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THE EFFECT OF POLE'S HEIGHT ON THE OUTPUT PERFORMANCE OF SOLAR POWER SYSTEM

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ABSTRACT

Solar energy is a renewable (non-conventional) source of energy supply that has been used as a reliable energy source in view of its economic importance and its wide range of applications. In this study the effect of pole's height on the output performance of solar power system has been investigated. A solar panel of 45 watts in capacity and an inverter of 0.5KVA were used. This panel was mounted on a fabricated metallic fixed pole of initial height 298cm from the ground level, adjacent to Ofrima complex, Abuja campus, University of Port Harcourt (Latitude $04^0\ 55^1$ North and Longitude $60^0\ 59^1$ East). The height of the pole was increased by 10cm daily from initial height 298cm up to 468 cm. The open circuit voltage and the short circuit current were measured at every 15 minutes interval from 7.00am to 6:15pm in the month of October to November. When the height of the pole was 318cm, the obtained maximum daily average output power was 16.83 Watts. At an increased height of 458cm, the minimum daily average output power was found to be 5.53 Watts. Thus, the power output decreases as the pole height increases daily at some instances. The trend is not uniform at all instances. It is assumed that more of the incoming solar radiation that impinges the solar panel surface area are reflected away or diffused. This study reveals that power output produced from solar power system is independent of the height of installation of solar panel from ground level. In fact, the maximum height of pole at which the solar panel may be installed is infinitesimal small compared to the distance between the sun and the solar panel. Hence, height of mount of solar panel has no significant contribution to its power output.

Key words: Open Circuit Voltage, Short Circuit Current, Pole's height, Renewable energy, Meter rule, Solar radiation.

INTRODUCTION

Solar energy can simply be referred to as the utilization of radiant energy from the sun. Solar power is used interchangeably with solar energy. It refers more specifically to the conversion of sunlight into electricity. The conversion can be either by photovoltaic, concentrating solar thermal devices, or by one of several experiment technologies such as thermoelectric converters, solar chimneys or solar ponds and solar cookers (http://www.thefullwiki.org/solar energy).

Solar energy is one of the renewable energy sources. Others are wind, geothermal, tidal and hydro. It is clean, abundant, pollution free and requires no dynamic mechanical parts for its energy conversion. 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 a parabolic trough to produce steam for the first solar steam engine and the use of concentrating solar powered devices for irrigation, electrification and locomotion.

The earth receives about 174 peta watts (PW) of incoming solar radiation (insolation) at the upper atmosphere. Approximately, 30 percent of it is reflected back to space while the rest is absorbed by clouds, oceans and land masses (http://www.sunwindsolar.com).

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 calculator powered by a single solar cell to off –grid homes powered by a photovoltaic array (http://www.thesolarled.com/k108-solar-energy-applications-of-electrical-generation.html).

Solar cells produce direct current electricity from the sunlight, which can be used, to power equipment or to recharge battery. Photovoltaic modules can be used for grid connected power generation. In this case, a stand-alone PV system with an inverter is required to convert direct current to alternating current.

In solar power generation, the solar panel absorbs the photons and initiates current. The resulting energy generated from photons that strike the surface of the panel allows electrons to be knocked out of their atomic orbits. The electrons are then released into electric field generated by their solar cell, which then pull these free electrons into a directional current (http://www.international-com.com /cells__solar_panel.html).

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 (Mah, 1998).

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 (Figure 1). This structure is called solar cell module or photovoltaic module. By connecting parallel or serially, the system is formed from a few Watt to Mega Watt (Yilmaz, et al, 2009).

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In the early days of photovoltaic, some 50 years ago, the energy required to produce a PV panel was more than the energy the panel could produce during its lifetime. During the last decade, however, due to improvements in the efficiency of the panel and manufacturing methods, the payback times were reduced to 3 – 5 years, depending on the sunshine available at the installation site. Today, the cost of Photovoltaic is around $2.5 US per Watt peak and the target is to reduce this to about $1.0 US per Watt peak by 2020 (Kalogirou, 2009)

Solar radiation data are very important to architects, engineers and scientists for energy-efficient building designs (Li and Lam, 2000)

The average solar radiation potential for a tropical climate region is about 16.4 ± 1.2 W / m^2 per day (Green, 2000).

For solar energy, PV is identified to be of good potential for wide scale application. 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 (Akpabio and Udoimuk, 2002).

Because of day/night and time of day variations in insolation and cloud cover, the average electrical power by a solar cell over a year is about 20% of its Peak Watts (Wp) rating (Lewis and Crabtree, 2005).

Using a PV system can be more expensive than bringing power lines to a site currently without service (off-grid homes, more than 0.25 mile or 0.4 kilometre away from mountain-top communication system). How much PV need depends on the power loads, when wanting to completely replace the electrical purchases from utility with a PV system (Chow et al, 2007).

In an effort to improve the output power of a solar panel, a gain of 6.4% and 6.1% were obtained at tilted angle of $\beta = \varphi$ and $\beta = /\varphi - \delta/$ respectively (Sunderan et al, 2011).

Mousazadeh et al (2009) reported that the sun tracker could boost the collected energy 10 – 100% in different periods of time and geographical conditions. It is found that the power consumption by tracking device is about 2 – 3% of the increased energy.

Khatib et al (2009) developed a cost effective single axis sun tracker by using the PIC controller to calculate the tilt angle of the solar collectors in order to investigate the accurate sun altitude angle. Specifically, the proposed tracker increased the energy collected by 50 – 60%.

Saengprajak and Pattanasethanon (2009) studied the crucial operating temperature at which mono-crystalline(c-Si) and multi-crystalline (mc-Si) solar modules yield enhanced power output.

Yilmaz et al, (2009) formulated an easy calculation method for generating electrical energy from solar panels for pre-cost analysis.

Mounting of the modules can be in various configurations such as ground mounting, track racks, side of pole and top of pole. In the roof mounting, the modules are in the form that can be laid directly on the roof. In the newly developed amorphous silicon technology, the photovoltaic sheets are made in shingles that can replace the traditional roof shingles on one-to-one basis, providing a better economy in the material and labour (Patel, 1999).

Khatib (2010) reiterated that whether the array is fixed or tracking, mounted at ground level or on a pole or building, the objective is a solidly mounted or anchored PV array that will last for many years and withstand all kinds of weather.

In this study top of pole mounting configuration was adopted. This paper thus investigated the effects in which the incremental height of the fixed mounting pole tracker had on the output performance of a solar power system. Though, effects of various parametric conditions such as temperature, solar flux, Relative Humidity (Omubo-Pepple et al, 2009) sun angle, shadow, tilt angle and so on have been studied by many authors but little or nothing has been reported as regards the mounting height effect on the solar power output.

MATERIALS AND METHODS

The materials employed for this study were 45 Watts Multi-Silicon Solar Panel (model STP045-12/Rb), 0.5KVA inverter, 100Ah Prostar Battery, manually fabricated fixed pole tracker, Metre rule and Digital Multimeter.

The initial height of the fixed tracking pole that held the solar panel from the ground level was 298cm. This height was increased by 10cm each day of the data collection. This was done so as to determine the effect of incremental height on the output performance of the solar cell.

The Solar Panel was connected to the inverter and the deep cycle solar battery. The multimeter was used at an interval of 15 minutes to measure the open circuit voltage, V_{oc}, the short circuit current, I_{sc} and the a.c. output current and voltage from the inverter.

The data was taken between 7.00a.m till 6.15p.m each day when the sun was finally set from October 21 – November 7, 2009. Increments in height were made daily at interval of 10cm until full capacity of the pole height of 488cm was reached (Figure 2).

The electrical characteristic of the photovoltaic (PV) cell is generally represented by the current versus voltage (i-v) curve. Short Circuit current is the current measured when the output terminals is shorted (or at zero voltage). Open Circuit Voltage is the voltage measured when the output terminal is open (or at zero current.

Since the open circuit voltage and short circuit current of the solar panel were measured, one can compute the power output of the solar panel using the relation:

$$P = I_{sc} \ x \ V_{oc} \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Where

I_{sc} = short circuit current
V_{oc} = open circuit voltage
P = power output from the panel

The expectation was to observe how gradual incremental height of the pole tracker would affect the power output of the system.

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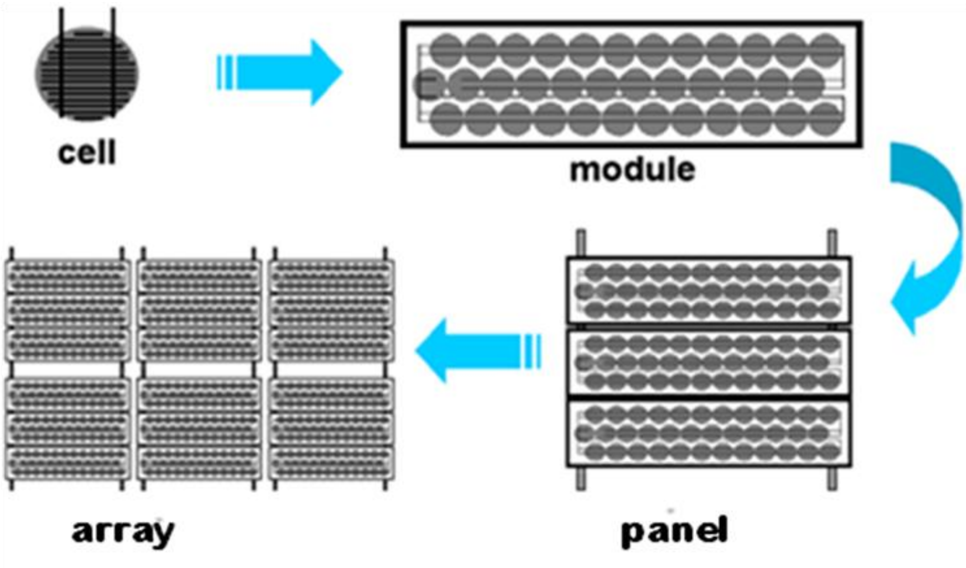

Figuer 1 : A schematic arrangement of solar cell, Module. Array and Panel

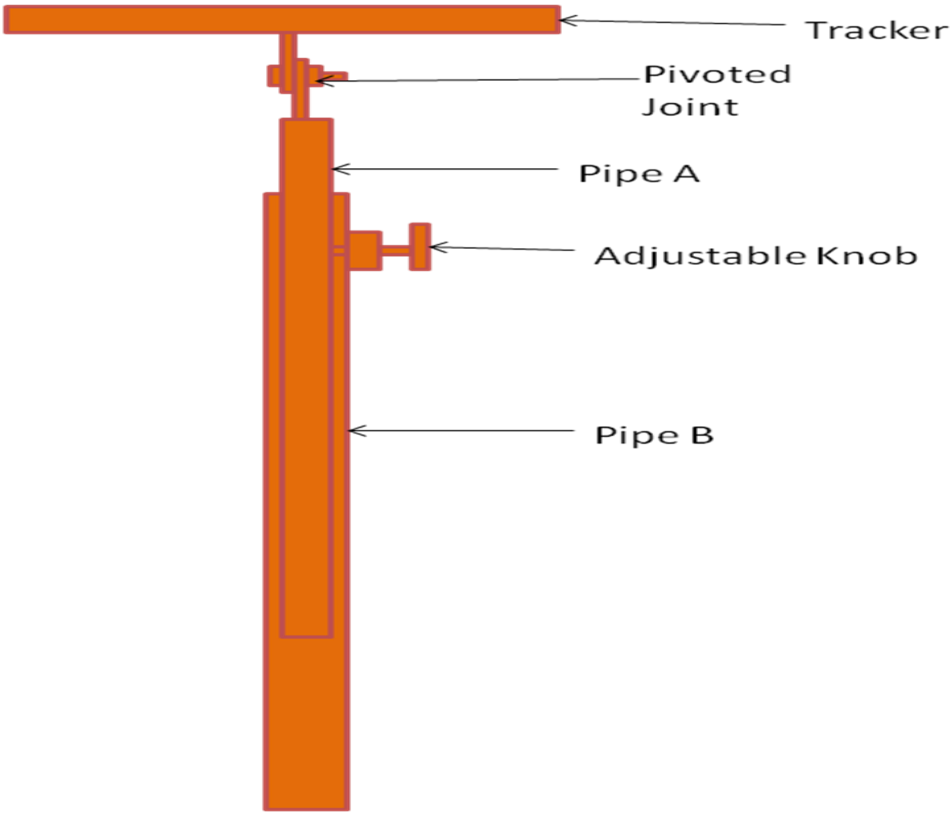

Figure 2: Manually fabricated pole tracker with adjustable height.

Table 1 below shows typical data collected on day 15. Each day has its data table throughout the study.

Table 1: Data collected on day 15 at 438cm pole's height

Time	V_{OC}	I_{SC}	Power (W)	Remark
7.00am	18.14	0.06	1.09	Cloudy Weather
7.15am	18.16	0.05	0.91	Cloudy Weather
7.30am	18.2	0.08	1.46	Low Intensity
7.45am	18.65	0.11	2.05	Low Intensity
8.00am	18.57	0.15	2.79	Low Intensity
8.15am	19.37	0.25	4.84	Low Intensity
8.30am	19.47	0.3	5.84	Low Intensity
8.45am	19.47	0.33	6.43	Low Intensity
9.00am	19.49	0.34	6.63	Low Intensity
9.15am	19.51	0.36	7.02	Low Intensity
9.30am	19.57	0.38	7.44	Low Intensity
9.45am	19.57	0.4	7.84	Low Intensity
10.00am	19.62	0.44	8.63	Low Intensity
10.15am	19.64	0.49	9.62	Low Intensity
10.30am	19.64	0.53	10.41	Moderate Intensity
10.45am	19.58	0.55	10.77	Moderate Intensity
11.00am	19.52	0.44	8.59	Moderate Intensity
11.15am	19.46	0.49	8.95	Moderate Intensity
11.30am	19.52	0.54	10.54	Moderate Intensity
11.45am	19.56	0.5	9.78	Moderate Intensity
12.00pm	19.5	0.54	10.53	Moderate Intensity
12.15pm	19.52	0.59	11.52	Moderate Intensity
12.30pm	19.42	0.61	11.85	Moderate Intensity
12.45pm	19.3	0.49	9.46	Low Intensity
1.00pm	19.36	0.51	9.87	Moderate Intensity
1.15pm	19.01	0.44	8.36	Low Intensity
1.30pm	19.21	0.5	9.61	Low Intensity
1.45pm	19.22	0.46	8.84	Moderate Intensity
2.00pm	18.88	0.35	6.61	Low Intensity
2.15pm	18.92	0.46	8.7	Low Intensity
2.30pm	19.06	0.36	6.86	Moderate Intensity
2.45pm	18.95	0.33	6.25	Low Intensity
3.00pm	19.08	0.38	7.25	Low Intensity
3.15pm	18.91	0.31	5.86	Low Intensity
3.30pm	18.9	0.26	4.91	Low Intensity
3.45pm	18.86	0.24	4.53	Very Low Intensity
4.00pm	18.67	0.19	3.55	Very Low Intensity
4.15pm	18.58	0.17	3.16	No Sunlight
4.30pm	18.46	0.15	2.77	No Sunlight
4.45pm	18.88	0.12	2.27	No Sunlight
5.00pm	18.04	0.1	1.8	No Sunlight
5.15pm	17.84	0.09	1.61	No Sunlight
5.30pm	17.04	0.05	0.85	No Sunlight
5.45pm	16.56	0.04	0.66	No Sunlight
6.00pm	13.94	0.02	0.28	No Sunlight
6.15pm	8.31	0	0	No Sunlight

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Table 2 below also shows the incremental height, the total power obtained daily and the average of the daily power.

Table 2: Showing Height, Total Daily Power and Average Daily Power

Day	Height (CM)	Total Power (Watts)	Average Power (Watts)
Day 1	298cm	335.06	7.13
Day 2	308cm	662.46	14.09
Day 3	318cm	791.14	16.83
Day 4	328cm	423.46	9.01
Day 5	338cm	506.82	10.78
Day 6	348cm	510.48	10.86
Day 7	358cm	503.63	10.72
Day 8	368cm	620.34	13.20
Day 9	378cm	455.62	9.69
Day 10	388cm	435.88	9.27
Day 11	398cm	429.62	9.14
Day 12	408cm	446.93	9.51
Day 13	418cm	394.38	8.39
Day 14	428cm	340.5	7.24
Day 15	438cm	279.59	5.95
Day 16	448cm	318.12	6.77
Day 17	458cm	260.05	5.53
Day 18	468cm	263.77	5.61

RESULTS AND DISCUSSION

Power – Time of the day Characteristics

On day 1, the panel was at an initial height of 298cm. The maximum power output for the day was 22.67 Watts at 1.00 pm and the intensity of sunshine was high. At the early hours of the day, there was mixture of a cloudy weather and rainfall (Figure 3). The maximum power output of 39.38 Watts at a height of 338cm was recorded on day 5. The intensity was considered high at 1.45p.m when this value was recorded. The early hours of the day was cloudy and likewise the evening period (Figure 4).

At a height of 348cm, the maximum power output obtained on day 6 was 36.89 Watts at 11.30a.m. The intensity of sunlight was high at the early hours of the day but the evening period was characterized with cloudiness and rainfall (Figure 5).

The maximum power output for day 7 was 35.25 Watts at 11.30am when the height of the pole was 358cm (Figure 6) and day 8 was characterized by a moderate intensity and a maximum power output of 39.74 Watts at 11.15am with pole height of 368cm. The afternoon period of the day was characterized by a very cloudy weather with no sunshine (Figure 7).

The height of the pole was kept at 378cm on day 9 and maximum power outputs of 33.5 Watts at 12.00pm with a very high intensity. There was a cloudy weather condition from the afternoon till the evening of the day (Figure 8). At a height of 398cm the maximum power output for day 11 was obtained as 24.5 watts at 9.30am (Figure 9). At a height of 448cm, the maximum power output for day 16 was 14 .14 Watts at 10:15am with a low sunlight (Figure 10).

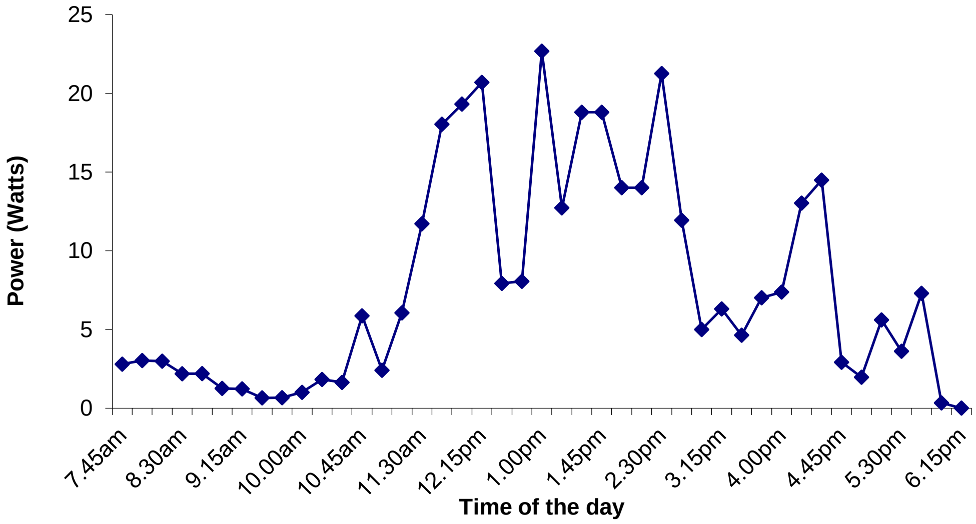

Figure 3: Graph of Power produced against time of the day for day 1.

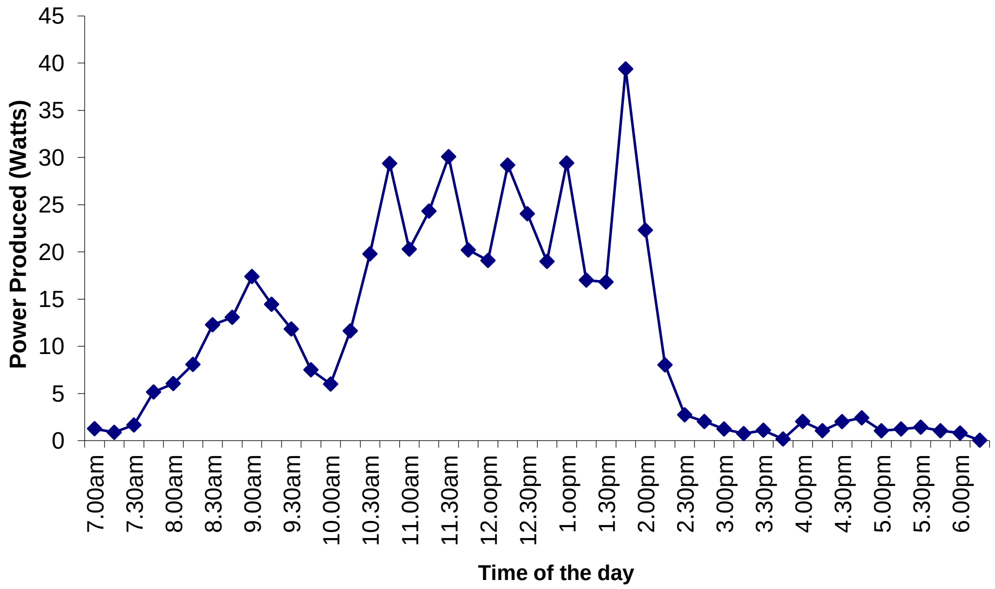

Figure 4: Graph of Power produced at each time of the day 5.

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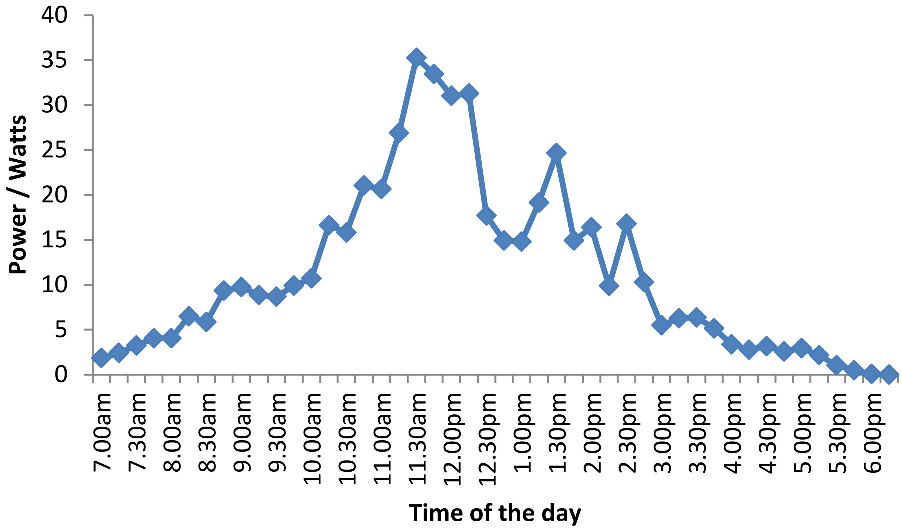

Figure 5: Graph of Power produced at each time of the day 6.

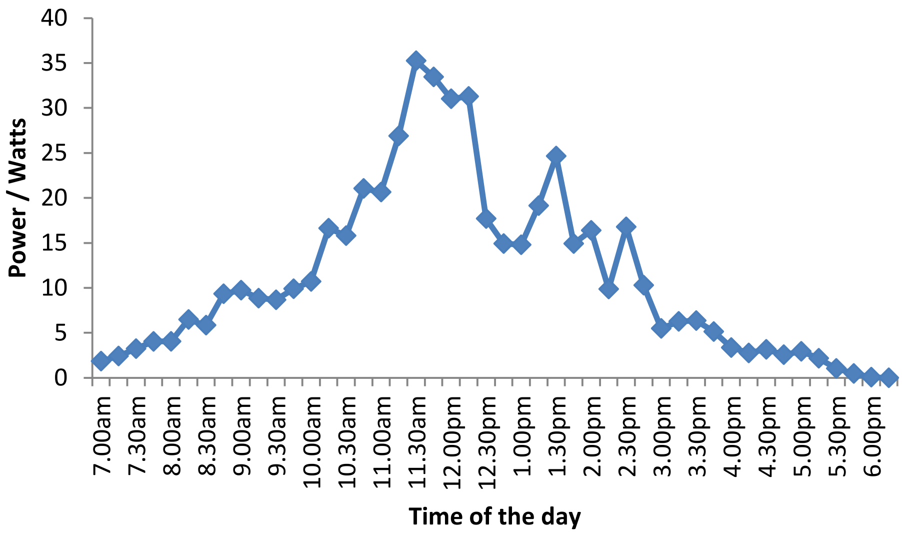

Figure 6: Graph of Power produced at each time of the day 7.

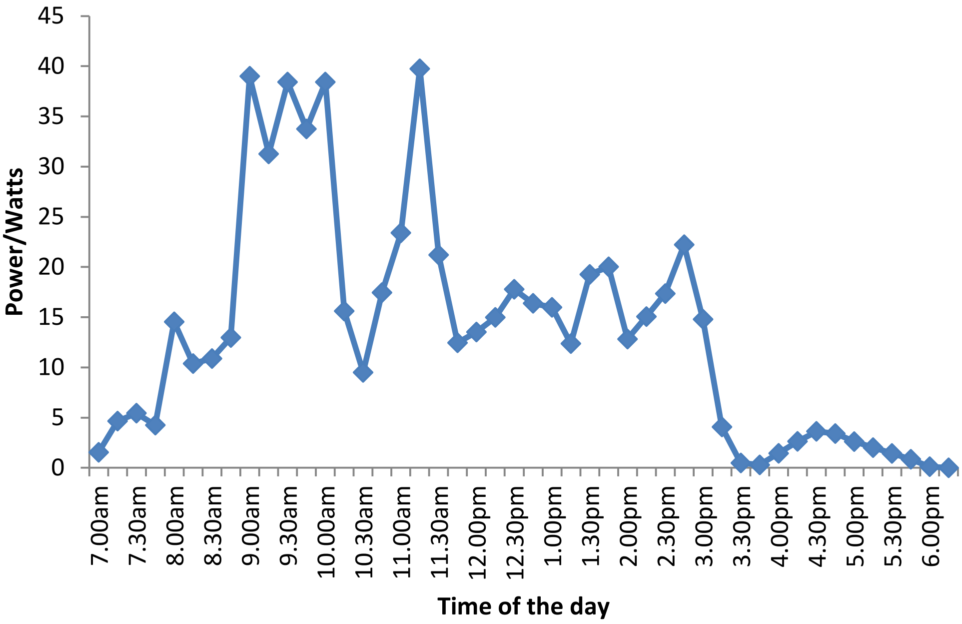

Figure 7: Graph of Power produced at each time of the day 8.

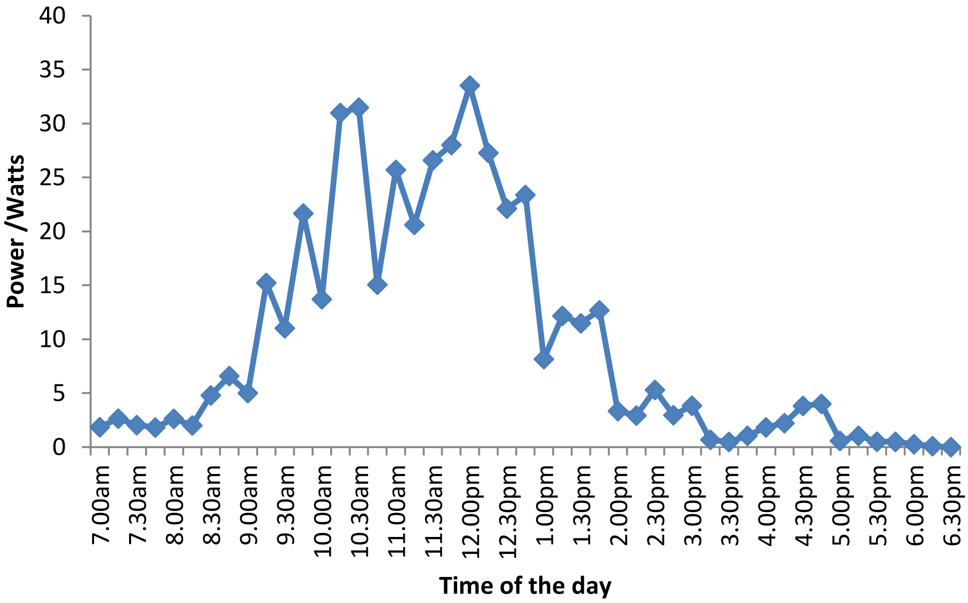

Figure 8: Graph of Power produced at each time of the day 9.

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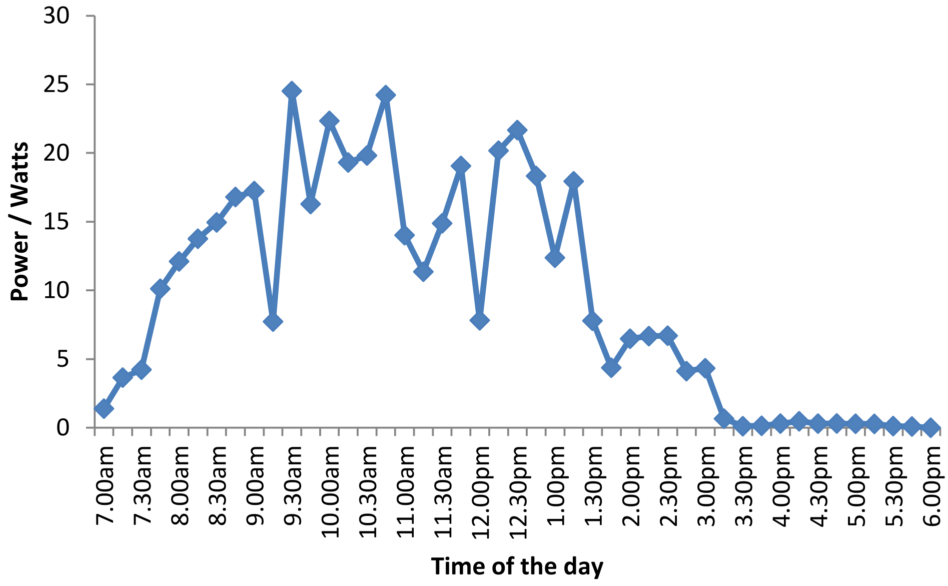

Figure 9: Graph of Power produced at each time of the day 11.

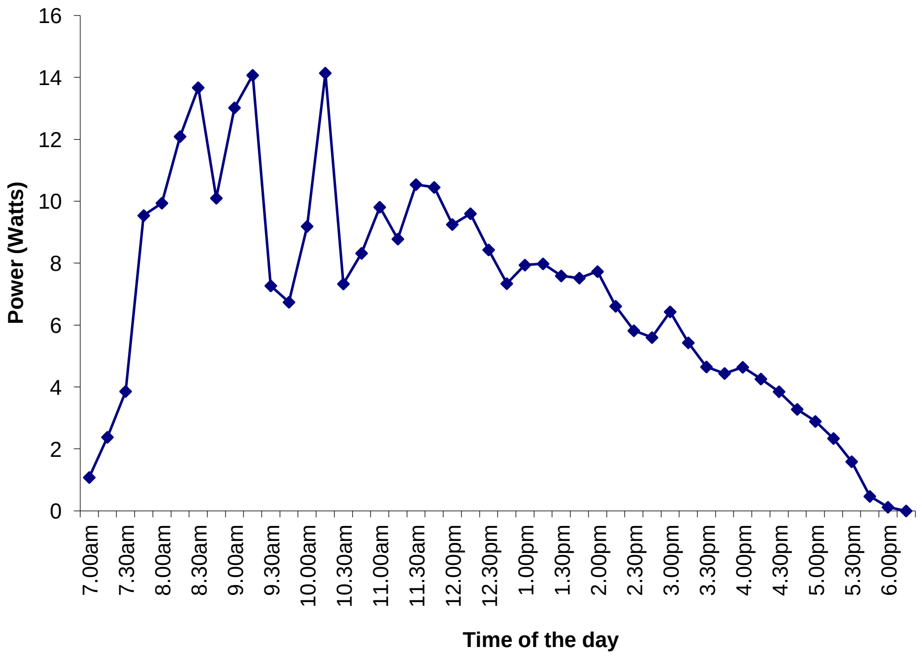

Figure 10: Graph of Power against Time of the day for day 16.

I-V CHARACTERISTICS

The I-V characteristics for day 8 show a maximum I_{sc} of 1.99 Amperes and V_{oc} of 19.97 Volts and a minimum I_{sc} of 0 Ampere when V_{oc} was 6.39V. The trend line shows an increase in voltage produces corresponding increase in current (Figure 11).

The I_{sc} for day 16 was similar to that day 15 because the value of I_{sc} throughout the day was not up to 1.0 ampere. The maximum I_{sc} of 0.72 Ampere with corresponding V_{oc} of 19.64 volts were obtained. The minimum I_{sc} gradually reduces to 0 Amperes when the V_{oc} was 3.15 Volts. Similarities in weather conditions were presumptuously responsible for identical day 15 and 16 characteristic curve (Figure 12). The trend line also shows direct proportionality between short circuit current and open circuit voltage.

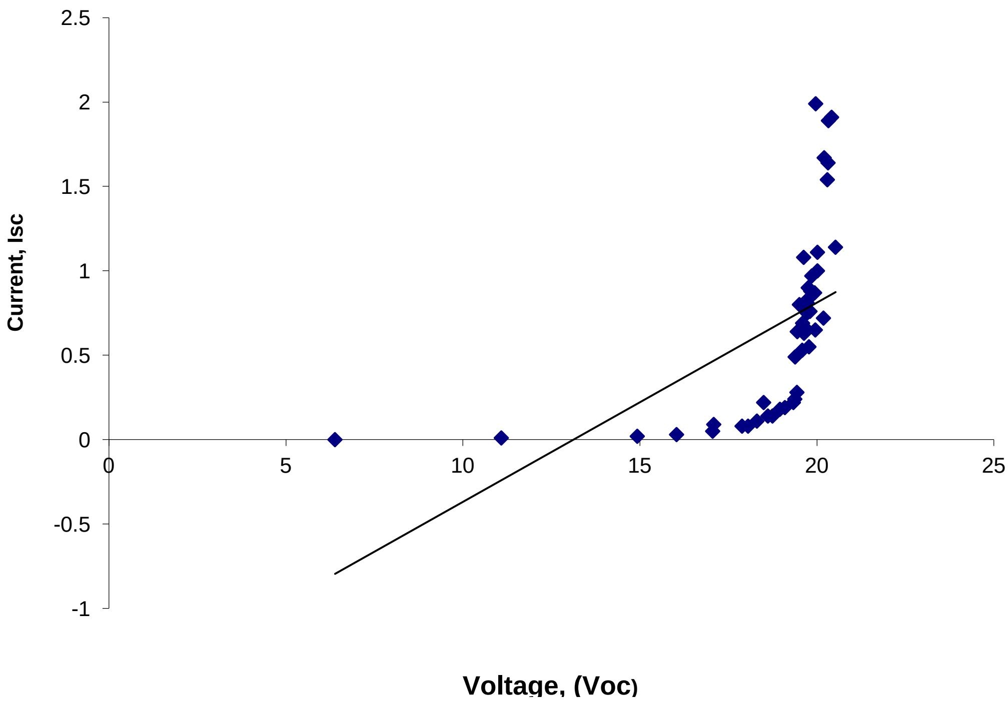

Figure 11: i – v characteristic for day 8.

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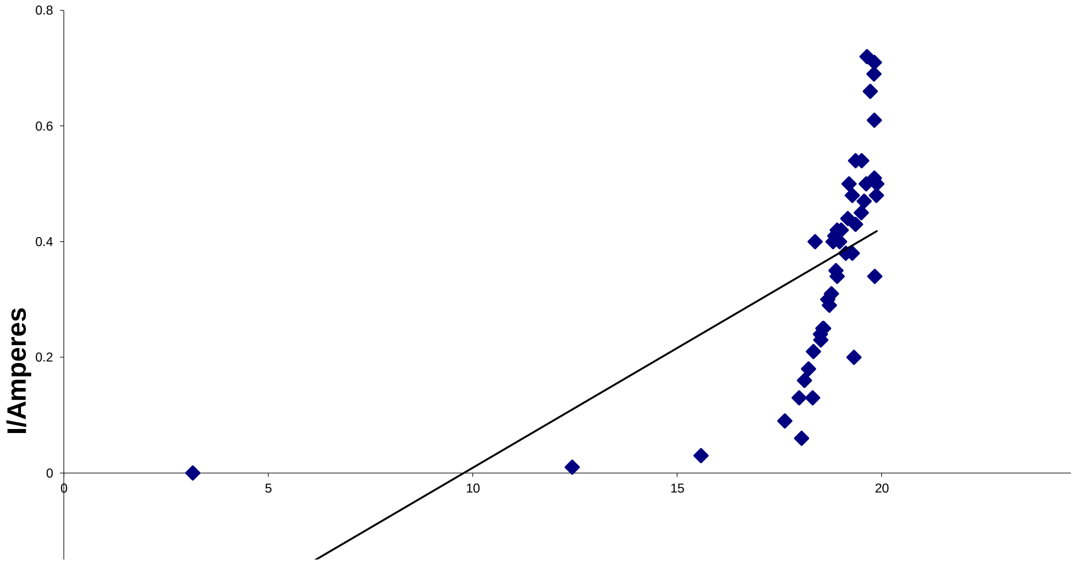

Figure 12: i - v characteristics for day 16

Height – Power Characteristics
Throughout the study, the maximum daily average power output was 16.83 Watts when the pole's height was 318cm. The minimum daily average power output was 5.53 Watts when the pole's height was 458cm (Table 2). One could have expected the average power output of the solar panel to increase as the height of the tracking pole increases each day towards the solar radiation, but the trend is not uniform. Thus, the power output decreases at some instances, as the height was gradually increased towards sun (Figure 13). It could be assumed that more of the solar radiation impinging the solar panel surface area were reflected and diffused even when the pole's height increases. The distance between the Sun and maximum pole's height is enormous for it to have produced significant effect.

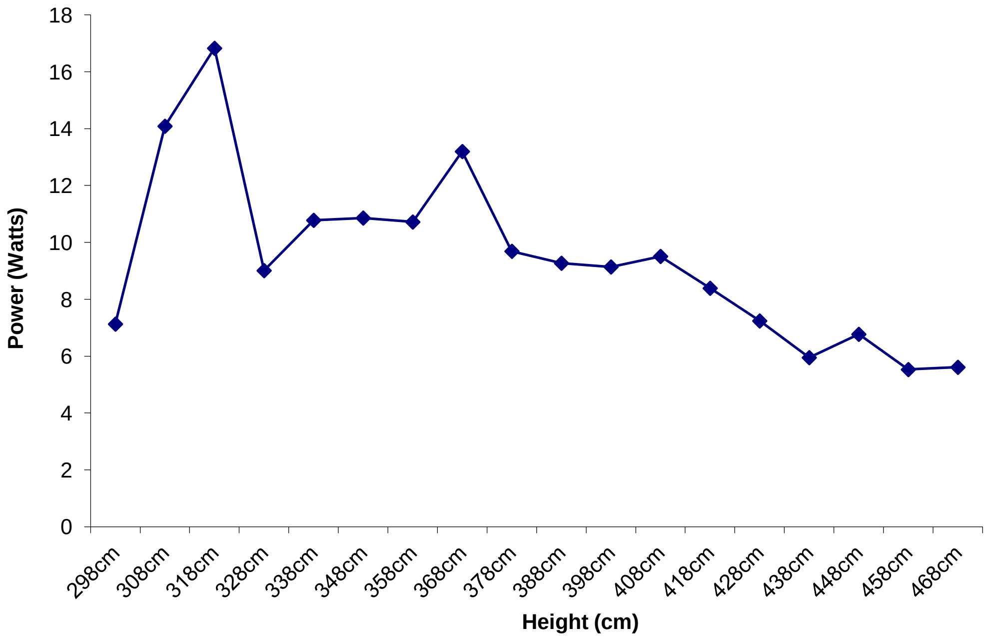

Figure 13: Graph of Daily Average Power Output against Daily height.

The study of effects of pole's height of a tracker on output performance of a solar power system reveals that, instead for the power output to increase as the pole's height increases towards the sun, the output power fluctuates i.e. decreases at some instances and increases at other instances. So, no uniform trend or proportionality is obtained. This then suggests that increasing the pole height of the solar panel may not have any significant effect on the power output. But, the power output is greatly influenced by the weather conditions. Thus, the pole, irrespective of its height, must be placed at a point where it can fully harness the incoming solar radiation.

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