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Performance Evaluation of a Solar Module at Ilorin

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Abstract

The performance of an 85W, 18V solar panel was investigated under tropical condition at Ilorin, (latitude 8^0 32^l N and longitude 4^0 34^l E). The variation of the open-circuit output voltage of the solar panel with time in different months; December, March and April representative of dusty, clear and cloudy sky conditions were studied. Results showed that the terminal voltage of the solar panel depends on the time of the day and the weather condition. From 7:00hr to 18:00hr, the terminal voltage of the solar panel ranges from 15V to 19V. A 12V 26Ah deep-cycle AGM battery storage battery, which is essential to store the electrical energy, was fully charged with the solar panel within 10 hours at this location.

Keyword: Solar energy, Solar panel, Tropical region, Day length, Ilorin.

1. Introduction

The energy crisis resulting from the shortage of petroleum in the developing world makes it necessary alternative energy sources, which are both clean and relatively cheap. Among possible alternative energy sources such as wind, tidal wave, geothermal and biomass, the most pollution-free and limitless source is solar energy (Evbogbai *et al*., 2009). Solar energy is the energy from the sun. It travels to the Earth through space in discrete packets of energy called photons. On the side of the earth facing the sun, a square kilometre at the outer edge of our atmosphere receives 1,400 Megawatts of solar power every minute (Holladay, 2008). However, only about one half of that amount reaches the earth's surface. The atmosphere and clouds absorb or scatter the other half of the incoming sunlight energy.

The spectrum of the solar light coming from sun covers from about 250 nm to about 2500 nm in energy spectrum. Visible light with respect to human beings covers from 400 to 700 nm, at which band the light intensity is very dense, which is about 1.5 $W/m^2/nm$ at 400 nm, then going up to about 1.75 $W/m^2/nm$ at about 550 nm and which then comes back to 1.5 $W/m^2/nm$ at 700 nm as can be deduced from figure 1 given below.

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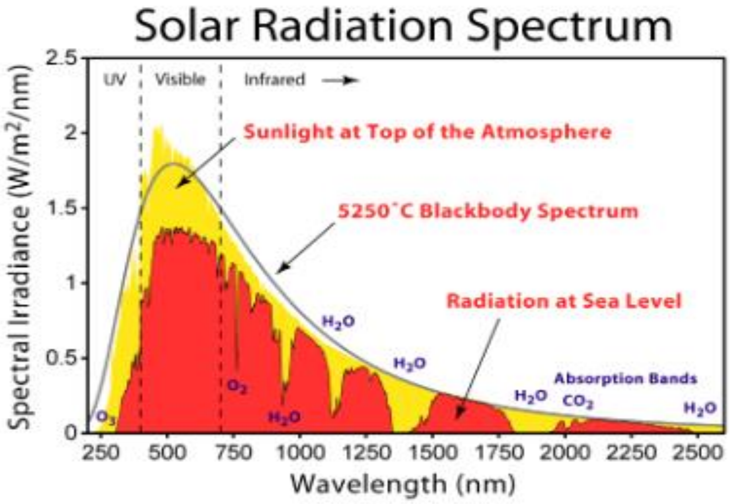

Figure 1.1: (Source: Wasfi, 2011)

The amount of solar radiation received in a location depends on the local time of day, the day of the year (season of the year), the amount of cloud cover and latitude at that location. It is to be noted that the solar intensity varies with the time of the day, peaking at solar noon and declining to minimum at sunset (Holladay, 2008).

The advantages of using solar energy for electricity generation outweigh the associated disadvantages. Solar energy is a clean and green energy. It does not pollute the environment and does not produce any greenhouse gas. In other words, its use does not contribute to the increase in global warming. Solar energy is completely renewable. As long as there is sunlight, there will be solar energy. This situation is unlike the use of fossil fuels, which will eventually be depleted with use. The dependence on oil is also decreased by the use of solar energy. Although, the initial cost for installing solar panel for electricity generation is high. Solar energy might be free but the equipment necessary to harness the energy is usually expensive.

Solar panels only work in the daytime (when the sun is out), so energy output from the solar system is only limited to the day. There is therefore a need to store the energy generated by the system during the period of sufficient sunlight to be used when sunlight is not available, which is done using deep cycle rechargeable batteries of very high amperage. (Evbogbai *et. al*., 2009).

Solar energy is best harnessed on sunny days as doing this on cloudy day is not really productive. This also means that it may be easier for certain regions, such as the tropical countries, to greatly harness solar energy as compared to the other less sunny regions or regions far away from the equator depending on which side of the hemisphere they are (Sukhatme and Nayak, 2008).

The tropic is a region of the earth surrounding the Equator. It is bounded in the Northern hemisphere by the tropic of Cancer in the northern hemisphere at approximately $23^{\circ}26'16''$ (23.4378^0) N and by the tropic of Capricorn in the Southern Hemisphere at $23^{\circ}26'13.4''$ (23.43706°) S; these latitudes correspond to the axial tilt of the earth (Muhammad, 1983). Africa, second largest of the earth's seven continent, is covering 23 percent of the world's total land area and containing 13 percent of the world's population (Newman, 2008). Africa straddles the equator and most of its area lies within the tropics.

Ilorin, the location of this experimental set up fortunately falls within the tropical region. It is located on latitude $8^0 32^l$ N and longitude 4^0 34^l E. Solar energy reaching the Earth in tropical zones is about $1KWhm^{-2}$ giving approximately $5\text{-}10KWh/m^2$ /day. In countries within 3.2 km of the equator, the use of such energy can be economically significant (Evbogbai *et. al*., 2009).

2. Materials and Methods

The components of this experimental set are: a solar panel (A crystalline silicon, 85W, and 18V), a solar charge controller, a 12V 26Ah battery, a digital multimeter, cables, a wooden table, and a ruler.

The specifications of the solar panel used are given below:

Dimension = 0.5 m by 1.2 m, Irradiance = $1000Wm^{-2}$, AM 1.5, Cell temperature = 25^0C

Open-circuit voltage, V_{OC} = 21.8V, V_{PM} = 17.6V, Output power, P_{max} = 85W.

P_{max} is the maximum power generated by the solar panel in full sunlight with the panel facing directly at the sun overhead in a clear sky and where the temperatures of the solar cells is at 25^0C. These are the standard test conditions (STC). V_{PM} is the voltage at STC.

The solar panel was positioned on a structure to ensure direct exposure to sunlight and to prevent shadow being cast on the solar panel. The solar panel was tilted at an angle, oriented North-South and facing the East, on the table, to ensure generation of maximum power by the solar panel. The device reacts best to direct light that is perpendicular to it for the production of the desired voltage and current. According to Gupta, 2012, the two most important parameters widely used for describing the cell electrical performance is the open-circuit voltage V_{oc} and the short-circuit current I_{sc} .

The short-circuit current is measured by shorting the output terminals, and measuring the terminal current under full illumination. Short circuit condition occurs when resistance tends to infinity. The maximum photo voltage is produced under the open-circuit voltage (Gupta, 2012).

A digital multimeter is then connected to the terminals of the cables, taking into account its polarities. Readings were taken with the meter and recorded at regular interval from dawn to dusk at an interval of one hour on daily basis (for the selected days of the year). The open-circuit output voltage of the solar panel was measured and recorded.

When charging the battery, the terminals of the solar panel were not connected directly to the battery but connected to a solar charge controller (also known as regulator) and then the battery to the charge controller. This is to prevent overcharging. Part of the indications of a fully charged battery, which is constancy of the voltage on the battery, was monitored and the battery was disconnected from the solar system.

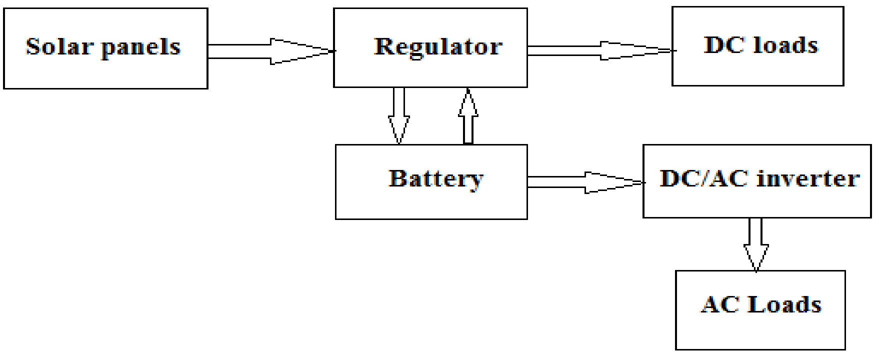

Figure 2.1: *A block diagram of solar power system* (Source: DianguinaDiarisso *et. al.*, 2013).

3. Results and Discussion

From all the plots (Figs. 3.1 – 3.6) of the voltage-time characteristics of the solar panel, it was observed that there is sharp rise in the output voltage of the panel from around 6:00hr of the day to 7:00hr. Also there is an increase in the voltage generated by the solar panel between 7:00hr and 8:00hr. The results of the variation of the output voltage of the solar panel with time show that the solar panel will operate maximally between the hours of 7:00 and 18:00 LT. This may vary depending on the season of the year. By around 9:00hr, it approaches its peak. Between the local time hours of 8:00 and 18:00, the curves shows a little variation in the output voltage of the solar panel, this could be attributed to climatic and weather conditions; especially amount of cloud present, which to a large extent affects the intensity of the sun and hence; the performance of the solar panel. The terminal voltage of the panel begins to drop progressively from 19:00hr, to zero around 19:30hr.

From figure 3.1 it can be observed that there is a decrease in the value of the voltage generated by the solar panel at 14:00hr and at 15:00hr; 17.92V and 17.85V respectively and a deep decrease at 16:00hr; having a value of 7.1V.The difference in the voltage is 10.75V.

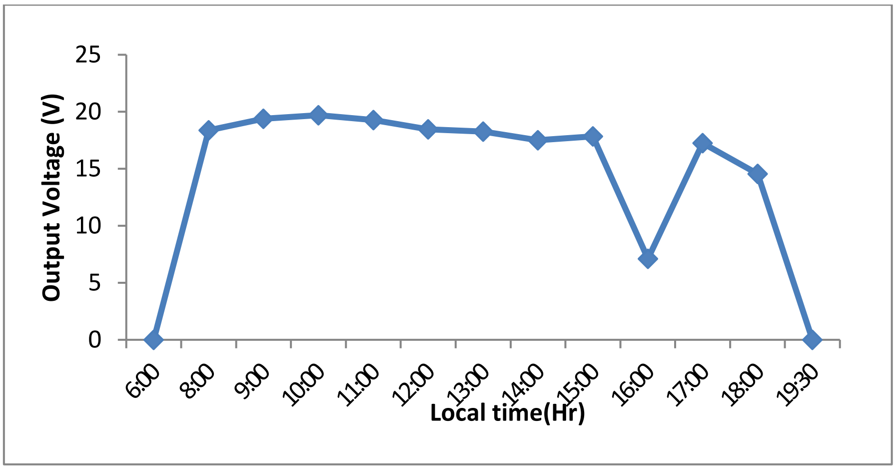

Figure 3.1: The variation of the output voltage of the solar panel with time of the day for a cloudy day on 11th December.

This is as a result of the enormous amount of cloud cover around 14:00hr on this day. What a huge amount of drop in the voltage! It started to rain around 15:00hr at the site of the set up and this contributed to the voltage measured at 16:00hr. The voltage measured, as generated by the solar panel, rises again to about 17.00V at 17:00hr when the rain had stopped. Indeed, weather condition determines the operation of solar cells for electricity generation in a particular location.

Considering the performance of the solar panel on a clear day as illustrated by fig.3.2, there are only little variations of the output voltage of the panel with time of the day from the hours of 8:00 to 18:00.

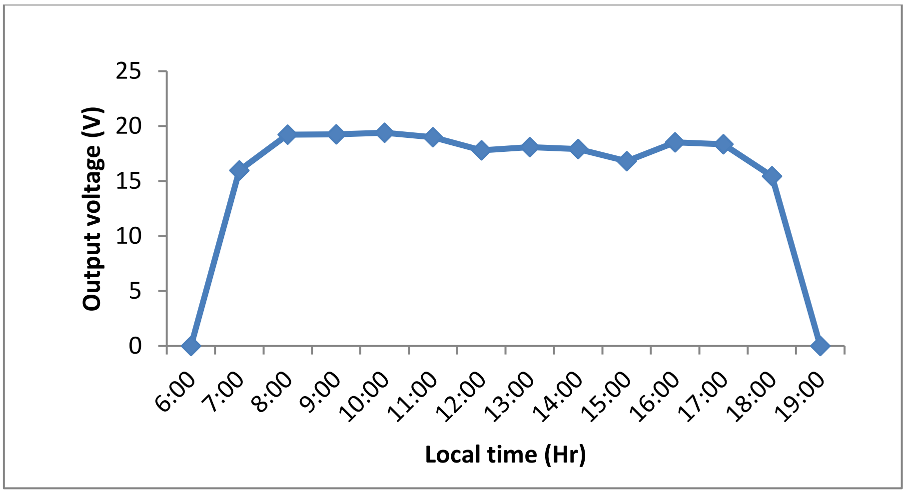

Figure 3.2: The variation of the output voltage of the solar panel with time of the day for a clear day on 12th December.

There was no marked decrease in the output voltage measured during the day. There was a high intensity of the sun available on this day for the solar cells to convert to electrical energy. Fig. 3.3 shows this comparison.

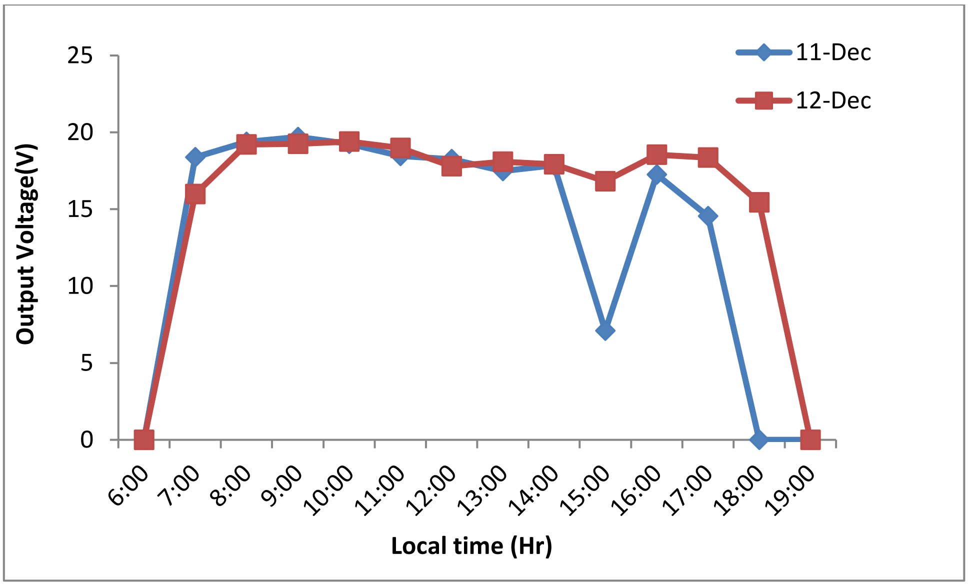

Figure 3.3: Comparison of the variation of output voltage of the solar panel with time of the day on a cloudy and a clear day; 11th December and 12th December respectively.

Figures 3.4 and 3.5 illustrate the performance of the solar panel on some other clear days, at a different position of the sun; the equinox. At this period, it was observed that the performance of the solar panel improved vis-a-vis its output voltage, compared with that of December; the solstice, at the location of the experiment.

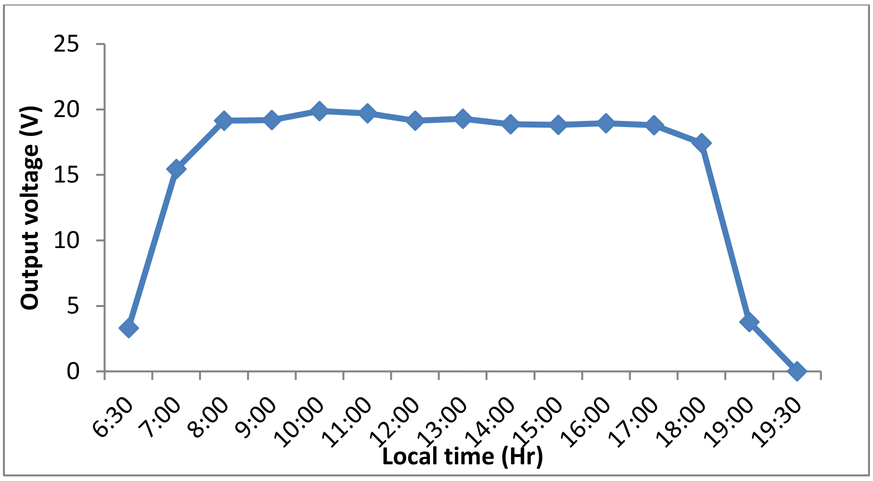

Figure 3.4: Variation of the output voltage of the solar panel with time of the day for a clear day on 26th March.

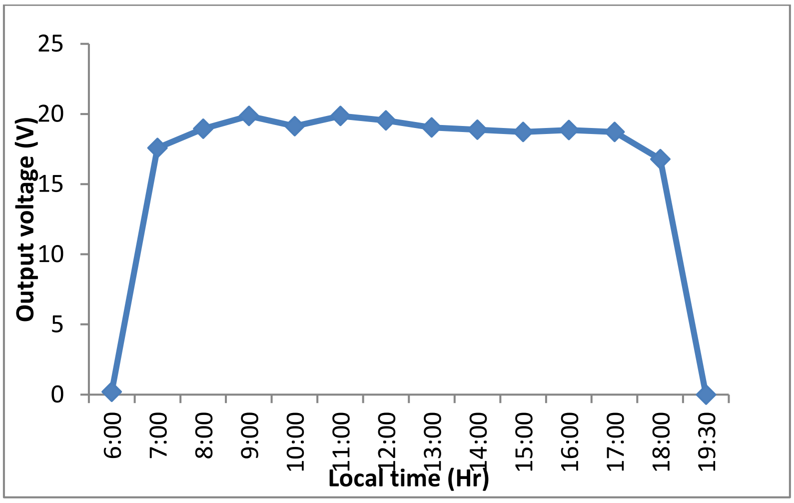

Figure 3.5: Variation of the output voltage of the solar panel with time of the day for a very clear and sunny day on 17th April.

Figure 3.6 shows the comparison of the operation of the solar power device at April (around the Equinox) and December (around the Solstice).

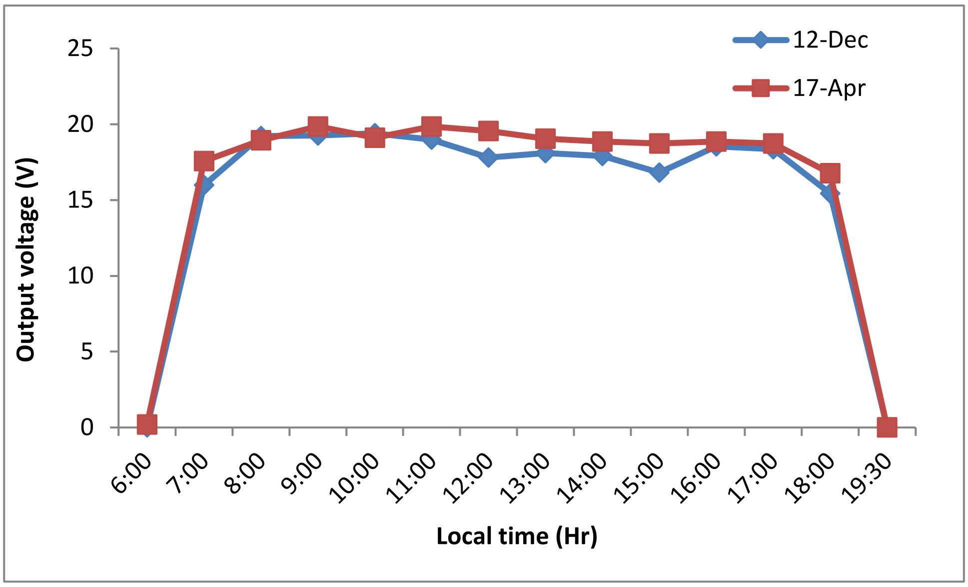

Figure 3.6: Comparison of the variation of output voltage of the solar panel with time of the day in the two different seasons (December and April).

From the curves, it was observed that there is an increase in the open-circuit output voltage of the solar panel in the month of April, compared with that of December. At 12:00hr, the voltage generated was 17.8V in December and 19.55V in April. The difference of **1.75V** existed between the two months, though at the same hour of the day. There were less of dust particles in the atmosphere, less of cloud cover and consequently, less of attenuation of solar radiation at this period. Although, one of the peculiarities of the location of the set-up is an almost regular 12 hours of sunlight throughout the year, except for differences in weather conditions at some period. However, the number of hours for sunlight in a location is a function of sun's declination angle at that location.

Theoretical approach to obtaining the day length

Mathematically, day length $N_d = (2/_{15})W_s$, (1)

W_s= sunrise hour angle,

W_s = Cos^{-1} (- Tan φ Tan β), (2)

where φ = location latitude; latitude of Ilorin, Nigeria = 8^0 32^1 N = 8.53^0, β = declination angle.

β = (0.006918 – 0.399912 CosΓ + 0.070257 SinΓ - 0.006758 Cos2Γ + 0.000907 Sin2Γ – 0.002697 Cos3Γ + 0.00148 Sin3Γ) (180/π), (Muhammad, 1983). (3)

Then, **Γ** = day angle, $\Gamma = (2 \pi (d_n - 1)) / 365$, measured in radians, (4)

d_n is the day number (Starting from 01 January as 1). Declination angle, β is the angular position of the Sun at solar noon with respect to the plane of the equator.

Applying the above given mathematical expressions; 1-4:

For 12th December, the day angle and the declination angle are 340.27^0 and -23.01^0 respectively. Therefore, the sunlight hour at the location is 11.5 hours. From the experiment the observed hours for sunlight on this day was about 10 hours.

For 17th April, the day angle and the declination angle are 104.54^0 and 10.19^0 respectively. Therefore, the sunlight hour at the location is 12.2 hours. The observed day length from the set-up was about 11 hours.

The observed values of open circuit output voltage of the solar module are not too far from the calculated values and did not go below the needed number of hours to fully charge a deep cycle battery for energy storage.

Theoretically, as the declination angle increases, the number of hours of sunlight in a day also increases. These are studied with the use of a solar power device, considering the results obtained in the given figures. However, when there was much amount of cloud cover, there was attenuation of solar radiation and hence a deviation from the theoretical value of the sunlight hour for the day.

4. Conclusion

The number of hours for the availability of sunlight in a day in Ilorin, Nigeria, shows that if solar energy is properly harnessed, it will go a long way in reducing the power supply problem. The geographical location and climatic factors of Ilorin in Nigeria favors the use of solar power system. There was not a day, out of the days which correspond to different seasons when measurements were taken, when the number of hours of day length in Ilorin is less than 10 hours. The battery can be fully charged by the use of solar panel within 10 hours at this location; hence, Ilorin and other locations within tropical region are favourable locations for harnessing solar energy vis-a-vis electricity generation within the tropical region. The work has contributed to the knowledge of harnessing solar energy for electricity generation by validating the fact that the tropical region, which is rich in solar radiation, is a feasible environment for use of solar module for energy generation.

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