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The Effect of Cloud on the Output Performance of a Solar Module

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Abstract:
The significance of solar energy in power production cannot be over emphasized. Its suitability as clean, abundant, pollution-free and non-mechanical moving parts system make solar power a cherish-able system for power production. This paper reports the study of the effect of light (sparse) cloud cover and heavy (thick) cloud cover on the output performance of solar module. The study was carried out in the environs of the University of Port-Harcourt (Latitude $4^0$55'58''N and Longitude $6^0$59'55''East), Rivers State, Nigeria (tropical climate region) using 250Watts Monocrystalline Solar Module inclined at 15^o and raised 2.0m above the ground level. It was observed that there was 23.80% loss in power output of the solar module due to light cloud cover and 66.75% loss in power output of the solar module due to heavy cloud cover when compared with the fully illuminated solar module. Hence, cloud cover has significant effect on the output performance of solar module.

Keywords: Solar radiation, Cloud Cover, Solar Module, Power Output, Electricity.

1. INTRODUCTION

The use of solar cells in generating electricity is becoming popular rapidly even in the developing countries. A shift from the use of fossil fuel as main source of energy to the use of photovoltaic cell will drastically prevent global warming. Solar energy has been acknowledged as a free and infinite source of energy. It is cheap, abundant, naturally available and free of pollution. Its use will decrease the rate of depletion of energy reserves. Solar energy is one of the renewable energy sources. Others are wind, geothermal, tidal and hydro. These renewable energy sources are naturally available in abundance for use. Solar technology has witnessed several developments since the time past which include the use of parabolic trough to produce steam for the first solar steam engine and the use of concentrating solar powered devices for irrigation, electrification and locomotion. Sunlight can be converted into electricity using photovoltaic (PV) Concentrating Solar Power (CSP) and various experimental technologies. Photovoltaic has mainly been used to power small and medium-sized applications, from the calculators powered by a single solar cell to off-grid homes powered by a photovoltaic array [1] Some cells produce direct current electricity from the sunlight which can be used to power equipment or to recharge battery. Photovoltaic modules can be used just like grid connected power generation. In this case, a stand-alone photovoltaic (PV) system with an inverter is required to convert direct current to alternating current. The major types of materials for building PV cells include crystalline and thin films, which differ in terms of light absorption efficiency, energy conversion efficiency, manufacturing technology and cost of production [2]. In order to increase the power output, a number of solar cells are connected together in parallel or in series and they are installed on a surface. This structure is called solar cell module or photovoltaic module. By connecting parallel or serially, the system is formed from a few Watt to MegaWatt [3]. Solar radiation data are very important to architects, engineers and scientists for energy-efficient building designs [4]. The earth receives about 174 petaWatts of incoming solar radiation (insolation) at the upper atmosphere. Approximately, 30% of it is reflected back to space while the rest is absorbed by clouds, oceans, and land masses [5]. The average solar radiation potential for a tropical climate region is about 16.4 ± 1.2 W/m^2 per day [6]. For solar energy, PV is identified to be of good potential for wide scale applications. Port Harcourt is a geographical location very close to Calabar metropolis which belongs to the subtropical climate region with typically hot and wet climate of characteristic distribution of total, diffuse and direct solar radiation [7]. Researchers have been studying various factors affecting the performance of solar photovoltaic cells in terms of environmental and designs. Solar modules work best in certain weather conditions, but since the weather is always changing, most solar photovoltaic modules do not operate under normal operating conditions. The performance of a PV system depends not only on its basic characteristics but also on the environmental factors such as temperature [8], humidity [9], shadow [10] e.t.c Cloud cover also known as cloudiness, cloud age, or cloud amount refers to the fraction of the sky obscured by cloud when observed from a particular location [11]. Okta is the usual unit of measurement of the cloud cover. The cloud cover is correlated to the sunshine duration. The least cloudy locales are the sunniest place while the cloudiest areas are the least sunny places (Figure 1).

Figure.1. A cloudy weather

During the day, the sun heats the earth, if skies are clear, more heat reaches the earth's surface and this leads to warmer temperatures. However, if skies are cloudy, some of the sun's rays are reflected off the cloud droplets back into the space.

Therefore, less of the sun's energy is able to reach the earth's surface which causes the earth to heat up more slowly, and thus cooler temperature. In this paper, the effect of cloudy weather on the performance of mono- crystalline solar module in the geographical location is quantified and reported.

2. MATERIALS AND METHOD

The materials employed in the study include two 250Watts mono-crystalline solar modules and Digital Multimeter. The specifications of the employed solar module are:

Maximum peak power = 250W
Production Tolerance = + 3%
Maximum Power current = 5.56A
Maximum Power Voltage = 18V
Short Circuit Current = 6.11A
Open Circuit Voltage = 21.24V
Application = 12Vdc

The specifications of the employed digital multimeter are:

Operating temperature = 10^0C to 50^0C
Maximum Voltage between any terminal and earth ground = 600V
Surge protection = 6kV per 600V.
Fuse of input = 11A
Storage temperature = -40^0C to +60^0C
Battery = 9 Volts Alkaline
Display = Digital LCD.

The experimental set-up was done at the University of Port Harcourt environs (Latitude $4^0$55'58''N and Longitude $6^0$59'55''E). The solar panel was set up in an open space, inclined at an angle 15^o [12] and to a height of 2.0metres from the ground level to absorb solar radiation directly (Figures 2 and 3). Depending on the movement of the sun during the day, part of the cells is shadowed by cloud cover that leads to reduced output yield, in particular, during cloudy periods.

Figure.2. Monocrystalline solar panels set up in an open space

Figure.3. Setup of solar panels under cloudy weather.

In order to predict the performance of solar module under cloudy conditions, measurements such as open circuit voltage (Voc), short circuit current (Isc), output power and weather conditions were recorded at interval of 15 minutes. One module acted as control set up which has total or full irradiance from the sun and the second module experienced partial irradiance from the sun due to cloud cover. Since it is difficult to have both clear weather and cloudy weather at the same hour of the day, the solar panel under clear weather days was taken as control test while the solar panel under cloudy weather days was taking as device under test (DUT). The readings were analysed and compared. The output power, P of a solar cell is determined from:

$$P = I.V = I_{SC} \ x \ V_{OC} \qquad (1)$$

Where:

I_{sc} is the short circuit current

V_{oc} is the open circuit voltage;

3. RESULTS

Table 1 typically shows the data collected during heavy cloud atmosphere and bright sunning days. Table 2 summarizes the V_{oc} and I_{sc} obtained during light cloud cover and fully illuminated solar module.

Table.1. Readings for the control (no cloud) and heavy cloud weather.

TIME	Isc (control)	Voc (control)	Power (control)	Isc (heavy cloud)	Voc (heavy cloud)	Power (heavy cloud)
7.00 a,m	0.52	19.08	9.9216	0.36	16.88	6.0768
7.15 a.m	0.87	19.52	16.9824	0.38	16.72	6.3536
7.30 a.m	0.62	19.02	11.7924	0.41	17.21	7.0561
7.45 a.m	1.23	19.79	24.3417	0.64	17.63	11.2832
8.00 a.m	1.24	19.85	24.614	0.66	17.65	11.649
8.15 a.m	2.22	19.95	44.289	0.99	17.87	17.6913
8.30 a.m	2.13	19.88	42.3444	0.9	17.76	15.984
8.45 a.m	2.74	19.84	54.3616	0.86	17.57	15.1102
9.00 a.m	1.05	19.01	19.9605	0.64	17.19	11.0016
9.15 a.m	0.66	18.76	12.3816	0.45	17.04	7.668
9.30 a.m	0.85	19.31	16.4135	0.59	17.38	10.2542
9.45 a.m	0.93	19.38	18.0234	0.44	17.09	7.5196
10.00 a.m	1.22	19.66	23.9852	0.44	17.07	7.5108
10.15 a.m	1.46	19.67	28.7182	0.57	17.37	9.9009
10.30 a.m	3.15	20.15	63.4725	0.81	17.57	14.2317
10.45 a.m	1.11	19.94	22.1334	0.47	17.17	8.0699
11.00 a.m	1.71	20.35	34.7985	0.58	17.34	10.0572
11.15 a.m	2.72	19.92	54.1824	0.35	16.6	5.81
11.30 a.m	1.18	19.75	23.305	0.38	16.72	6.3536
11.45 a.m	1.08	19.97	21.5676	0.39	16.78	6.5442
12.00 p.m	1.16	19.89	23.0724	0.4	16.85	6.74
12.15 p.m	0.99	19.88	19.6812	0.41	16.91	6.9331
12.30 p.m	0.95	19.87	18.8765	0.21	15.71	3.2991
12.45 p.m	0.87	19.78	17.2086	0.18	15.55	2.799
1.00 p.m	0.81	19.77	16.0137	0.14	15.05	2.107
1.15 p.m	0.79	19.76	15.6104	0.15	15.47	2.3205
1.30 p.m	0.80	19.77	15.816	0.17	16.57	2.8169
1.45 p.m	1.46	19.67	28.7182	0.43	17.17	7.3831
2.00 p.m	0.85	19.31	16.4135	0.13	15.37	1.9981
2.15 p.m	1.08	19.97	21.5676	0.17	16.39	2.7863
2.30 p.m	1.71	20.35	34.7985	0.12	14.87	1.7844
2.45 p.m	3.15	20.15	63.4725	0.18	15.96	2.8728
3.00 p.m	1.16	19.89	23.0724	0.14	15.12	2.1168
3.15 p.m	0.93	19.38	18.0234	0.19	16.51	3.1369
3.30 p.m	1.24	19.85	24.614	0.2	17.37	3.474
3.45 p.m	0.80	19.77	15.816	0.15	16.07	2.4105
4.00 p.m	1.22	19.66	23.9852	0.13	15.32	1.9916

TIME	Isc (control)	Voc (control)	Power (control)	Isc (light cloud)	Voc (light cloud)	Power (light cloud)
7.00 a,m	0.95	18.71	17.7745	0.97	18.68	18.1196
7.15 a.m	0.45	18.73	8.4285	0.55	18.75	10.3125
7.30 a.m	0.81	18.75	15.1875	0.75	18.82	14.1150
7.45 a.m	0.89	18.77	16.7053	0.98	18.56	18.1888
8.00 a.m	0.81	18.90	15.309	0.91	19.02	17.3082
8.15 a.m	0.91	18.92	17.2172	1.01	18.99	19.1799
8.30 a.m	0.99	18.99	18.8001	0.97	19.09	18.5173
8.45 a.m	1.02	19.03	19.4106	1.20	19.30	23.160
9.00 a.m	0.81	19.14	15.5034	0.92	19.41	17.8572
9.15 a.m	0.87	19.24	16.7388	0.97	19.42	18.8374
9.30 a.m	0.54	19.35	10.449	0.45	19.53	8.7885
9.45 a.m	0.66	19.33	12.7578	0.88	19.64	17.2832
10.00 a.m	1.80	18.91	34.038	1.22	18.36	22.3992
10.15 a.m	0.96	19.80	78.408	1.42	18.79	26.6818
10.30 a.m	1.24	18.63	23.1012	1.52	19.56	29.7312
10.45 a.m	1.24	18.97	23.5228	1.80	19.86	35.748
11.00 a.m	4.55	19.50	88.725	1.57	19.80	31.086
11.15 a.m	4.91	19.33	94.9103	1.51	19.57	29.5507
11.30 a.m	4.11	20.10	82.611	1.92	19.42	37.2864
11.45 a.m	4.00	19.45	77.8000	1.98	19.17	37.9566
12.00 p.m	4.32	20.12	86.9184	1.88	19.08	35.8704
12.15 p.m	3.59	19.50	70.005	0.87	19.23	16.7301
12.30 p.m	1.25	18.56	23.200	2.66	19.66	52.2956
12.45 p.m	1.80	19.81	35.658	2.43	19.32	46.9476
1.00 p.m	2.11	19.72	41.6092	2.66	19.83	52.7478
1.15 p.m	0.95	18.21	17.2995	1.62	19.29	31.2498
1.30 p.m	0.45	18.25	8.2125	1.85	19.72	36.482
1.45 p.m	0.80	17,15	13.7200	2.75	19.84	54.560
2.00 p.m	1.53	18.91	28.9323	2.55	18.74	47.787
2.15 p.m	3.44	19.80	68.112	2.47	18.47	45.6209
2.30 p.m	3.51	19.90	69.849	1.54	18.45	28.413
2.45 p.m	2.63	19.76	51.9688	1.74	18.54	32.2596
3.00 p.m	1.75	19.08	33.39	2.53	18.15	45.9195
3.15 p.m	2.55	19.98	50.949	2.83	18.34	51.9022
3.30 p.m	0.95	17.98	17.081	2.93	18.22	53.3846
3.45 p.m	1.08	18.17	19.6236	2.41	18.21	43.8861
4.00 p.m	2.00	19.92	39.84	2.54	18.07	45.8978

Table.2. Readings for the control (no cloud) and light cloud weather.

4. DISCUSSION

Figure 4 compares the output power against time of the day in-situ for heavy cloud weather and no-cloud weather. At 8:30a.m, the output power was 42.3W during no-cloud cover and 15.9W during heavy cloud weather. At 2:45p.m, the output power was 63.5W during bright sunning day but 2.8W when the cloud cover was heavy. Similar trends were obtained from graphs of output power against time of the day for other measurement days such as in Figure 5.

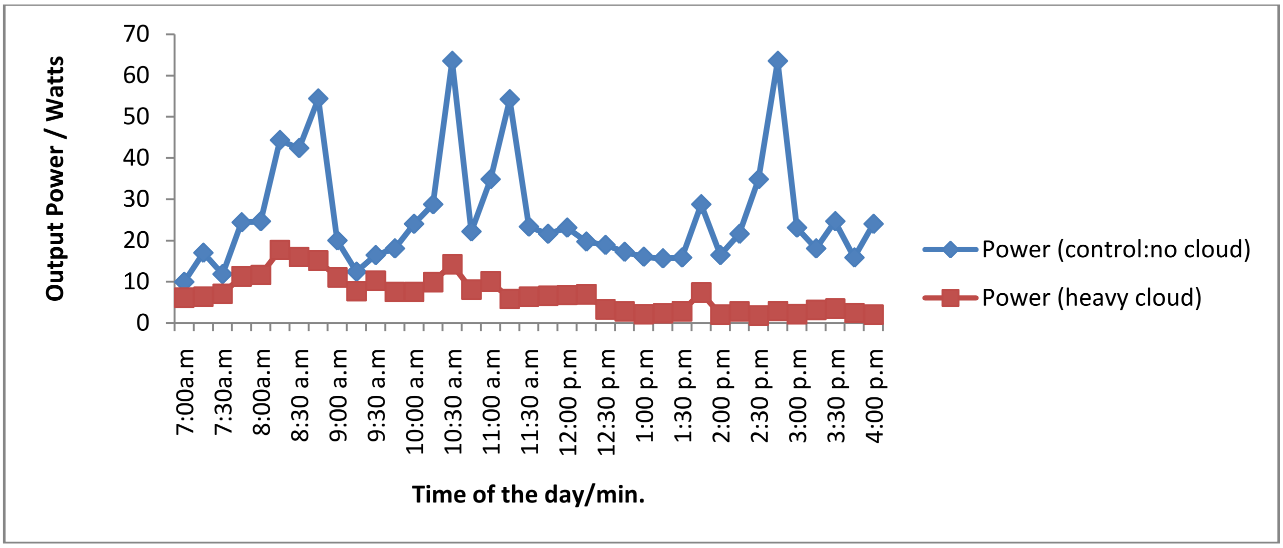

Figure.4. Comparism of output power by the module during no-cloud and heavy cloud (Day 1)

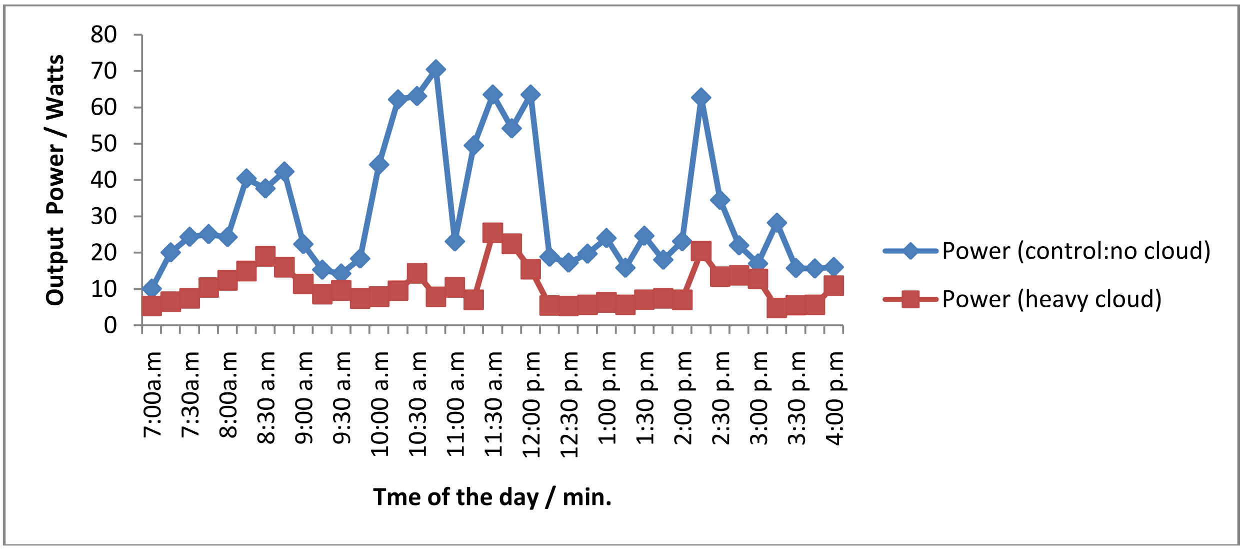

Figure.5. Comparism of output power by the module during no-cloud and heavy cloud (Day 2).

The output power was observed to be high during bright sunning days compared to during heavy cloud cover. Similar trends were observed during the bright sunning days and light cloud days (Figure 6). There were significant power outputs between 10.00a.m - 12.00 noon and 2.00p.m – 3.00p.m under bright solar radiation compared to output power under light cloud cover. Table 3 averaged the values of V_{oc} and I_{sc} for both light cloud cover and fully illuminated solar module for some days. Figure 7 compares the output between fully illuminated and light cloud cover.

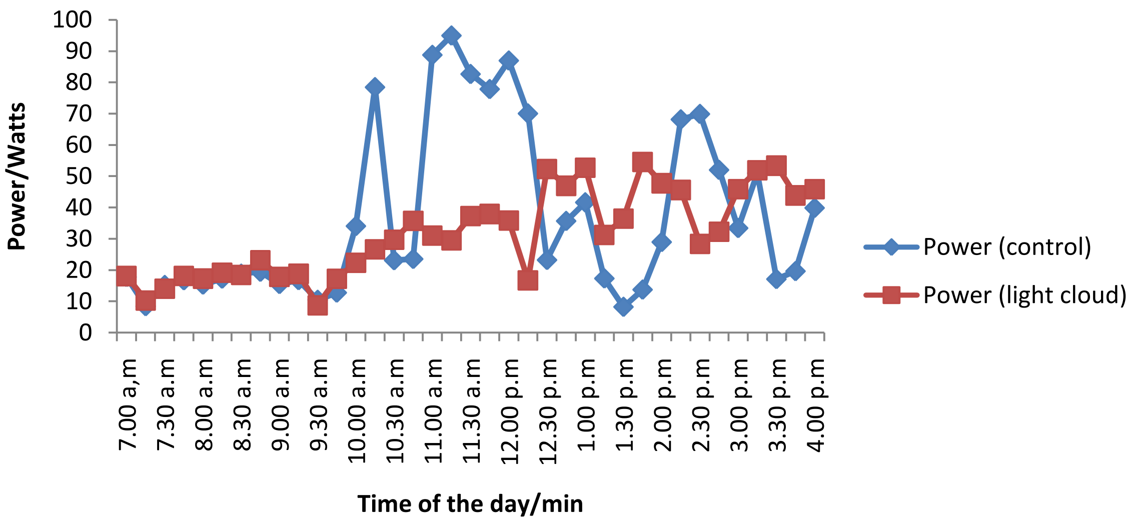

Figure.6. Comparism of output power by the module during no-cloud and light cloud.

Table.3. The average of daily short circuit current (I_{sc}) and open circuit voltage (V_{oc}) for light cloud and fully illuminated solar module.

	Fully illuminated			Light Cloud		
Days	I_{sc} (amps)	V_{oc} (volts)	Power (Watts)	I_{sc} (amps)	V_{oc} (volts)	Power (Watts)
1	1.34	20.12	26.9608	1.21	18.45	22.3245
2	2.45	19.87	48.6815	2.02	17.53	35.4106
3	3.27	18.56	60.6912	3.34	15.66	52.3044
4	4.02	19.66	79.0332	3.75	15.21	57.0375
5	5.62	14.79	83.1198	4.06	14.87	60.3722

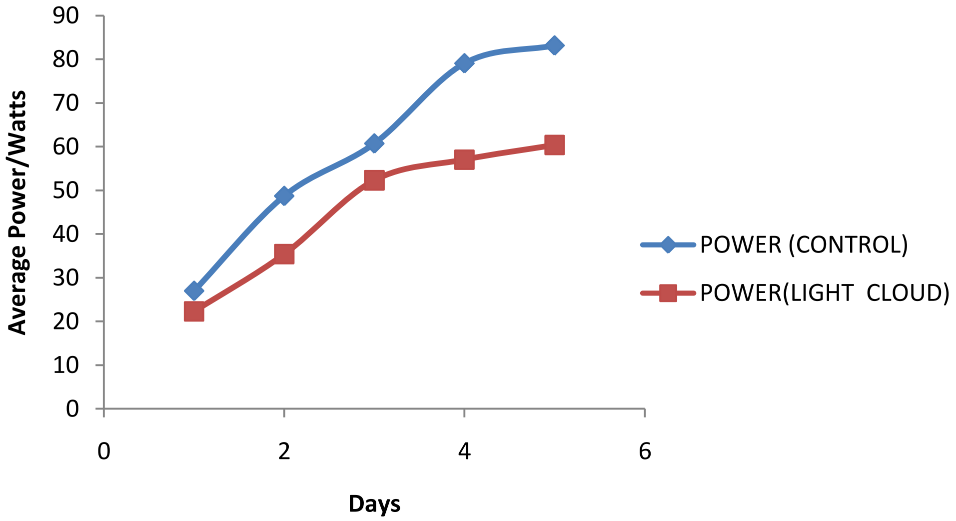

Figure.7. Average output power by the module during no-cloud and light cloud cover..

The percentage loss in power output due to heavy cloud cover is:

$$\%\ loss\,(heavy\,cloud) = \frac{31.367 - 10.429}{31.367}\ x\ 100 = 66.75\%$$

Also, the percentage loss in power output due to light cloud cover is :

$$\%\ loss\,(light\ cloud) = \frac{59.697 - 45.490}{59.697}\ x\ 100 = 23.80\%$$

The evaluations above thus show tremendous loss in the power out put of solar module due to cloud cover. This loss could range between 23% and 67% of the maximum power output to be generated by solar module under full irradiation. The loss thus depends on the thickness of the cloud cover. Hence, cloud cover has effect on the output performance of solar module.

5. CONCLUSION

The use of renewable energy source such as solar power system will reduce gas emissions that are as a result of burning fossil fuels, strong ozone layer will be created and quality of the earth's atmosphere will be improved. Cloud cover affects the power output of mounted solar panels. The cloud exhibits inverse relationship with solar power production.

The solar power output decreases as the thickness of cloud cover increases. Within the geographical location, the percentage loss in output power due to light cloud cover on photovoltaic module is estimated as 23.80%. Also, the percentage loss in output power due to heavy cloud cover on photovoltaic module is estimated as 66.75%. Since cloud is a natural phenomenon, the control mechanism may be a difficult task. A region that constantly experiences heavy cloud cover will lose significant amount of power output from solar module.

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