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RESEARCH ARTICLE

Evaluation of the optimum Tilt angle of a Monocrystalline Module and performance in Anyigba Kogi State-Nigeria

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Abstract
This research Evaluation the Optimum Tilt Angle of a Monocrystalline solar Module and its Performance using a 100watt solar module, erected on an adjustable wooden rack, the output power was recorded against the tilt angl , the ambient temperature, current and voltage for every tilt angle were also recorded. The result from the experiments showed that the optimum performance angle is at angle between 0° and 10^0 with the highest output been at 81.65 watt at 0^0c,the power output was seen to decline as the temperature increases. It was conclude that the best optimum tilt for Anyigba is 10^0c so the panes can self-clean rather than being on an horizontal surface.

Keywords: Photovoltaic cells; Performance Evaluation; Solar Energy; Mono-crystalline modules

Introduction

Solar energy is gaining traction as the day goes by despite all odds, this is because solar energy is renewable, sustainable, clean and available almost in any location on earth. Solar energy through photovoltaic (pv) cell can convert energy from the sun directly into electricity (Bagnall *et al.*, 2008). Photovoltaic effect generates potential when radiation ionizes the regions in or near the potential barrier . the self-generated electromotive force (e.m.f) delivers power to the load. The photovoltaic phenomenon works based on the principle of quantum theory (Musa 2010). Effort to popular solar cell as a means of generating electricity was not successful ontill the energy crises in 1970s which encourages the use of an alternative sources of energy around the world. The solar pv technology has witness tremendous reduction in price in recent years (kumar and Rosen, 2011)
The energy can be used and applied in many facet of life, such as lighting, transportation, heating, use in homes, offices and health facilities, quit a number of research have been published stemming different aspect of solar energy from boosting efficiency, performance evaluation, and performance based on location. Solar system are assembled in a series and parallel to optimize voltage and current and power . The system can include aside the solar module, a battery for storage, inverter, charge controller and *balance* of systems. Some systems include sensors to record sunlight intensity and other meteorological factors (keogh *et al*, 2004).
Pv cell are classified in the first, second and third generation cell. The first generation are main the crystalline pv cell consisting of monocrystalline and polycrystalline, multi-junction pv cells, and ribbon silicon cell they are the most dominant in the market with an efficiency of between 14-27% (Kumar and Rosen, 2011).
The second generation pv cells are also referred to a thin film solar cell. These are thin layers semiconductor applied on substrate. The main highlight of a thin film solar pv is that it requires less materials in terms of semiconductor materials needed for production and this

results in low cost of production, example of such are the Amorphous silicon(A-Si), Cadmium Tellurid, copper-indium-serinade(CIS) (Parida *et al., 2011*). The second generation cels are promising to reduce cost of production with no adverse effect on our environment, they have efficiency of about 5-10% (chaar et al,2011). The maximum recorded efficiency of a solar cell is 23% under standard test condition (STC) (chaar et al,2011).

The third generation solar cell are mostly in the laboratory, these types of cell are fabricated using various materials apart from silicon, this materials includes conductive plastics, nanotubes, silicon wire, organic dye aided at improving on the commercially available solar cell through efficiency interim of the band of radiation utilized by the cell to generate energy and less cost.

Because of the high cost of the first-generation solar cell, toxic and difficulty in the availability of materials needed for the Second and the third generation pv cells, the third generations emerge to bridge the gap. The third-generation solar cell are different from the first- and second-generation cell, as they do not work on the principle of P-N junction as compared to others. Example are the dye sensitized cell(DSSC),Perovskite Sensitized Solar Cells, and organic cells.

Photon voltaic system have a large initial cost but pay for itself in the long run, it also have small maintenance cost compared to other sources of generation of electricity. Silicon cell are the largest of the various types of solar panel in the market, with a life time period pof 20-30 years (chaar et al,2014)

Solar PV Cell Model

The workings of a photovoltaic cell can be modelled through the equivalent circuit equation which can be used to examine the correct output and parameters of an ideal solar cell. The equivalent circuit represented by equation (1) shows the output current passing into the resistance (Ramakrishna and Mathar, 2009).

$$I = I_L - I_0\left[exp^{\frac{V+IR_{se}}{v_t}} - 1\right] - \frac{V+IR_{se}}{R_{Sh}}$$
(1)

The (V) is the output voltage of the model while (I) is the currrent , (I_0) is the diode reverse saturated current , (V_t) is the thermal voltage ($\frac{nKT}{q}$). (I_L) is the current generated by absorption at short circuit, (R_{se}) is the series resistant and (R_{sh}) is the shunt resistance in the equivalent circuit (Wansah *et al, 2014*).

Researchers have developed methoxides of evaluating the performance of photovoltaic systems. (Li *et al* , 2005) worked on the performance of a small pv system in city university of Hong Kong and the amount of solar irradiance falling on the panel was estimated using an approach called luminous efficacy approach. (Huang *et al*, 2006) proposed a system design called ‘ near-maximum-power operation’ that maintains the performance of a pv system very close to the MPPT(Maximum power point tracking) and the long term performance was determined to be higher than 90%.

Material and Method

This research evaluates the performance of a 100watt monocrystalline panel empirically to determine the performance, effect of temperature, optimum tilt and the output. The research work was carried out using instruments, such as a digital multimeter, ammeter, angle meter and table/rack to collect and analyze data in kogi state university, Anyigba on coordinate (7.493N, 7.1736E) in North-Central Nigeria. The solar panel was placed on a wooden adjustable rack which was erected several angle upward facing the southern hemisphere and oriented east-west which was supported by adjustable rack at different interval starting from 0^0, 10^0, 20^0, 30^0, 40^0, 50^0, 60^0, 70^0, 80^0 and 90^0 and the readings of the out voltage(V), current(I) and temperature of the PV module in degree centigrade (^{0}c) was recorded at different angle and and different interval of time, 8:00am, 10:00am, 12:00pm and 4:00pm,

Figure 1: Solar panel on an erected wooden rack.

Results

Table 1: Table of value 0°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.3	1.08	24.08	27
10:00	23.2	350	81.20	28
12:00	23.2	3.55	81.65	30
2:00	22.29	3.09	70.76	35
4:00	22.70	2.53	57.42	42

Table 2: Table of value from 10°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	23.00	0.08	18.40	26
10:00	23.30	2.95	68.74	27
12:00	23.10	3.25	75.08	29
2:00	23.20	3.30	76.56	28
4:00	22.70	1.80	40.86	34

Table 3: Table of value from 20°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.90	0.67	15.34	26.
10:00	23.30	2.77	64.54	30.
12:00	28.80	3.15	71.82	33
2:00	22.50	3.01	67.73	35
4:00	22.60	2.65	51.08	36

Table 4: Table of value from 30°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	23.00	0.92	21.16	26
10:00	23.2	2.48	57.54	30
12:00	22.8	2.82	64.29	35
2:00	22.3	3.22	71.80	36
4:00	22.3	1.59	35.46	37

Table 5: Table of value from 40°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.70	0.68	15.44	28
10:00	22.90	2.23	51.07	34
12:00	23.00	3.00	67.00	35
2:00	22.6	2.70	61.02	35
4:00	22.2	2.18	48.40	37

Table 6: Table of value from 50°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.5	0.50	11.25	22
10:00	22.8	2.21	50.39	30
12:00	22.5	2.47	55.56	34
2:00	22.6	2.6	58.76	35
4:00	22.4	2.34	52.42	36

Table 7: Table of value from 60°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.0	0.60	13.20	24
10:00	22.5	2.20	49.50	30
12:00	22.7	2.60	59.02	34
2:00	22.3	2.24	49.95	35
4:00	22.2	2.00	44.40	37

Table 8: Table of value from 70°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	23.3	0.57	12.71	22
10:00	22.7	1.71	38.82	30
12:00	22.3	2.48	55.30	35
2:00	22.4	2.56	57.34	38
4:00	21.8	1.09	24.76	36

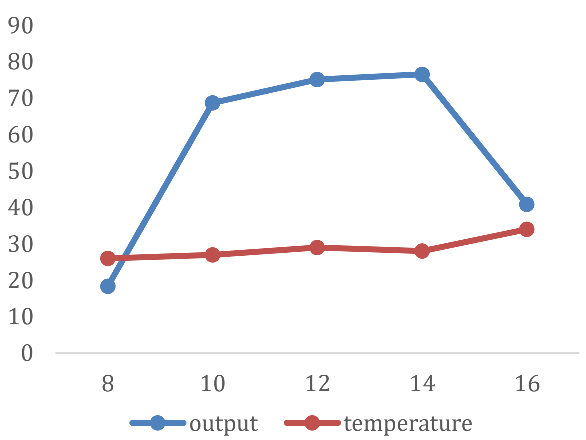
Table 9: Table of value from 80°

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	22.0	0.70	15.40	22
10:00	22.5	2.30	51.75	31
12:00	22.8	2.60	59..28	35
2:00	22.4	2.26	50.40	35
4:00	22.2	20.01	44.62	37

Table 10: Table of value from 90^0

S/N	Tilt of Angle	Average Daily Output (Watt)
1	0°	63.02W
2	10°	55.93W
3	20°	54.10W
4	30°	50.05W
5	40°	48.99W
6	50°	45.68W
7	60°	43.21W
8	70°	37.59W
9	80°	44.29W
10	90°	34.64W

Figure 2: The Graph of Output Against Temperature at angle of 0°



Discussion

The result from the table shows that by 8:00am in the morning, when the solar panel is inclined at 0^0 tilt angle the voltage was 22.3V and the current (I) was given was 1.08A. The temperature of the PV modules was at 27^0C and the output was 24.08watt. At 10:00am the voltage was observed to be 23.2V, the current was 3.50A while the temperature of the PV module increased to 28^0C, the device and the power output was 81.20watt. At 12:00noon, the PV voltage is 23.0V, direct current is reduced to 3.55A and the temperature of the PV module increase to 30^0c and power output was 81.65watt and began to decrease with time , at 4.00pm the current decreased to 22.7V due to the cloud cover over the sunlight, the current also reduces to 2.53A as temperature of the PV module increased to 42^oc and output decreased to 57.43watt. table (2) also follows the same pattern asa table (1) but with a reduction in values of the parameters under investigation. This is as a result of a change in the tilt angle of the module, the output continued to decrease as the tilt angle varies from 0^oc to 90^0c. Table (10) shows the daily average output power of the module and was found to be 63.03Watt at 0^0c and 55.93 Watt and continued to decrease as the tilt angle increases. These results show how the temperature and tilt angle affects the output and determine the best angle tilt compared to the normal capacity of the mono-crystalline solar panel.

Table 11: Table of value for average power output at various panel tilt

TIME(H)	VOLTAGE(V)	CURRENT(I)	POWER(WATT)	TEMPERATURE(^{0}C)
8:00	21.8	0.40	8.72	27
10:00	22.4	1.06	23.74	30
12:00	22.3	2.18	48.61	36
2:00	22.0	2.10	46.20	36
4:00	22.2	2.07	45.95	34

Conclusion

The result shows the performance of the 100watt mono crystalline module, at angle 0° the highest output 81.65 Watt at 30^0c was recorded, follow by a record of 75.08 Watt at 29^oc peak and 10^0c. The peak output is not up to the expected output labeled on the pv module; maximum power (100 watt), and for the current labeled (6.40A). From the result above the maximum performance of Solar PV Module (SPVM) in Anyigba in February is within acceptable value with about 81.65% out at optimum tilt angle and ambient temperature of 30^0c. The average daily output was found to be 63.02 W at 0^0c and 55.93W at 10^0 , which is about 60% output of the nominal output value of the pv module, Therefore the use of mono-crystalline SPVM is encouraged at Anyigba at 10^0c so the system can self clean rather than mounting modules on a horizontal surface (0^0c) .

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