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Voltage-Time Characteristic of a Solar Panel in Ambrose Alli University, Ekpoma Nigeria

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Abstract: The voltage-time characteristics of a 140 W, 33 V solar panel is presented in this research. The readings and plots obtained shows that the terminal voltage of solar panel depends on time of the day. Between 7:30 am to 6:00 pm, the terminal voltage of solar panel is at maximum. From 7:00 pm to 6:00 am, the terminal voltage of the solar panel is zero. A storage battery is therefore, necessary to store electrical energy to be used at night. The voltage generated by the solar panel depend on the geographical location of the site, time of the year, time of the day and local weather condition. The geographical location and climatic conditions of Ekpoma in Nigeria favours the use of solar power system. The successful implementation of solar power programs will go along way in reducing the power supply problem, poverty alleviations and climatic changes in Nigeria and the world at large.

Key words: Solar, renewable, pollutionfree, voltage, time, season, location, cost

INTRODUCTION

The energy crisis resulting from the developing world wide shortage of petroleum emphasizes the need for alternative energy sources, which are both inexpensive and clean. Among possible alternative energy sources such as wind, Tide and Wave, Geothermal, Biomass and Magneto-Hydro-Dynamic, the most pollution free and limitless source is solar energy.

The basic resource for all solar energy system is the sun. Solar energy appears to be the most promising among the non-conventional sources of energy. The sun's great energy release is the result of an elaborate chemical process in the sun's core-a process of thermo-nuclear fusion like the reaction in hydrogen bomb. Sun radiates energy of about 3.5×10^{23} kW into space and only 2×10^{14} kW reaches the earth (Patton, 1975).

This stupendous solar energy, which is non exhaustible, could drive the civilization forever, if it could be properly and economically harnessed. The serious draw-backs associated with it, includes very low energy density per unit area. It is available for only a part of the day, cloudy and hazy atmospheric condition largely reduce the energy received.

Therefore, in harnessing solar energy for generation of electrical power large areas to collect sufficient amount of energy and the means to store it will be required.

Knowledge of the quantity and quality of solar energy available at a specific location is of prime importance for the design of any solar energy system. Although, the solar radiation (insolation) is relatively constant outside the earth's atmosphere, local climate influences can cause wide variation in available insolation on the earth's surface from site to site. In addition, the relative motion of the sun with respect to the earth will allow surfaces with different orientation to intercept different amount of solar energy (Gupta, 2007).

From astronomical study (Ekeh, 2003), the sun converts 6×10^{11} kg of mass into energy each second. This is equivalent to 10^{23} kW of electric power. The diameter of the sun is 1.39×10^{6} km and is located 1.5×10^{8} km from the earth. The surface of the sun is at an effective temperature of 5762^{0} K. This is the temperature at which the sun transmits the electromagnetic energy radiated to the earth.

Just outside the earth's atmosphere, the sun's energy is continuously available at the rate of 1,367 W on every square meter facing the sun due to the earth's rotation, asymmetric orbit about the sun and the contents of its atmosphere, a large fraction of this energy does not reach the ground.

Solar energy reaching the earth in tropical zones is about 1 kWh m^{-2} giving approximately 5-10 kWh/m^2/day. In countries within 3.200 km of the equator use of such energy can be economically significant.

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The quantity of solar energy received at any given point on the surface of the earth depends on its geographical location, time of the year, time of the day and local weather conditions (Jackson and Iloabachie, 2003).

Variation during the year in the distance between the sun and the earth lead to annual variations in the solar constant of ±3.5% (about 50 W m^{-2}) (Ekeh, 2003).

Nigeria, a developing country in West Africa falls within the tropical zone. She is well endowed with solar energy due to its geographical location between latitudes 4° and 14° North of the equator. Climatically, Nigeria has two seasons the wet (raining season) and dry (harmattan season). The wet season is between the months of May to September, with is peak in the months of June, July and August. The dry season falls within the months of October to April. In most places no rain in the months of November to February. Based on this geographical location and season, Nigeria has abundant daily Sun shines, especially in the middle belt and Northern region in comparison to the coastal states in the southern Nigeria been influenced by the presence of the Atlantic Ocean.

The solar radiation level on a horizontal surface in Nigeria ranges between 3.7 kWh/m^2/day along the vast areas to about 7.0 kWh/m^2/day along the semi arid zone (Ekeh, 2003).

The greater percentage of Nigeria receives on the average a solar radiation level of about 5.5 kwh/m^2/day. The solar radiation is attenuated during the harmattan period and during the raining season. The country receives about 5.081×10^2 kWh of energy per day from the sun with >2000 h sunshine per year. The use of solar appliance with 10% efficiency to cover 1% of the country surface could generate energy output equivalent to about 10 m barrels of oil per day. This is about 8 times the present level of oil production in Nigeria.

Solar constant is highest during the dry season (December-February time period) and lowest during the rainy season (May-August time period). The solar energy variation due to geographical location is due to the angle that the sun makes with a horizontal plane on the surface of the earth. In addition, it is also, the obvious variations due to the time of the dry and local weather conditions.

In Nigeria solar energy can be put to practical uses, such as rural electrification of small and isolated communities, water pumping, storage of drugs and vaccines in health clinics, powering remote transmitters in telecommunication and railway signaling, catholic protection of oil pipelines and storage tank, television viewing and street lightning (Koval and Leonard, 1991).

In this research, effort is made to determine directly the quantity and quality of voltage generated by solar module (photo voltaic cell) as a function of time. This experiment was conducted on a daily basis for a period of one week on a clear sunny day during the dry season and on a cloudy and raining day during the raining season.

This direct deterministic approach becomes necessary because of lack instruments and tools to measure the intensity of sun at the site. This approach proves accurate because the voltage generated by the PV module varies with time, which is in consonance with the variation of solar radiation (insolation) with time. It should be noted that the solar radiation at any point in time determines the voltage generated by the photovoltaic modules.

The information provided in this research, would assist every individual, group and co-operate bodies in the process of tapping and utilizing solar energy for electric power generation in a distributed and co-generation scheme (Odubigi and Davidson, 2003). This research will assist the engineers and manufactures in providing new system designs that will expand the solar market world wide and permit all to benefit from this clean sustainable and distributed source of energy.

MATERIALS AND METHODS

Location: This experiment was conducted in the department of Electrical and Electronics Engineering in Ambrose Alli University Ekpoma, Edo state, Nigeria. Ekpoma is in Esan West Local Government areas of Edo state, Nigeria, is situated between latitude 6°10' and 6°45' North of the equator and between Longitude 6°10' and 60°40' East of the Green wish meridian (Ayansi *et al*., 2007).

Drainage: The area have tributaries of Ossiad river which drawn into the Benin river, these tributaries include the Orle stream. The river is characterized by deeply incised valley, which penetrates almost the center of the plateau. The most remarkable observation about the Ishan drainage system is that no stream or river of any size runs across the region, so that the water supply is a problem except where boreholes are dung.

Climate: The studied area experiences the human tropical climate, which is characterized with wet and dry season. The dry season, which lasts between November and March usually, coincide with the period of low sun, while he wet session, which lasts between April and October, coincides with the period of high sun.

The rain usually falls from conventions storms and hence, is unevenly spread throughout the day of the wet season. The mean annual rainfall is estimated at 1.556 mm.

The month of July and September have the highest rainfalls in the year. During the dry season, the prevailing North, East winds also referred to as the harmattan being cold, dust and rainless ness to the area.

Vegetation: The predominant vegetations are the moist deciduous forest, which is very rich in timber resources. The canopy is more open than in the rain forest region which lies to the south. Apart from the tropical hard wood, timber such as iroko. Obeche etc. industrial and food crops found in the area include oil palm, rubber, plantain and many local important fruits thrive well in the forest. These forest products are the basic raw material for the saw millers and furniture industries enhances the standard of living in the urban center thereby aggravating the disparity in the quality of life between the larger and smaller settlements in the study area.

Soil: These soils are less leached and consequently retain the advantage of a good rooting depth were they contain a fair clayey content, they provide a good growing medium for cocoa, rubber and other tree crops.

Solar energy: Only a fraction of this energy can be utilized for solar power generation since substations could cover only a very small fraction of the earth. Also, some of the solar energy never reaches the earth's surface as the earth's atmosphere scatters and selectively absorbs a portion of the incoming electromagnetic radiation.

Mathematically, solar constant is given by:

$$S=\frac{\alpha R_s^2 T_s^4}{D^2} \quad (1)$$

where:

α = Stefan's constant = 5.67×10^{-8} Wm^2 k^4.
R_S = Radius of the sun (sun treated as a back body) = 7×10^5 km.
D = Distance traveled by the radiation outward from the sun = 1.5×10^8 km.
T_S = Temperature of the sun = 5762^0 k. Substituting values, solar constant.
S = 1361.0988 W m^{-2}.

However, accepted established average annual value of the solar constant is 1367 W m^{-2}.

Solar energy equation: The energy received by the collector per square metre (net) is:

$$q = I \propto \tau - (\varepsilon_F + \varepsilon_B)\, \sigma\, (T_4 - T^4_0) \quad (2)$$

Table 1: Rating of solar panel

Specification	Rated value	Units
Power output	140	Watts
Rated voltage	33	Volts
Open circuit voltage	42.8	Volts
Maximum system open voltage	600	Volts
Short circuit current	4.7	Amps
Rated current	4.25	Amps
Series fuse	15	Amps
Solar radiation	1000	Wm^{-2}
Temperature	25	°C

where:

ε_F = Front emissivity of absorber.
ε_E = Black emissivity of absorber.
σ = Stefan-Boltzmann-constant = 5.67×10^{-8} W m^{-2}K^4.
τ = Transmittance of cover plate (typical value = 0.93).
T^O = Temperature of cover plate in Kelvin (K).
T = Temperature of absorbing panel in Kelvin (K).
$\propto$ = Absoptivity of absorbing panel.

The equipment used in this experiment includes, a 140 W, 33 V Dc shell Bp type solar panel having the specifications shown in Table 1.

Solar charge controller (Regulator) 12 V, 10 Amps auto switch solar charge controller us used for this research 266, clamp meter. Oscilloscope 2.5 mm copper conductors.

Experimental procedure: Two copper conductors of diameter 2.5 mm and length 10 m are connected to the positive and negative terminals of the 33 V solar panel.

The solar panel is mounted on a rooftop of about 7 m high, where it will be exposed directly to sunlight. The other ends of the copper conductors are connected to oscilloscope to view the nature of the voltage waveform of the solar panel. A digital volt meter is then connected to the terminal of the copper conductors taken into account its polarities.

The readings of the digital voltmeter are recorded on regular basis. The experiment is conducted form dawn to dusk on daily basis.

The average daily, reading were obtained and plotted on voltage-time curve to illustrate the variation of voltage of solar panel with time of the day.

RESULTS AND DISCUSSION

Figure 1 shows the voltage-time characteristic for a clear sunny day on Thursday 3rd January 2008.

From this curve, it is clear that the voltage rises sharply between 6:00 and 7:00 by 7:30 am, it approaches its peak. Between 7:30 am and 6:00 pm, the curve shows a little variation in the output voltage of the solar panel,

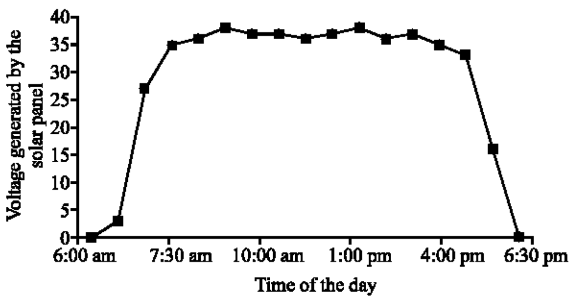

Fig. 1: Voltage-time characteristics for Thursday, 3rd January 2008

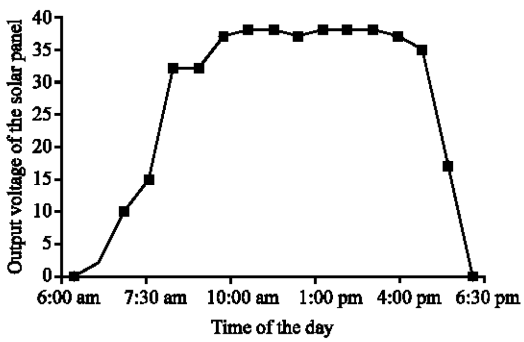

Fig. 2: Voltage-time characteristics for Wednesday 21st May 2008

this could be attributed to climatic and weather conditions which to a large extent affects the intensity of the sun.

Figure 2 shows the voltage-time characteristics for a cloudy and raining day on Tuesday 21st may 2008. Between 6:00 and 9:30 am it was cloudy and raining, this affected the intensity of the sun getting to the solar panel and hence, the output voltage of the panel during this period is attenuated as reflected on the curves. Between the hours of 10:00 am and 6:00 pm, the sky was clear and sunshine, hence, the solar panel was at its maximum performance with little variation due to weather condition.

Figure 3 shows a Comparison of Fig. 1 and 2, it is clear that the geographical location of the site climate and weather condition, season and time of the year determines the intensity of the sun reaching the earth, hence, the output voltage of solar panel. From the above results, it is clear that the variation of terminal voltage of the solar panel is time dependent which is a reflection of the intensity of the sun at any point in time.

The intensity of the sun on the earth depends on the geographical location, rotation of the earth and whether condition.

The waveform displayed on the oscilloscope and the digital voltmeter reading shows that the output voltage of

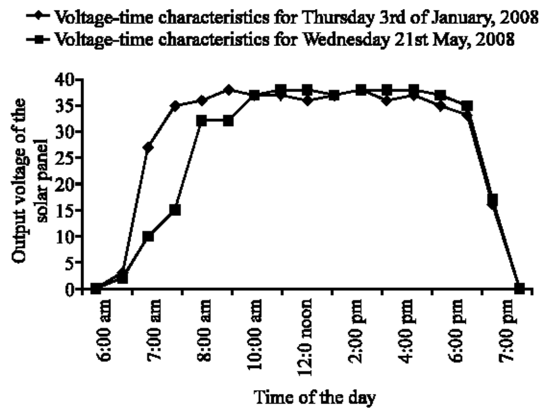

Fig. 3: Comparison of the voltage generated by the solar panel for 2 different days and season

the solar panel is a direct current, hence, an inverter would be need to enable it power alternating current loads.

It is clear from this study that the solar power is available for a period of about ten hours of the day. It therefore, means that storage batteries would be necessary to store electrical energy to be used at night when the intensity of the sun relative to the position of the site will be zero, due to the rotation of the earth.

CONCLUSION

The technological and industrial greatness of any nation depends on the availability and stability of it electric power supply, the solar energy, if properly harness can go along way in reducing the power supply problem in Nigeria (Ekeh and Evbogbai, 2005) since, it can be used in remote voltages not connected to the National grid. The geographical location and climatic factors of Ekpoma in Nigeria favoured the use of solar power system. The successful implementation of solar power programs in Nigeria will go along way in fighting against poverty and climatic changes.

This study was limited to one solar panel. Effort should be made to compare the output voltage with time for two or more panels from different manufacturers. Equipment for measuring the intensity (radiation) of the sun should be provided so that the intensity of the sun can be plotted against time. Effort should equally be made to produce the solar panels locally, so as to reduce the cost of solar power generation.

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