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THE EFFECT OF HUMIDITY AND TEMPERATURE ON THE EFFICIENCY OF SOLAR POWER PANEL OUTPUT IN DUTSIN-MA LOCAL GOVERNMENT AREA (L.G.A), NIGERIA

Jamilu Tijjani Baraya[1+]
Bello Hamza Abdullahi[2]
Ugochukwu Sylvester Igwenagu[3]

[1,2,3]*Department of Physics, Faculty of Physical Sciences, Federal University Dutsin-Ma, Katsina State, Nigeria.*
[1]*Email: tjamilu@fudutsinma.edu.ng Tel: +2348036959101*
[2]*Email: abnabelders@yahoo.com Tel: +2348023362628*
[3]*Email: igwenaguugochukwu8@gmail.com Tel: +2348167397483*

(+ Corresponding author)

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ABSTRACT

Solar energy is a large inexhaustible source of energy were the power from the sun intercepted by the Earth is over a trillion watt, which is many thousand times larger than the present consumption rate on the earth of all commercial energy sources. The sun could supply all the present and future energy need, presently the major way of extracting this energy is through solar panel and the efficiency of the energy conversion is in high consideration. Research has revealed that different factors can affect the efficiency of the panel, using a DT830B Digital Multi-meter and HTC-1 Clock/Temperature/Hygrometer on a Dp-Li21 polycrystalline solar panel. This work took the liberty of analyzing the effect of humidity and temperature on the efficiency of the solar panel. The result obtained shows that current production is highly aided by temperature within 42-45°C and humidity below 35% and voltage production remains fairly stable with temperature below 42°C and humidity below 60% while the power production is fairly stable with humidity below 40% and maximum with temperature at 45°C, for power production on a panel mounted and to be mounted to be within maximum range, this analysis is to be carried out and put into consideration.

Contribution/ Originality: This study contributes to the rectification of power fluctuation encountered in the use of solar panel, when the analysis is adopted and the recommendations are observed it will reduce the harmful effect the fluctuating power output has on the external connected devices.

1. INTRODUCTION

Solar energy is a very large, inexhaustible source. The power from the Sun intercepted by the Earth is over a trillion watt, which is many thousand times larger than the present consumption rate on the earth of all commercial energy sources. This implies that solar energy could supply all the present and future energy needs of the world at a continuous basis. This makes it one of the most promising of the unconventional energy sources, presently the major way of extracting this energy is through solar panel. There is no such thing as a perfect technology; research reveals that different factors can affect the efficiency of solar panel mounting systems. Some of these factors have been studied to either increase or decrease the power production from the three types of mountings such as sun intensity, cloud cover, relative humidity, and heat build-up [1]. Photovoltaic cells are solar energy applications and are used to convert the solar energy directly into electricity by pairs of semiconductor interacting with the effect of light [2]. The limited efficiency of the photovoltaic is the hindering reason for the widespread use of solar cells. The primary cause of the photovoltaic cell low efficiency is that it uses a small part of the energy in the solar spectrum [3].

The weather has been studied to have some significant effect on electromagnetic waves [4]. Solar radiations are members of the electromagnetic waves. Photovoltaic cells employ solar radiations in their operation; hence these cells are affected by the weather or condition of the atmosphere which they are exposed [5]. In a cloudy day, the amount of radiation surely will be smaller than that of a sunny day.

Nonetheless, attention has been on how to improve on output efficiency of photovoltaic cells through the materials used in its construction but not limitations in weather. The Earth's atmosphere is composed of gases which are held together by gravity. It protects the Earth and all living things therein from solar radiation. It consists of different layers with pressure, thickness, density, and mass that also varies.

Changes in the atmosphere can produce variations in the conditions of the atmosphere which can greatly affect the Earth and its inhabitants. One of the factors which can cause these changes in the air is humidity. Humidity refers to the amount of water vapour in the air or atmosphere: It is characterized not by moist air but by the water content of the mixture of water vapour and other components of the air [6].

Humidity may be absolute or relative. Absolute humidity is the amount of water vapour in a unit volume of air which is expressed in kilograms per cubic meter. It does not change according to the temperature of the air. When there is a high amount of water vapour in the air, absolute humidity will also be high. Relative humidity is the percentage or ratio of the amount of water vapour in a volume of air at a given temperature and the amount that it can hold at that given temperature. An amount of water vapour in warm air will result to a lower relative humidity than in cool air [6].

As far as the efficiency of the solar cell is concerned, efficiency is termed as the amount of the light that can be converted into usable format of electricity. Because of the efficiency depends upon the value of Maximum Power Point of the Solar cell, due to the above effect of humidity, the maximum power point is deviated and that indirectly results in decreasing of the Solar Cell Efficiency [7].

This work seeks to investigate the effect of humidity and temperature on the efficiency of solar power panel at Dutsin-Ma Local Government Area (L.G.A), Katsina state which will be achieved through evaluation of the effect of humidity and temperature on the voltage performance of photovoltaic panel, evaluation of the effect of humidity and temperature on the current performance of photovoltaic panel and evaluation of the power output of the photovoltaic with respect to humidity and temperature.

2. MATERIALS AND METHODS

2.1. Study Area

Dutsin-Ma, a Local Government Area in Katsina state lies between latitude $12^o17.00'$N to $12^o17.84'$N and longitude $007^o26'$E. It is bounded by Kurfi and Charanchi L.G.A to the north, Kankia L.G.A to the east, Safana and Dan-Musa L.G.A to the West, and Matazu L.G.A to the South-east [8] as shown in Figure 1. Dutsin-Ma L.G.A has a land size of about 552.323 km^2 with a population of about 169,829 as at 2006 national census. The people are predominantly farmers, cattle rearers and traders.

Figure-1. Map of Katsina state showing the location of Dutsin-Ma Ibrahim and Maiwada [9].

2.2. Materials Used

i. Dp-Li21 polycrystalline solar panel.
ii. HTC-1 Clock/Temperature/Hygrometer.
iii. DT830B Digital Multi-meter.

2.3. Methods

The two major weather parameters (temperature and humidity) will be measured intermittently with time in the course of daylight and simultaneously when there is total, partial and no cloud cover/shadow-cast, output voltage and output current of the photovoltaic panel will also be measured. The photovoltaic panel is the poly-crystalline cell type with 3 W, 7.2V rating. The dimension of the photovoltaic plate is 14cm by 23cm. The panel was mounted about 25cm above the ground and exposed to direct sunlight. The outputs of the photovoltaic panel (current and voltage i.e. short circuit current and open circuit voltage respectively) were measured with the aid of a multi-meter and the humidity and temperature were also measured with HTC-1 Clock/Temperature/Hygrometer.

From the readings which will be obtained, the power from the solar panel will be determined using Equation 1. The maximum power that the solar panel can give out can be calculated using Equation 2. The normalized power output efficiency can be calculated using Equation 3 as shown by Bashir, et al. [10]. It has been shown by Ike [11] that the open circuit voltage and short circuit current depend on parameters like solar irradiance and temperature as indicated in Equation 4 and 5 and also efficiency with environmental condition shown by Equation 6.

$$P_{mea} = V_{mea} \text{ x } I_{mea} \quad (1)$$

$$P_{max} = V_{max} \text{ x } I_{max} \quad (2)$$

$$\eta_p = \frac{P_{mea}}{P_{max}} \times 100 \quad (3)$$

$$V_{oc} = \frac{nKT}{Q} \ln\left(\frac{I_{sc}}{I_o} + 1\right) \quad (4)$$

$$I_{sc} = bH = I_{max} \quad (5)$$

$$P_e = \frac{P_{mean}}{P_r} \times 100 \quad (6)$$

Where P_{mea}, V_{mea}, and I_{mea} are the measured power, voltage and current respectively. P_{max},V_{max} and I_{max} are the maximum power, voltage and current respectively that the module can give out. I_{sc} is the light saturated current, I_o is the saturation current, Q is the electronic charge, K is the Boltzmann constant and T is the temperature of the panel, P_{mean} is the average measured power P_r is the panel rated power.

3. RESULTS AND DISCUSSION

3.1. Results

The result was obtained from a practical analysis of the effect of humidity and temperature on a Dp-Li21 polycrystalline solar panel using HTC-1 Clock/Temperature/Hygrometer and DT830B Digital Multi-meter. The value for the temperature and humidity were gotten from the environment and on the solar panel by the HTC-1 Clock/Temperature/Hygrometer also the open circuit voltage and short circuit voltage from the solar panel were gotten from the DT830B Digital Multi-meter. Table 1 shows the results obtained from the practical set-up without any form of cloud cover or shadow-cast on the solar panel and Table 2 shows the results obtained from the practical set-up with partial and total form of cloud cover or shadow-cast on the solar panel. The results obtained are tabulated.

3.2. Discussion

It is difficult to make comparisons of the sun's energy falling upon the Earth at different locations because of the variation in the intensity of the sun's radiation during the day and also the variations in the length of the day. Figure 2 shows that the insolation reaches its peak at noon when the sun is at its highest point in the sky. An insolation depends on the angle of incidence of the sun's rays with the ground, increasing during the day from a very low value at dawn as the sun rises to a peak at noon and falling again as the sun sets.

The graph in Figure 3 also shows that, in this case, the total received daily energy over the 12 hours of daylight will be about 5.3 kWh. The available solar energy and thus the Equivalent Hours of Full Sun also depend on the atmospheric conditions in case of cloud cover and pollution.

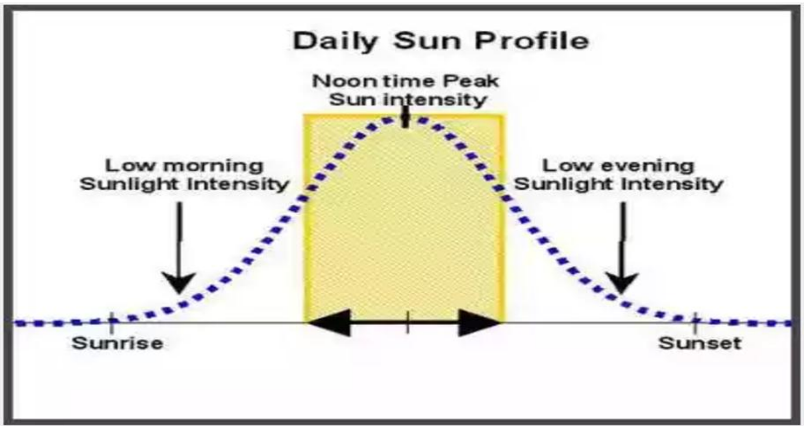

Figure-2. Variations of solar radiation intensity with time.

Table-1. Results obtained from the practical set-up without any form of cloud cover or shadow-cast on a ±4W polycrystalline solar panel.

S/N	Day	Time	Environmental temperature (℃)	Panel temperature (℃)	Environmental humidity (%)	Panel surface humidity (%)	Voltage (V)	Current (A)	Power (W)	Efficiency (η_p)
01	Wed	10:00am	32.6	34.5	65	52	6.93	0.24	1.66	41.5
02	31/7	11:00am	38.5	42.4	37	36	6.62	0.47	3.11	77.5
03		12:30am	31.4	34.2	66	56	6.77	0.53	3.59	89.8
04		1:00pm	33.2	50.1	40	21	6.46	0.46	2.98	74.5
05		2:00pm	34.9	43.4	47	37	6.54	0.44	2.88	72.0
06	Sat	10:00am	28.9	29.2	65	64	6.90	0.34	2.35	58.8
07	03/8	10:30am	31.9	32.3	58	55	7.15	0.28	2.00	50.0
08		12:00pm	33.5	33.7	49	48	6.89	0.22	1.52	38.0
09		1:00pm	34.1	34.4	46	49	6.71	0.46	3.09	77.3
10		3:00pm	32.0	37.5	50	40	6.97	0.31	2.16	54.0
11	Sun	9:00am	26.4	27.3	80	74	7.22	0.34	2.45	61.3
12	04/8	1:00pm	30.0	32.4	58	52	6.93	0.57	3.95	98.8
13		2:00pm	30.4	30.9	71	58	7.14	0.40	2.86	71.5
14		3:00pm	33.2	32.0	49	46	7.10	0.35	2.49	62.3
15		3:30pm	34.0	35.4	47	45	6.92	0.36	2.49	62.3
16		4.00pm	34.9	35.8	44	42	6.73	0.27	1.82	45.5
17		4.30pm	35.0	37.0	44	41	6.74	0.25	1.69	42.3
18		5:00pm	33.5	35.4	47	44	6.64	0.17	1.13	28.3
19	Tue	10:00am	27.2	27.3	80	79	7.28	0.42	3.06	76.5
20	06/8	11:00am	33.7	39.1	52	37	6.90	0.49	3.38	84.5
21		12:00am	33.9	37.9	53	40	7.11	0.57	4.05	100
22		1:00pm	32.4	39.9	59	38	7.15	0.52	3.72	93.8
23		1:30pm	33.9	40.0	51	40	6.97	0.52	3.62	90.5
24		2:00pm	32.5	36.5	56	36	7.20	0.54	3.89	97.3
25	Wed	9:00am	26.4	26.6	82	81	7.18	0.26	1.87	46.8
26	07/8	9:30am	29.3	31.2	71	64	7.13	0.32	2.28	57.0
27		10:00am	29.4	31.5	70	63	7.06	0.35	2.47	61.8
28		10:30am	30.6	36.0	65	50	6.99	0.38	2.66	66.5
29		11:00am	33.8	35.9	51	50	7.10	0.45	3.20	80.0
30		11:30am	33.7	38.4	52	39	6.83	0.41	2.80	70.0
31		12:00pm	34.0	37.3	50	45	6.93	0.46	3.19	79.8
32		12:30pm	34.4	37.4	49	44	6.94	0.49	3.40	85.0
33		1:00pm	35.5	37.4	45	40	6.96	0.52	3.62	90.5
34		1:30pm	34.0	38.4	55	44	6.81	0.38	2.59	89.8
35		2:00pm	33.7	38.2	45	40	6.85	0.41	2.81	70.3

36		2:30pm	33.4	38.7	56	39	6.88	0.42	2.89	72.3
37		3:30pm	34.4	35.0	52	50	6.73	0.14	0.94	23.5
38		4:00pm	32.9	34.0	53	50	6.64	0.05	0.33	08.3
39		4:30pm	33.4	35.3	54	52	6.76	0.16	1.08	27.0
40	Thu	8:30am	25.1	25.9	87	80	7.12	0.20	1.42	35.5
41	08/8	3:00pm	25.8	26.9	88	84	7.34	0.34	2.50	62.5
42		3:30pm	31.9	32.1	56	57	7.08	0.35	2.48	62.0
43	Fri	1:30pm	25.4	26.5	85	85	7.21	0.22	1.59	39.8
44	09/8	2:00pm	29.3	34.8	70	50	7.02	0.41	2.88	72.0
45		2:30pm	29.6	31.9	69	60	7.18	0.44	3.16	79.0
46		3:00pm	29.9	33.2	71	55	6.90	0.31	2.14	53.5
47		3:30pm	31.4	31.8	62	59	6.72	0.11	0.74	18.5
48		3:40pm	30.8	31.9	65	60	6.95	0.19	1.32	33.0
49		4:00pm	30.4	31.8	67	60	6.85	0.15	1.03	25.8
50		4:30pm	30.6	32.4	65	59	6.84	0.21	1.44	36.0
51		4:40pm	31.8	32.8	59	54	6.98	0.25	1.75	43.8
52		5:00pm	30.7	31.3	63	62	6.65	0.08	0.53	13.3
53	Sat	9:00am	25.5	26.5	82	80	7.34	0.34	2.50	62.5
54	10/8	10:00am	27.1	27.7	80	75	7.38	0.47	3.47	86.8
55		11:00am	31.5	36.6	58	48	6.89	0.55	3.79	94.8
56		12:00pm	33.0	39.7	53	36	6.85	0.57	3.90	97.5
57		1:00pm	32.1	40.4	57	35	6.75	0.58	3.92	98.0
58		1:30pm	32.3	39.9	56	35	6.81	0.48	3.27	81.8
59		2:00pm	32.3	38.0	57	37	7.13	0.50	3.57	89.3
60		2:30pm	32.8	46.2	56	26	6.81	0.47	3.20	80.0
61		3:00pm	32.4	45.2	55	25	6.80	0.41	2.79	69.8
62		3:30pm	32.1	36.4	54	40	7.04	0.37	2.60	65.0
63		4:00pm	32.5	34.9	54	45	6.99	0.33	2.31	57.8
64	Sun	12:00pm	27.4	28.1	80	75	7.24	0.38	2.75	68.8
65	11/8	1:00pm	32.1	40.4	57	37	6.81	0.53	3.61	90.3
66		1:30pm	32.8	41.3	54	33	6.80	0.52	3.54	88.5
67		2:00pm	33.2	43.2	50	27	6.79	0.49	3.33	83.3
68		2:30pm	34.2	44.3	47	28	6.70	0.46	3.08	77.0
69		3:00pm	33.8	41.4	47	32	7.27	0.41	2.98	74.5
70		4:00pm	32.9	44.2	48	44	6.25	0.23	1.44	36.0
71		5:00pm	31.5	33.9	50	46	7.01	0.22	1.54	38.5
72	Mon	8:00am	26.4	26.9	79	78	6.89	0.11	0.76	19.0
73	12/8	9:00am	28.1	32.8	66	56	6.88	0.20	1.38	34.5
74		10:00am	29.1	31.4	64	51	6.94	0.27	1.87	46.8

75		11:00am	30.0	31.5	60	56	7.12	0.30	2.14	53.5
76		12:00pm	30.4	32.0	59	53	7.29	0.30	2.19	54.8
77		1:00pm	32.8	36.8	51	39	7.08	0.39	2.76	69.0
78		2:00pm	32.6	37.5	52	40	6.87	0.54	3.71	92.8
79		3:00pm	27.5	29.8	72	65	7.42	0.28	2.08	52.0
80		4:00pm	30.8	39.2	61	35	6.84	0.26	1.78	44.5
81		5:00pm	30.5	36.5	65	40	6.95	0.25	1.74	43.5
82	Tue	3:00pm	32.4	37.6	62	37	7.00	0.40	2.80	70.0
83	13/8	4:00pm	31.9	37.8	63	39	6.87	0.36	2.47	61.8
84	Wed	7:00am	26.0	26.2	81	84	7.00	0.14	0.98	24.5
85	14/8	7:30am	27.1	31.0	79	60	6.83	0.21	1.43	35.8
86		8:00am	30.6	34.7	62	51	6.77	0.25	1.69	42.3
87		8:30am	29.5	32.8	65	53	6.85	0.22	1.51	37.8
88		9:00am	30.1	33.5	64	49	6.88	0.27	1.86	46.5
89		9:30am	30.9	34.1	59	51	6.95	0.31	2.15	53.8
90		10:00am	32.0	38.6	60	38	6.80	0.37	2.52	63.0
91		10:30am	31.2	40.4	58	36	6.75	0.42	2.84	71.0
92		11:00am	31.1	40.2	61	35	6.78	0.42	2.85	71.3
93		11.30am	33.8	41.4	47	32	7.00	0.48	3.36	84.0
94		12.00pm	33.5	40.1	49	35	6.83	0.48	3.28	82.0
95		12:30pm	33.7	41.8	46	31	6.88	0.47	3.23	80.8
96		1:00pm	34.4	45.0	46	25	6.80	0.52	3.54	88.5
97		1:30pm	35.0	39.7	45	33	7.28	0.50	3.64	91.0
98		2:00pm	33.2	49.8	40	21	6.46	0.46	2.98	74.5
99		2:30pm	35.1	43.5	42	28	6.95	0.41	2.85	71.3
100		3:00pm	34.7	40.9	45	32	6.93	0.38	2.63	65.8
101		3:30pm	33.8	39.7	45	33	7.06	0.33	2.33	58.3
102		4:00pm	33.9	37.3	45	39	6.83	0.22	1.50	37.5
103		4:30pm	32.9	33.9	46	45	6.60	0.07	0.46	11.5
104		5:00pm	31.1	31.4	55	54	6.78	0.07	0.47	11.8
105		5:30pm	31.6	34.5	54	45	6.76	0.14	0.95	23.8
106		6:00pm	31.2	31.4	57	56	6.70	0.10	0.67	16.8

Note: P_{mean} = 258.21/106 = 2.436 W.

Table-2. Results obtained from the practical set-up with partial and total form of cloud cover or shadow-cast on a ±4W polycrystalline solar panel.

S/N	Day	Time	Environmental temperature (℃)	Panel temperature (℃)	Environmental humidity (%)	Panel surface humidity (%)	Voltage (V)	Current (A)	Power (W)	Efficiency (η_p)
01	Sat	9:50am	27.1	27.4	74	70	6.87	0.11	0.76	19.0
02	03/8	10:10am	31.2	31.5	60	58	6.86	0.16	1.10	27.5
03		10:30am	32.5	32.2	52	53	6.62	0.09	0.60	15.0
04		11:00am	32.9	33.0	52	50	6.67	0.11	0.73	18.3
05		12:00am	32.3	32.5	51	48	6.80	0.24	1.63	40.8
06		12:30pm	32.8	33.2	52	49	6.31	0.20	1.26	31.5
07		1:00pm	33.3	34.2	46	50	6.89	0.21	1.45	36.3
08		2:00pm	33.4	37.4	47	40	6.75	0.24	1.62	40.5
09		3:30pm	31.2	31.2	55	55	6.36	0.04	0.25	06.3
10	Sun 04/8	3:30pm	33.5	33.2	50	46	6.80	0.24	1.63	40.8
11	Tue	10:36am	30.2	30.0	65	62	6.70	0.12	0.80	20.0
12	06/8	12:22pm	32.5	33.4	55	51	6.74	0.20	1.35	33.8
13		12:46pm	32.4	37.8	59	40	6.58	0.10	0.66	16.5
14	Wed	9:10am	31.3	31.4	65	63	6.87	0.22	1.51	37.8
15	07/8	12:31pm	35.5	37.4	45	40	6.56	0.15	0.98	24.5
16		3:47pm	31.4	31.8	58	54	6.54	0.06	0.39	09.8
17		3:56pm	34.2	34.5	53	50	6.54	0.08	0.52	13.0
18		4:21pm	33.1	34.0	53	50	6.22	0.03	0.19	04.8
19	Thu	9:02am	24.4	24.5	85	84	6.44	0.03	0.20	05.0
20	08/8	9:31am	24.8	24.9	87	84	6.55	0.04	0.26	06.5
21		10:03am	26.3	26.9	82	77	6.72	0.07	0.47	11.8
22		10:35am	26.9	27.3	81	79	6.75	0.08	0.54	13.5
23		11:01am	28.2	28.5	75	68	6.78	0.10	0.68	17.0
24		3:21pm	34.9	34.8	49	52	6.98	0.27	1.88	47.0
25		3:32pm	31.8	32.1	62	57	6.47	0.06	0.39	09.8
26		4:02pm	31.7	31.8	61	59	6.72	0.08	0.54	13.5
27		4:29pm	31.2	31.1	63	59	6.57	0.06	0.40	10.0
28		4:44pm	30.9	30.8	62	62	6.47	0.04	0.26	06.5
29		5:00pm	29.5	29.5	68	70	6.38	0.03	0.19	04.8
30	Fri	2:32pm	28.8	31.5	71	65	6.87	0.22	1.51	37.8
31	09/8	2:45pm	29.6	31.1	69	62	6.81	0.13	0.89	22.3
32		3:31pm	31.4	31.7	60	59	6.55	0.07	0.46	11.5
33	Sat	9:44am	30.5	31.0	61	60	6.71	0.09	0.60	15.0
34	10/8	9:50am	30.5	31.0	61	61	7.03	0.14	0.98	24.5
35		10:00am	28.8	30.0	65	59	6.29	0.05	0.31	07.8

36		12:41pm	32.9	39.2	53	37	6.14	0.09	0.55	13.8
37		1:20pm	32.1	40.2	58	37	6.28	0.08	0.50	12.5
38		2:10pm	32.2	39.6	57	36	6.48	0.08	0.52	13.0
39		3:35pm	32.1	36.5	55	42	6.94	0.23	1.60	40.0
40	Mon	9:30am	29.6	31.5	60	57	7.80	0.15	1.17	29.3
41	12/8	10:10am	30.6	33.1	59	51	6.91	0.18	1.24	31.0
42		11:10am	30.7	32.0	56	54	6.96	0.24	1.67	41.8
43		12:20pm	30.1	29.6	59	60	6.44	0.04	0.26	06.5
44		3:40pm	30.1	31.6	64	60	6.64	0.10	0.66	16.5
45	Tue	10:23am	27.6	27.8	78	77	6.95	0.11	0.76	19.0
46	13/8	11:10am	28.2	29.2	74	70	6.81	0.13	0.89	22.3
47		11:35am	30.5	31.1	66	60	6.62	0.09	0.60	15.0
48		12:02pm	30.9	32.2	65	59	7.12	0.10	0.71	17.8
49		12:36pm	31.1	33.1	63	54	6.85	0.16	1.10	27.5
50		1:07pm	32.6	35.3	57	48	7.15	0.18	1.29	32.3
51		1:34pm	33.5	33.2	55	52	6.78	0.13	0.88	22.0
52		2:00pm	31.5	32.6	65	57	6.67	0.09	0.60	15.0
53		2:32pm	31.9	36.8	61	42	6.90	0.31	2.14	53.5
54		2:55pm	32.4	37.6	61	37	6.40	0.08	0.51	12.8
55		5:00pm	31.5	31.4	60	63	6.28	0.03	0.19	04.8
56	Wed 14/8	6:30pm	31.4	31.2	60	56	4.93	0.06	0.30	07.5

Note: $P_{mean} = 54.13/56 = 0.9333$ W.

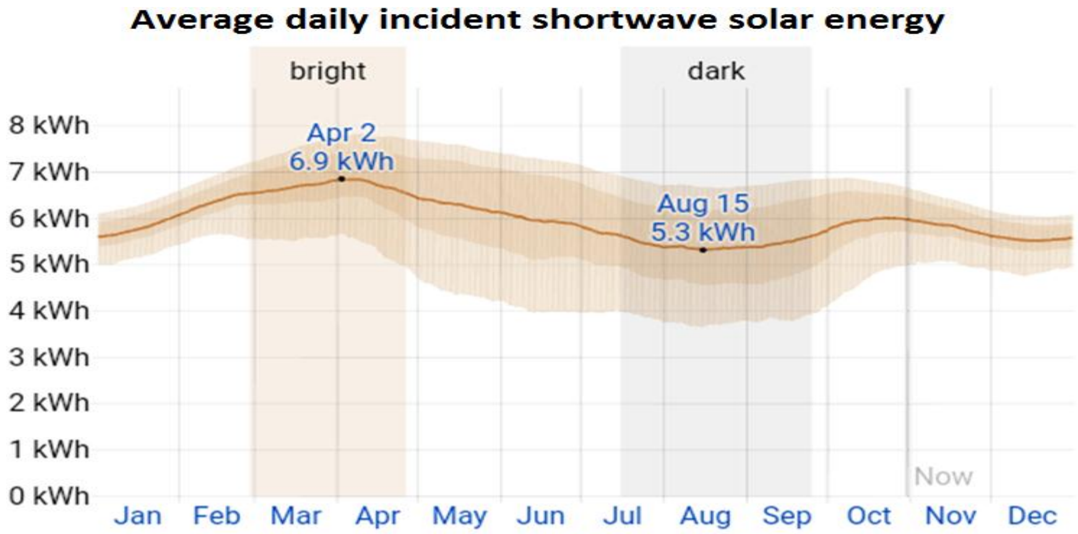

Figure-3. The average daily short wave solar radiation energy reaching the ground.

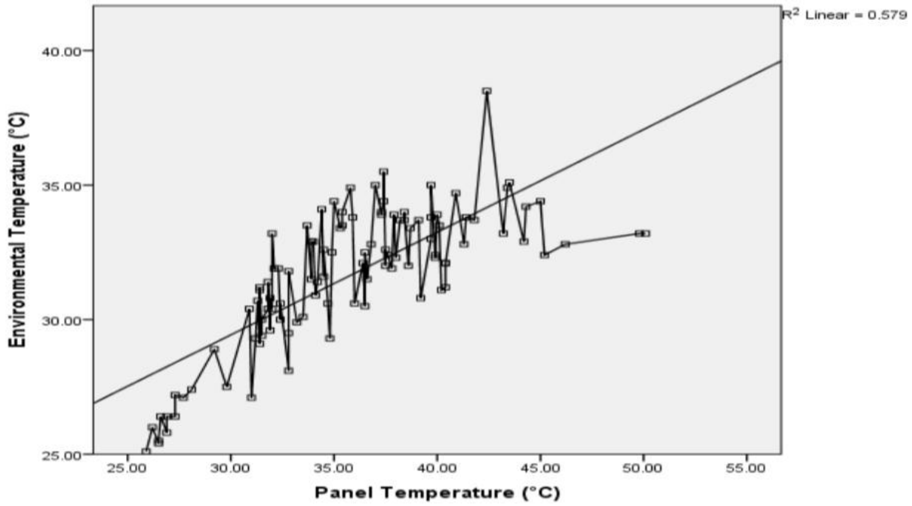

Figure-4. Environmental temperature against panel temperature. The line of best fit indicate positive correlation. It shows that the air temperature surrounding the panel determines how hot the panel will get.

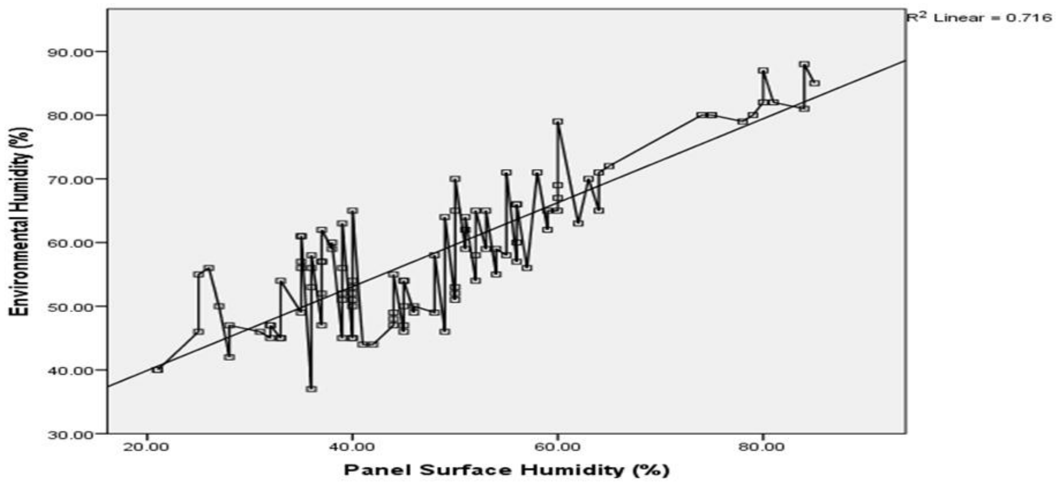

Figure-5. Environmental humidity against panel surface humidity. The reference line indicates positive slope, showing that the environmental humidity around the panel determine how humid the panel surface will be.

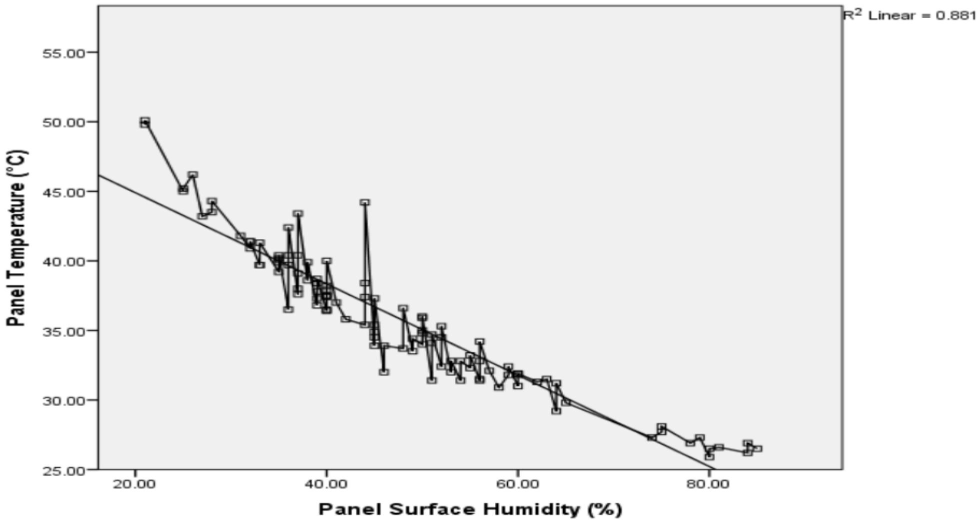

Figure-6. Panel temperature against panel surface humidity. This shows a negative slope which implies that as humidity increases, temperature decreases.

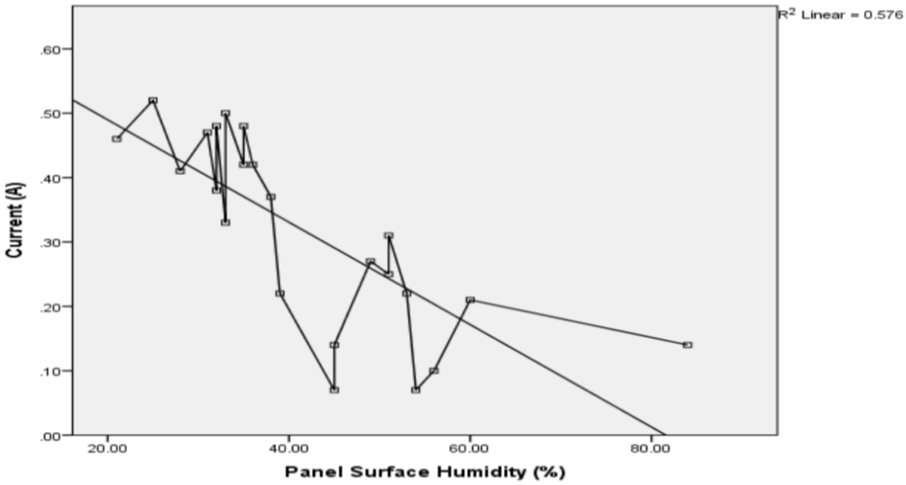

Figure-7. Current against panel surface humidity. This shows an average/estimated inverse proportionality between current and humidity.

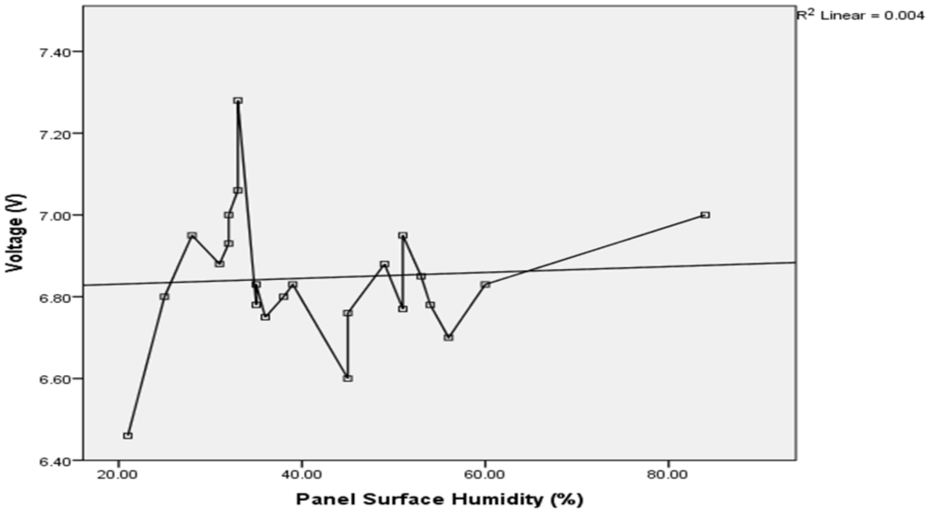

Figure-8. Voltage against panel surface humidity showing a fairly constant voltage production which has a linear increment above 60%.

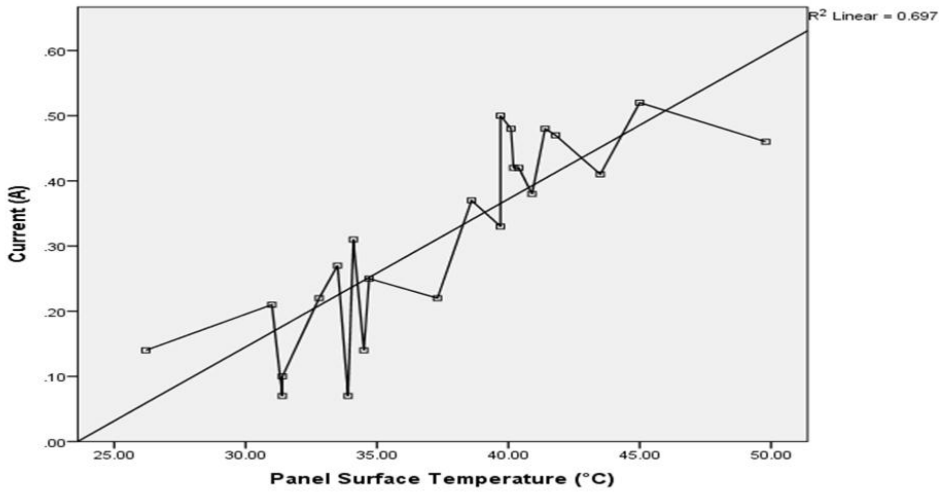

Figure-9. Current against panel temperature showing high current production at both 39.7ºC and 45ºC, the temperature starts dropping above 45ºC.

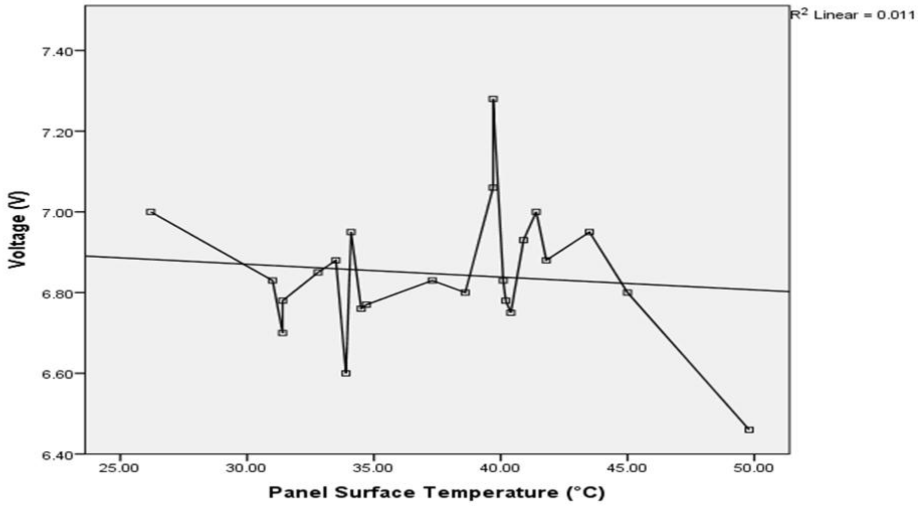

Figure-10. Voltage against panel temperature. Indicating one max and min where the max and min is dependent on both temperature and time of the day/intensity, the voltage starts dropping above 45ºC and it also show that voltage production is only fairly stable below 45ºC.

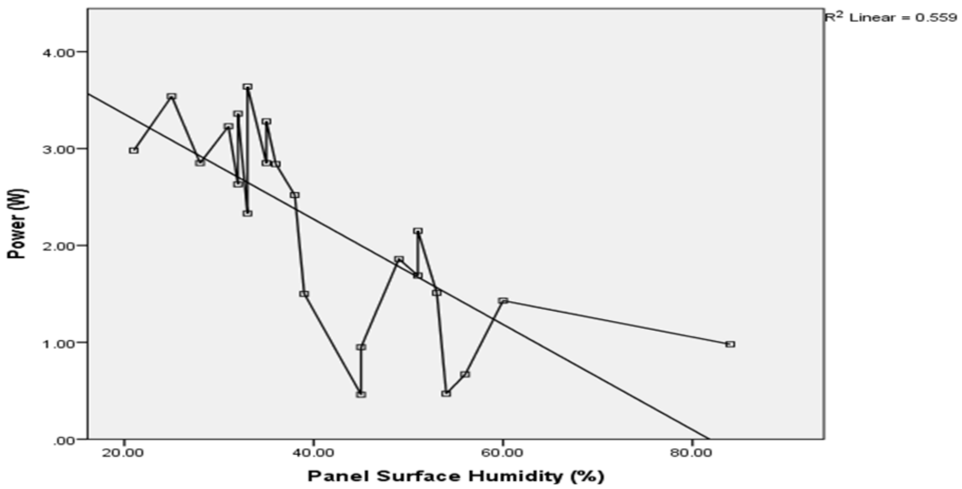

Figure-11. Power against panel surface humidity without any form of cloud cover or shadow-cast; showing a fairly stable power below 35%.

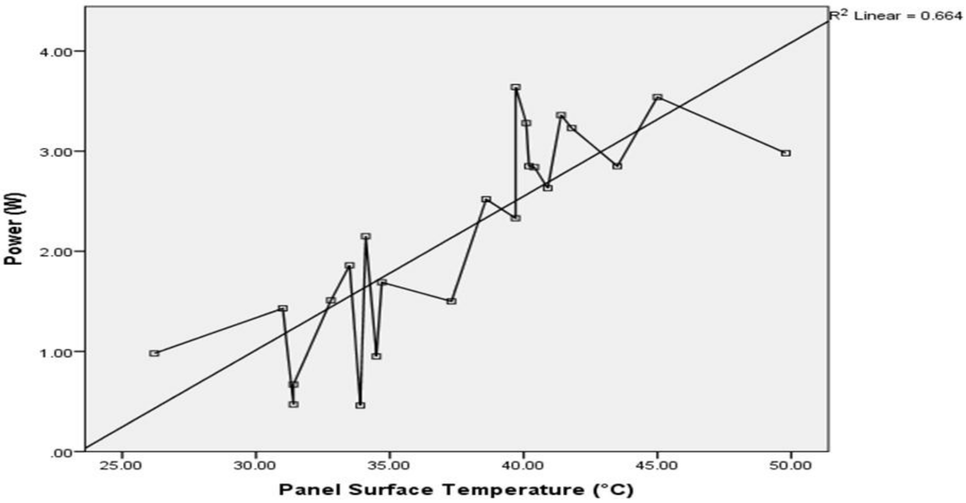

Figure-12. Power against panel temperature without any form of cloud cover or shadow cast; showing an uneven positive slope which has an increment until it reaches 45°C.

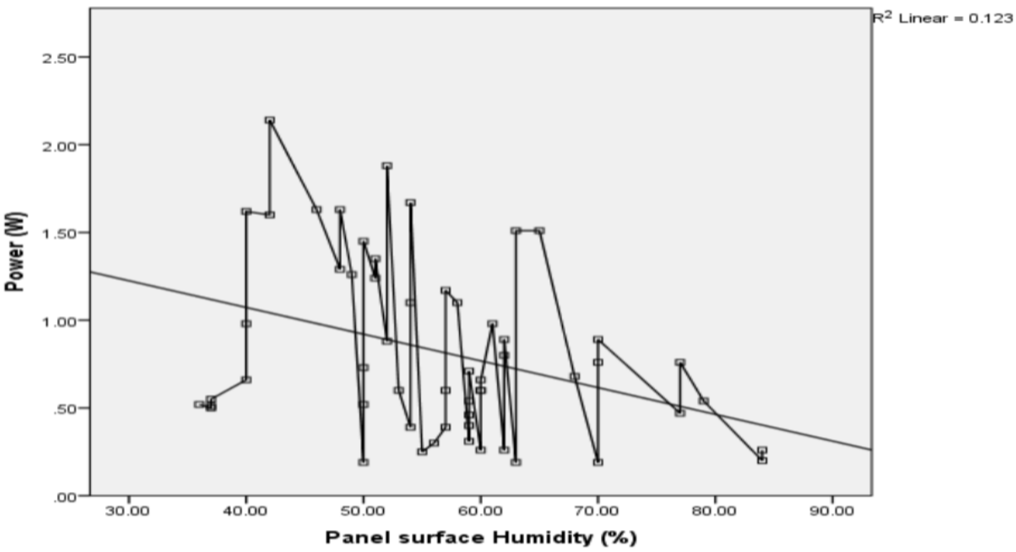

Figure-13. Power against Panel surface humidity showing the power production on the panel with cloud cover.

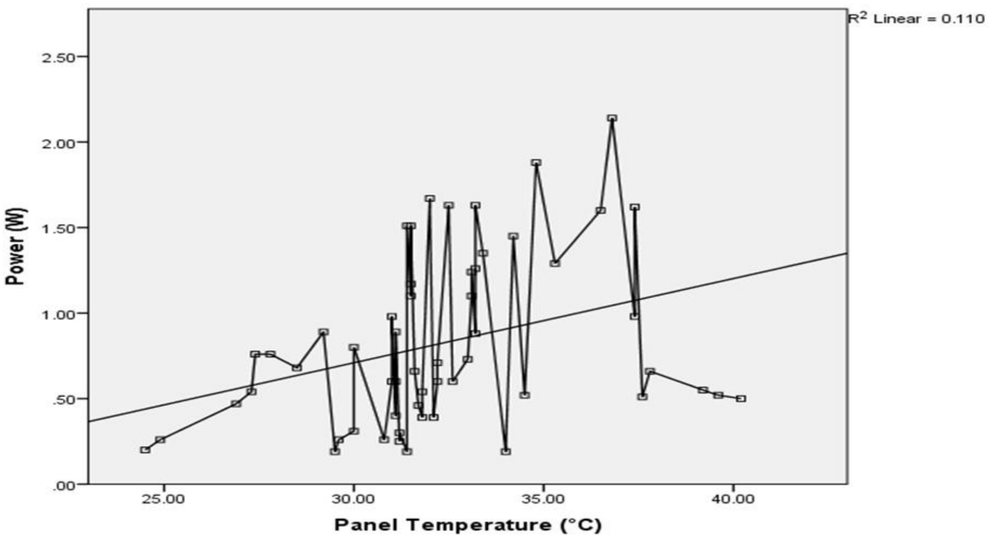

Figure-14. Power against Panel Temperature for data with cloud cover or shadow-cast; showing that power production increase fairly linearly but starts dropping above 36.8°C.

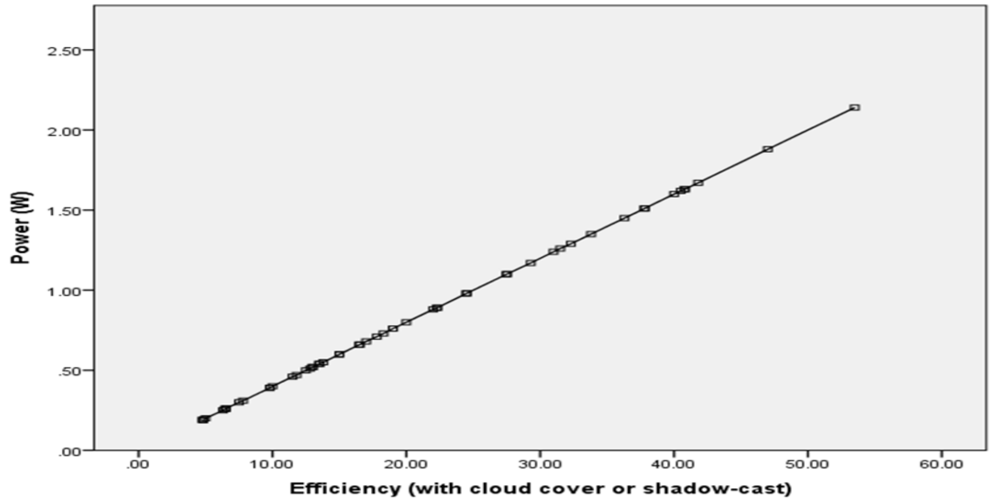

Figure-15. Power against efficiency (with cloud cover or shadow-cast).

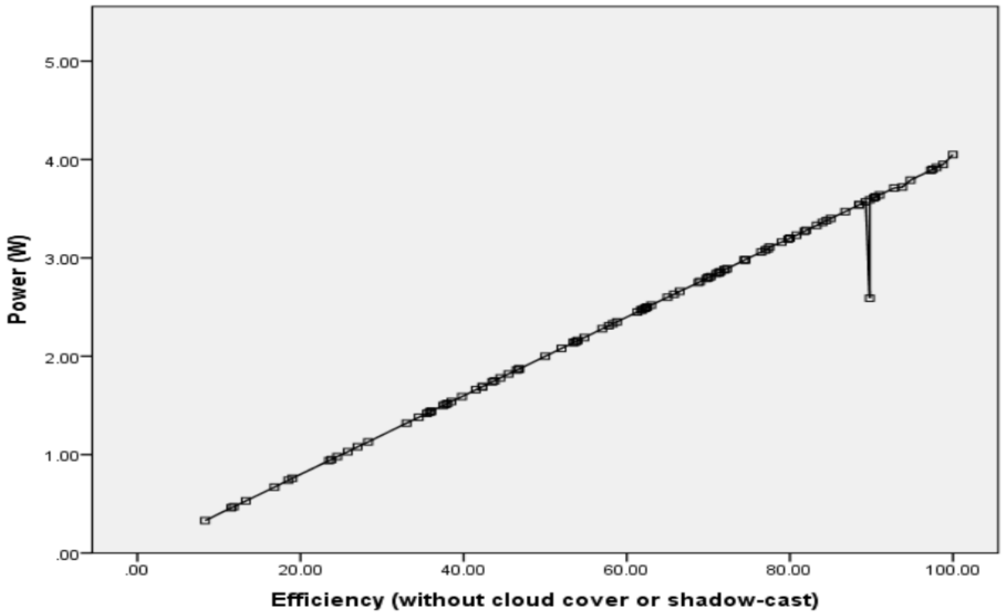

Figure-16. Power against Efficiency (without cloud cover or shadow-cast).

The graphs in Figure 12 and Figure 14 shows that temperature has significant effect on power production and also Figure 11 and Figure 13 shows that humidity has a significant effect on power production. Humidity reduces the effect of temperature as shown by the graph in Figure 11. This invariable means that the humidity acts as a coolant on the panel.

For efficiency:

1. without any form of cloud cover or shadow-cast: Normalization Power Efficiency has its maximum efficiency at the panel rated power while with cloud cover its maximum efficiency is about half the panel power rated showing a significant drop in production due to shadow-cast or cloud cover indicated by the graphs in Figure 15 and Figure 16.

2. without any form of cloud cover or shadow-cast: Power Efficiency with environmental condition:

$$P_e = \frac{2.43594}{4} \times 100 = 60.9\%$$

3. with cloud cover or shadow-cast: Power Efficiency with environmental condition:

$$P_e = \frac{0.9333}{4} \times 100 = 23.3\%$$

The efficiency P_e without any form of cloud cover or shadow-cast and with cloud cover or shadow-cast is 60.9% and 23.3% respectively showing that the P_e dropped about half which invariable means that shadow-cast or cloud cover does not support power production. Also irregularities (fluctuations) indicated by the line graph indicates that factor beyond the work scope of study is in play.

Ike [11] investigated the effect of temperature on the performance of a photovoltaic solar system in eastern Nigeria. The results showed that there is an indirect proportionality between the power output produced by the system and the ambient temperature of the locality. Thus the application of photovoltaic technology in the conversion of solar energy to electricity is not favorable during the period of very high ambient temperature than the period of low ambient temperature. The result indicated that PV solar panels must be installed at a place where they receive more air current so that the temperature remains low while the power output remains high. Kazem and Chaichan [12] carried out a research in Sohar city on the effect of humidity on photovoltaic performance based on experimental study. Results indicated that increasing relative humidity reduce the current. Increasing relative humidity from 67% to 95% reduced the current by 44.44%. In spite of high relative humidity of Sohar city the PV panel produced 62% of the maximum current in the worst condition. The voltage of PV dropped significantly with increasing relative humidity. Relative humidity has an adverse impact on solar radiation so that the resultant negative influence reflects on the PV cell output voltage. Panjwani and Narejo [13] studied the effect of humidity ranges between (40 to 78%). The study results indicated that there is an estimated loss of about 15-30% of the PV power. Humidity brought down the utilized solar energy to about 55-60% from just 70% of utilized energy. The reason for this reduction resulted from the basal layer of water vapor lied at the front of the solar cell directly facing the sun.

4. CONCLUSION AND RECOMMENDATIONS

From the results obtained, the humidity varies with temperature changes, so also is the rate at which the solar panel can provide power to an external circuit. The power production which is of optimal priority is to be highly considered and a method of panel temperature stability within the range of maximum power output is to be adopted, since the temperature has more effect on the panel while the humidity has effect on the temperature (considered as a cooling effect).

4.1. Recommendations

The experimental findings recommend the following:

i. A cooling method is to be adopted for more effective power production: humidity serves as a coolant; an artificially induced humidity can come in handy in stabilizing the temperature effect on the panel.

ii. The solar panel will perform better if mounted on a position clear of any form of shadow casting on it.

iii. An artificially induced temperature will come in handy to maintain the temperature at the position of maximum power production.

iv. Other PV materials also need to be considered to check for materials with better power productivity irrespective of the environmental weather fluctuations.

v. A filter circuit attached to the output end will reduced the fluctuations encountered and by extension avoids damage on any device receiving the power.

vi. Regular cleaning of the panel surface should be practiced since interference with direct irradiance reduces power output.

vii. Other factors beyond humidity and temperature should also be put into consideration.

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