Experimental Study on the Optimal Tilt Angle of Photovoltaic Panels In Yulin of Shaanxi Province

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ABSTRACT

As one of the main forms of solar energy, photovoltaic (PV) power generators have been developed rapidly in the past few years. An experimental PV system with 4 different tilt and azimuthal was installed in Yulin of Shaanxi province in this paper. The solar modules were installed towards the East, South and West and each azimuth for 4 different tilt angles: 30°, 35°, 40°and 90°. In these positions the values of current, voltage, power and solar radiation intensity were measured. The optimum positions were determined in which maximum values of solar intensity and power were recorded. The results show that PV module oriented gives the greatest value of electrical energy towards the South for the tilt angle of 40°.

1. INTRODUCTION

As a substitute for fossil energy sources, the PV panels has been widely used as a long term, inexhaustible, environmentally friendly and reliable energy technology. Therefore, the selection and proper installation of PV modules directly affects the output of system .

Solar radiation data is usually measured in the form of global radiation on a horizontal surface at the corresponding latitude. PV modules are tilted so that they collect maximum radiation. Since the flat-plate solar collectors are installed at an angle to the horizontal, it is necessary to calculate the optimum tilt angle which maximizes the amount of collected energy. It is generally known that in the northern hemisphere, the optimum collector orientation is South facing and that the optimum tilt angle depends on the latitude and the day of the year. In winter, the optimum tilt is greater (usually latitude +15°), while in summer the optimum tilt angle is lower (usually latitude -15°) [1]. There are many papers which make different recommendations for the optimum tilt angle, based only on the latitude [2]. In practice, a collector plate is usually oriented South facing and at a fixed tilt angle which is set to maximize the average energy in the period of one year. It has been found that for every location on earth with specific

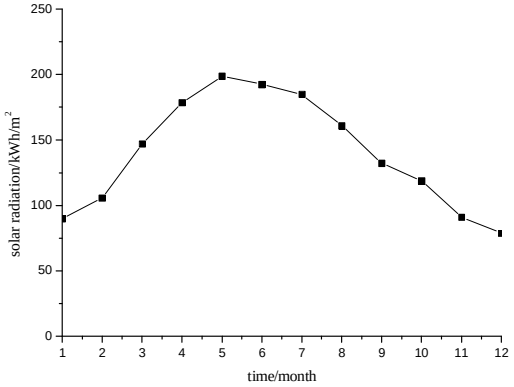

Figure 1. Monthly solar radiation

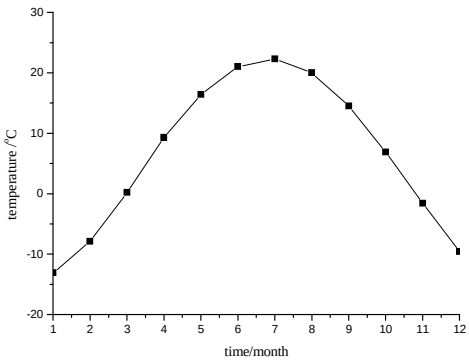

Figure 2. Monthly average temperature

radiation characteristics, there is an optimal tilt angle for the best solar energy.

This experiment evaluates the performance of four PV modules at different tilt angles and fixed Shaanxi province has three landforms which are Shaanxi northern plateau, Guanzhong plain and Qinba mountain land in south of Shaanxi. So climate type is also divided into three types.The climate of northern Shaanxi belongs to arid regions and semi-arid climate in the temperate zone and Guanzhong's climate belongs to Semi-humid climate in the temperate zone and the one of northern Shaanxi belongs to north orientation in order to define the optimal tilt angle in Yulin. The monthly solar radiation data and PV power output have been measured and the relationships between theirs and the tilt angle have been analized. According to the experimental data analysis, the optimal tilt angle has been obtained.

Figure 3. Solar module in the 110kv substation of Yulin Mazhaliang

2 RESOURCE CONDITION

In Shaanxi province of China, it is about 870 kilometers from northern to southern of Shaanxi. Subtropical humid climate. In this case, the distribution of solar energy resources has a big gap in different regions, especially between north and south in Shaanxi province, the annual total sunshine radiation is 3830-5750 MJ/m^2, the annual sunshine time is 1270-2900 hours and the sunshine ratio is 28%-64%. And Yulin is located in the north of Shaanxi.

This PV system was installed in 110kv substation of Yulin Mazhaliang area. Yulin locates in 109°34'2.74" N and 38°9'11.65" E.The yearly average temperature is 10 .This area is the most abundant solar energy resources in Shaanxi. It has annual average total sunshine duration of 2900h.The experiment was to make sure of the amount of PV modules, its tilt angle and orientation.

According to the meteorological data of NASA Surface meteorology and Solar Energy,the monthly solar radiation and average temperature are shown as Fig.1 and Fig.2.

Table 1 Output power ration and scale factor of PV modules with respect to PV module 2

Module	output power	scale factor

number	ration	
1	0.989767024	1.010338773
2	1	1
3	1.013990054	0.986202967
4	0.919052	1.088078

3□EXPERIMENTAL SETUP

As shown in Fig.3., four PV modules facing towards the south with various tilt angles of 30°, 35°, 40° and 90° have been installed in the substation of Yulin. The PV power output and solar radiation data have been measured for each PV module. The size of each PV module is 1.575m×1.066m, with an area of about 1.679m^2 and maximum power 230W.

Figure 4. Radiation meter for the solar radiation

Figure 5. The measurement system of PV module output

For the experimental system include: solar photovoltaic power testing system, solar radiation monitoring system and so on. The DC voltage and current collector was used for the data acquisition of voltage /current (power). A radiation meter was used for the data acquisition of solar addiation, temperature, air speed as shown in Fig.4 and Fig.5

4□RESULTS ANALYSIS

The experimental period is from January 1, 2012 to November 31, 2012. On January 29. Except some national vacations□just like spring festival, labor day ,national day and so on).The experiment lasts 344 days.

Due to their difference in productive process, there are some differences in four PV modules' efficiency .Comparing with four PV modules' output ,some corrections in efficiency must be done. The output power ration and scale factor of PV modules with respect to PV module 2(towards the south with tilt angle of 35°).For offsetting the influence on efficiency difference, the actual output of PV modules must multiply by the scale factor before comparing with each other.

Table 2 Output power ration and scale factor of PV modules with respect to PV module 2

Tilt angle	East (kwh)	West (kwh)	South (kwh)
30	267.93	249.54	339.18
35	263.99	244.12	343.78
40	259.9	238.5	346.77
90	184.72	167.96	262.6

Based on Fig 6, it can be shown that the solar module oriented towards the east at an angle of 30° generates electrical energy of 267.93 Wh, which is maximal electrical energy for the East. In Fig. 7 Solar module oriented towards the South gives the greatest value for electrical energy for the angle of 40° of 346.77kWh, which is the maximum registered value for electrical energy. It is shown in Table 2 that for

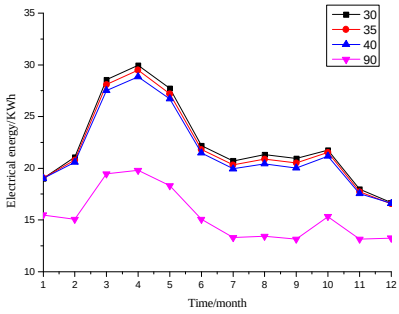

Fig. 6. Monthly energy output of 4 PV modules with different tilt angle towards the south

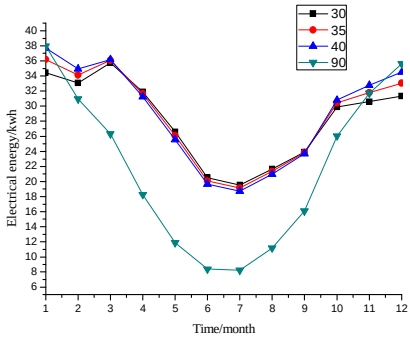

Fig. 7. Monthly energy output of 4 PV modules with different tilt angle towards the east

fixed angles of 30°, 35°, 40° and 90° solar module oriented towards the South gives the greatest values of electrical energy and for the angle of 40° the greatest value is given by a solar module oriented towards the South. Values of obtained electrical energy for the East, South and West positions for the angles 30°,

35°, 40° and 90°, are shown in figures 6−9.

On the basis of the above mentioned without shadow, the conclusion can be shown as following:

1) Solar module oriented towards the East gives the maximum values of electrical energy in March and April.The minimum values of electrical energy in November and December .The angle of 90° generates the minimum value for electrical energy. The angle of 30°generates the maximum value for electrical energy.

2) Solar module oriented towards the West gives the maximum values of electrical energy in March

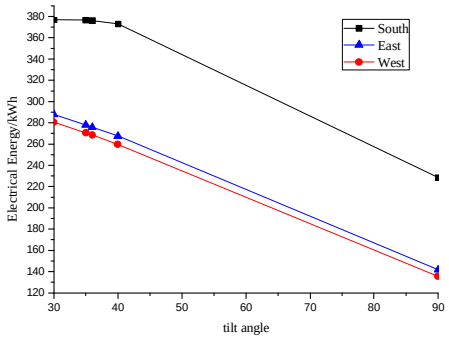

Fig. 8. Monthly energy output of 4 PV modules with different tilt angle at different azimuth

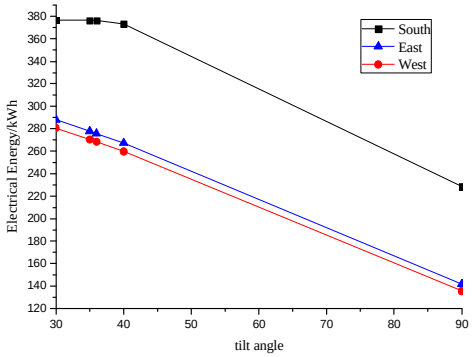

Fig.9. Yearly energy output of 4 PV modules with different tilt angle towards the west

and April.The minimum values of electrical energy in November and December .The angle of 90°generates the minimum value for electrical energy. The angle of 30°generates the maximum value for electrical energy.

3) Comparing with oriented towards the West, PV module orented towards the East generates more electrical energy.It is the reason that the temperature is lower in the morning so that it makes PV module efficiency higher.

4□Solar module oriented towards the South gives the maximum values of electrical energy in January and December.The minimum values of electrical energy in July and June.The angle of 90°generates the minimum value for electrical energy. The angle of 40°generates the maximum value for electrical energy.

5) PV system is mainly influenced by the solar radiation and ambient temperature.In winter solar radiation is weak but the environment temperature is low,the PV module efficiency is higher.In summer solar radiation is intensive, but the environment temperature is high.The PV module efficiency is low.All in all ,the power generation capacity is greater in winter than in summer.According to the climate in Yulin , the winter is sunny and summer is rainy . The experimental data conforms to this trend.

5□CONCLUSION

1) Solar module oriented towards the South gives the greatest values of electrical energy for all the chosen angles.

2) Considering the actual installation,when PV arrays must be installed towards the West or the East , generating capacity of 90 ° angle is lowest and its electrical energy is only 50% of the maximum value .

If it is only installed on the building of facing to east or west,PV system should be installed towards the east.

3) Because of influenced by solar radiation and ambient temperature,PV module's electrical energy is maximum in winter and minimum in summer throughout the year.

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