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Effect of Tilt Angle on the Performance of Hotovoltaic Cell in Yola, Nigeria

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ABSTRACT
Photovoltaic (PV) modules are being increasingly used in large as well as small scale installations. The performance of PV panels is affected by effect of partial shading due to trees, passing of cloud; neighbouring buildings tilt angle and any other means. This paper is an attempt to carry out systematic study of the effect of Tilt angle on the performance of PV cell and on the Power output, Fill factor and Efficiency of solar panel. The solar panel was first mounted at 15° to the horizontal and after 30 minutes, the voltage and current generated with the corresponding atmospheric temperature were recorded. The same procedure was repeated for angle 20°, 25° and 30°. The result obtained shows that the tilt angle at which a solar panel will be mounted for maximum power performance at fixed position in Yola is 24°. In general, the tilt angle of the solar panel and the orientation are dependent on the month of the year and the location of the place of research.
Keywords: Photovoltaic cell, tilt angle, power output, solar panel, fill factor, temperature

INTRODUCTION
The Photovoltaic effect was first noted by a French Physics that certain material would produce small amount of Electric field, Albert Einstein described the nature of light and photovoltaic technology that it was too expensive to gain wider spread use in 1954 .Sunlight is made up of tiny particles called photons which are being converted to electrical energy. Every hour, enough of this energy reaches the world to meet the world's energy demand for the whole world. Photovoltaic panels consists of many solar cells, these are made of materials like silicon, one of the most common elements on earth. (John, 2011). The effect of shading from panel rows in solar cell systems was studied using weather data from Sweden. A model is developed which takes into account shading as well as concealing effects. In the model the influence on cell characteristics of the irradiance and temperature is included. The calculations are compared with measurements from a test station for solar cell modules and fair agreement is found. (Passias, & Kallback, 1984).

Shade is a significant design factor affecting the performance of many Photovoltaic systems. Measuring the extent of shade on a solar array can be challenging due to the fact that shadows move as the sun position moves throughout the day and year. This is further complicated by the changes in the source of shade itself. For example, a tree can sway in the wind or lose its leaves during the winter, changing the type of shade it casts on a solar array (Sathyanarayana, 2014). Shade impact depends on the verity and area of the shade. It may cause current mismatch which results in loss of power. In this study, the effect of uniform and non-uniform shading on the performance of PV panel will be investigated under the Yola, Adamawa State North-East Nigeria climatic condition.

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MATERIALS AND METHODS

The materials that were used for this research work are Monocrystalline solar panel, shadow from building, Voltmeter, Ammeter, Pyrheliometer, Thermometer (Digital), Laptop and masking tape

Table 1: Specification of PV Panel. Timtere et al, (2018)

Company name	Yingli Solar Panel
Model No.	YL080-17B2/3
No of cells	72
Cell material	Monocrystalline silicon
V_{OC}	22.00V
I_{SC}	5.04A
V_{MP}	17.00V
P_{MAX}	80W
Maximum system voltage	50V
Operation temperature	0°C to 85°C

To obtain the desired results two type experiments were conducted separately. The research was conducted in the month of October. A rectangular photovoltaic (P-V) panel (911 mm x 655 mm x 30 mm) mounted on an adjustable stand seen in Plate 1, was used for investigating the effect of partial shading for zero, one third, half and three quarter.

Plate 1: Photo showing zero shading

The effect of tilt angle on the PV system was investigated using the same solar panel. The solar panel was mounted in an open space and in such a way that it can be tilted from 15°, 20°, 25° 30° to the horizontal and was face towards the south. The panel was fixed at 24° inclination towards south because for we to have a maximum output from the panel the tilt angle has to be 15° plus the latitude of that location and Yola is located along latitude

9°N for countries in the northern hemisphere, solar panels should always face true south. The solar panel was first mounted at an angle 15° to the horizontal for 30minutes and the voltage and current generated with the corresponding atmospheric temperature were recorded. The same procedure was repeated from 200, 250 and 30 in Girel part of Adamawa State Nigeria. In each of the experiments conducted the following measurements were taken

i. Voltage and current using digital multimeter
ii. Temperature using digital thermometer
iii. Pyranometer for measuring the irradiance from the sun

Statistical analyses of all the measurement was done using MAT-LAB software,

MICRO SOFT EXCEL

Adamawa state lies between longitude 12° 30'-12.50 E OF the Greenwich Meridian and latitude 9°-9.33 of the equator. The total land area covered by the state is approximately 39,742.13 sq km. Adamawa state lies within a mobile belt of the West African craton. This experiment was conducted in the Girel Local Government Area of Adamawa state and the temperature varies from 27°C-40°C within the month of October 2018.

RESULTS AND DISCUSSION

The values of the performance /figure of merit was calculated as follows

i. Fill factor was calculated using equation 4
ii. Efficiency was also evaluated using equation 6
iii. Power output was calculated using equation 8
iv. Correlation relationship was also done between power output, efficiency and temperature using equation 9

Effect of Tilt Angle on the Performance of PV Cell

Tables 2, 3, 4, 5 shows the results for current, voltage and power generated by solar panel at an inclination of angle 15°, 20°, 25°, 30° to the horizontal and the corresponding temperature with the solar panel oriented toward the south inclined from angle 15°, 20°, 25°, 30° at a succession of 30minuite interval the power generated and the corresponding temperature was recorded. The results reveals that improper orientation of the solar panel has actually lead to drastic drop in the output of the solar panel from Tables 2, 3, 4, 5. We can also see that as we continue to increase the tilt angle to the horizontal both the efficiency and the fill factor was reducing (Table 6). The PV panel output decreases significantly when the tilt angle becomes far off from its optimum value, (the optimum tilt angle for this this research work is 24°) and the output continuously drops how far it away from the optimum angle. According to recommendation made by some researches, the optimal angle of solar panel during winter is the latitude of the site of installation plus15°. Hence, the optimal tilt angle of a solar panel in of Yola Adamawa State North East could be (15°+9°) or 24°. Figure 1 shows the characteristics of I-V current to voltage performance efficiency at different tilt angle 15°, 20°, 25°, 30° and also figure 1 shows the graph of power against voltage as the result curves indicate, the increasing in the light intensity due to increase in the inclination angle made the power directly proportional to

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the temperature. However the increment of the power with the temperature is differing from one elevation angle to another.

Table 2: Values of I_{MP}, V_{PM}, P_M, T°C, η and FF at tilt angle of 15°. (Area=0.597m²)

I_{MP}(A)	V_{MP}(V)	P_M(W)	T°C	η(%)	FF(%
4.40	18.20	80.08	27.10	17.76	72.22
4.41	18.25	80.48	27.70	17.85	72.58
4.47	18.17	81.21	29.00	18.00	73.24
4.38	18.23	79.84	30.30	17.71	72.00
4.44	18.27	81.11	30.30	18.00	73.15
4.36	18.25	79.57	31.70	17.66	71.76
4.27	18.23	77.74	31.30	17.24	70.11
4.25	18.22	77.14	32.80	17.12	69.57
4.31	18.15	78.23	33.20	17.27	70.55
4.27	18.22	77.79	34.70	17.27	70.16

Table 3: Values of I_{MP}, V_{PM}, P_M, T°C, η and FF at tilt angle of 20°. (Area=0.597m²)

I_{MP}(A)	V_{MP}(V)	P_M(W)	T°C	η(%)	FF(%)
4.00	18.00	72.00	29.90	15.96	64.94
4.11	18.02	74.06	30.50	16.40	66.79
4.12	18.07	74.45	30.90	16.50	67.14
4.02	18.09	72.72	31.80	16.11	65.58
4.10	18.23	74.74	32.50	16.58	67.41
4.00	18.02	72.08	33.80	15.98	65.00
4.03	18.00	72.54	34.30	16.08	65.42
4.21	18.21	76.66	35.70	16.99	69.14
4.11	18.08	74.31	36.10	16.48	67.02
4.01	18.06	72.42	38.80	16.08	65.31

Table 4: Values of I_{MP}, V_{PM}, P_M, T°C, η and FF at tilt angle of 25°. (Area=0.597m²)

I_{MP}(A)	V_{MP}(V)	P_M(W)	T°C	η (%)	FF (%)
3.98	16.71	65.51	28.90	15.51	59.08
3.99	16.73	66.75	30.40	14.80	60.20
4.00	16.81	67.24	30.80	14.90	60.64
4.03	17.11	68.95	31.90	15.28	60.18
3.97	17.00	67.49	32.50	14.95	60.86
3.89	17.22	66.99	32.90	14.78	60.41
3.96	17.08	67.52	33.50	14.95	60.89
3.87	17.05	65.98	34.70	14.63	59.51
3.85	17.03	65.57	36.50	14.53	59.14
3.82	17.00	64.34	37.90	14.26	58.03

Table 5: Values of I_{MP}, V_{PM}, P_M, T°C, η and FF at tilt angle of 30°. (Area=0.597m²)

I_{MP}(A)	V_{MP}(V)	P_M(W)	T°C	η (%)	FF (%)
3.88	16.31	63.28	29.40	14.02	57.07
3.97	16.33	64.83	30.60	14.36	58.47
3.99	16.39	65.39	31.90	14.48	58.97
3.88	16.46	63.86	32.60	14.16	57.59
3.86	16.34	63.07	32.90	13.97	56.87
3.83	16.31	62.47	33.80	13.84	56.34
3.81	16.27	61.99	34.70	13.75	55.90
3.81	16.25	61.91	35.20	13.72	55.84
3.79	16.23	61.51	36.80	13.62	55.47
3.77	16.21	61.11	38.70	13.55	55.10

Table 6: Summary of the values of η & FF for different tilt angles

Angle 15°		20° Angle		Angle 25°		Angle 30°	
η %	FF %	η %	FF %	η %	FF %	η %	FF %
17.76	72.22	15.96	64.94	14.51	59.08	14.02	57.07
17.85	72.58	16.40	66.79	14.80	60.20	14.36	58.47
18.00	73.24	16.50	67.14	14.90	60.64	14.48	58.97
17.71	72.00	16.11	65.58	15.28	62.18	14.16	57.59
18.00	73.15	16.58	67.41	14.95	60.86	13.97	56.87
17.66	71.76	15.98	65.00	14.78	60.41	13.84	56.34
17.24	70.11	16.08	65.42	14.95	60.89	13.75	55.90
17.12	69.57	16.99	69.14	14.63	59.51	13.72	55.84
17.27	70.55	16.48	67.02	14.53	59.14	13.62	55.47
17.27	70.16	16.06	65.31	14.26	58.03	13.55	55.10

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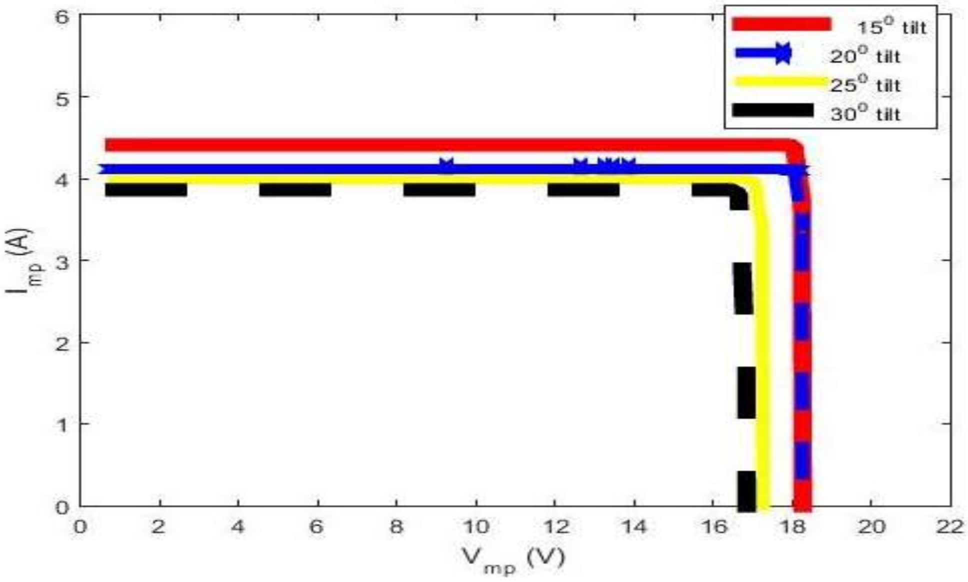

Figure 2: P-V characteristics of PVC at different tilt angle

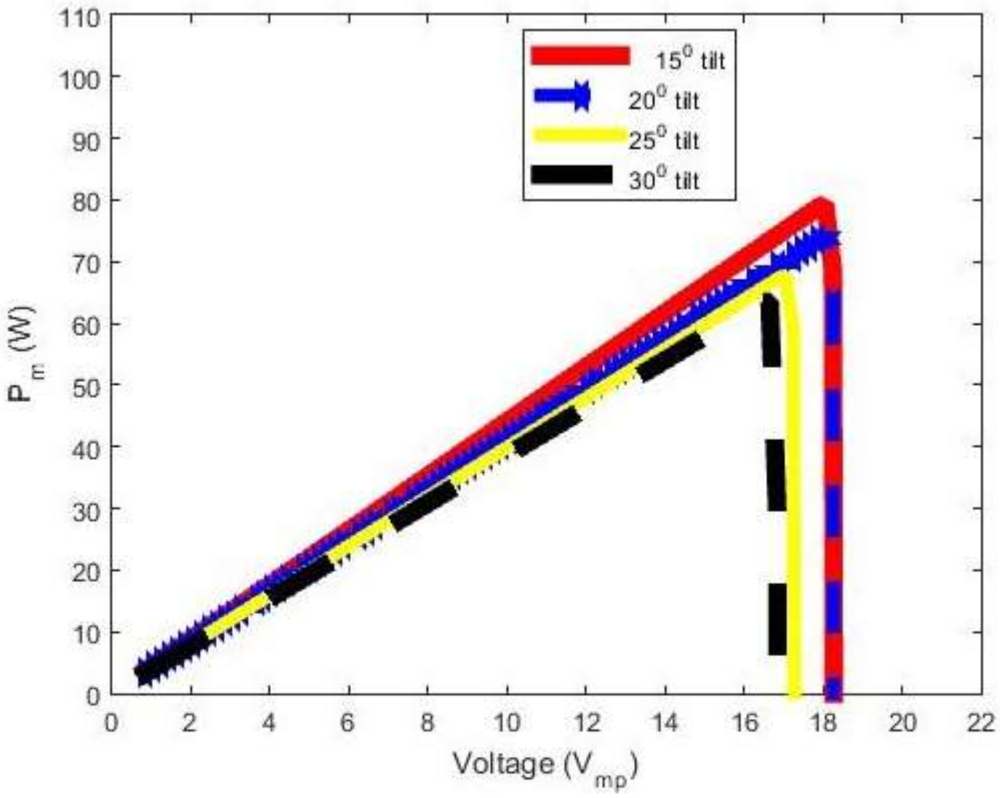

Figure 3: P-V characteristics of PVC at different tilt angle

CONCLUSION

The studies showed that the tilt angle at which the solar panel generated maximum power output in Yola was 24°, and temperature had no much effect because the values of temperature were within the same range.

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