual tilt angle actually is very close to the computer simulation results.

In addition, the results also confirm that the authorized result by PVSY-50 for the South as an tilt angle of 15° does not apply to all of Taiwan's various regions should vary with the temperature around the time and the longitude and latitude conditions are different, leading to solar radiation, the power output are also different. The tilt angle should vary with installation of PV modules location and effective regulation and also similar with (Cheng *et al*., 2009; Sanchez and Cheng, 2009) he results that ranging from 0-85 latitude in the Northern hemisphere. In order to prove the reliability of using the latitude angle as the angle for the tilted panel, the correlation was made between the performance obtained with the system using the optimal angle and the system with the site's location angle. Results indicate that an average of 98.6% a system's performance with the optimal angle can be obtained using the latitude angle for the tilted panel.

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