DETERMINATION OF POWER EFFICIENCY IN SOLAR INSTALLATIONS USING THE SOLAR PANEL I-V CHARACTERISTICS

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Abstract

Solar energy is a renewable energy source and is available in abundance in Nigeria. Electricity generation from solar panel involves the conversion of energy from light to electrical energy. This energy conversion process requires maximum efficiency for unnecessary losses to be eliminated in the system. Solar panels are required to be operated at certain fixed voltage to ensure maximum power is transferred. This paper presents the experimental verification of the IV characteristics of a typical 100W solar panel according to IEC61724 standard. The current flowing through a variable load and the corresponding voltage across its terminals were measured at a fixed 2 V increment. The results obtained show that solar panel used, operated at 25% less than the required full capacity when directly connected to the batteries at the battery nominal voltage of 12V.Therefore, operating solar installations at the peak power voltage serves as cure to energy losses in solar renewable energy systems. In a great measure, this will aid the efficiency and sustainability of this renewable energy system which invaluably adds to the growth of the economy.

Keywords: *Solar, Characteristics, Power, Panel, Efficiency*

1 Introduction

Solar energy is the free energy derived from the particles of light called photons, solar energy can be used for heating by a concentration of the rays of the light to a spot using mirrors, but the most efficient means of harnessing the energy from the sun is the use of photovoltaic cells, this cells convert the energy derived from the photons to electricity by its semiconductor action. According to Markvart (2000), "the energy supply from the sun is truly enormous: on average, the Earth's surface receives about 1.2×10^{17}W of solar power." (p. 1). This energy is enough to satisfy the entire energy needs of the world, but the limitation is the availability of efficient means of conversion and storage of the energy derived. This paper is aimed at investigating the characteristics of a typical solar panel with a view to determining the percentage power derived from the solar panel when used at the nominal battery voltage of 12V.

2 Photovoltaic Cells

"The word Photovoltaic is a combination of the Greek word for Light and the name of the physicist Allesandro Volta. It identifies the direct conversion of sunlight into energy by means of solar cells. The conversion process is based on the photoelectric effect discovered by Alexander Bequerel in 1839. The photoelectric effect describes the release of positive and negative charge carriers in a solid state when light strikes its surface" (solarserver,n.d.).

"A solar module can be seen as a black box that with two connectors, producing a current, I, at a voltage, U. For the purpose of the electrical characteristics of a solar cell, the inside of that black box can be described by an electric circuit with only 4components:

Current Source: This is the source of the photo current, and it is:

$$I_{ph} = A_{cell} H \xi \quad (1)$$

with the cell area, A, the intensity of incoming light, H, and the response factor ξ in units of A / W.

Diode: This non-linear element reflects the dependence on the band gap and losses to recombination. It is characterised by the reverse current, I0, which measures the leakage of electrons and re-combining and by a quality factor, q, with values ranging between 1 - 2, an empirical factor.

Shunt Resistor Rp: represents losses incurred by conductors.

Serial Resistor Rs: also reprents losses incurred by non-ideal conductors.

The relationship between I and U of a single cell is then expressed by:

$$I_{Cell} = I_{ph} - I_0 \left[exp\left(\frac{U_{Cell} + I_{cell} R_S}{U_T} \right) - 1 \right] - \frac{U_{Cell} + I_{cell} R_S}{R_p} \quad (2)$$

With thermal voltage $U_T = \frac{qkT}{e}$ with temperature, T (in Kelvin), Boltzmann constant k = 1.38e-23 and the elementary charge e = 1.602e-19. Using this formula, we can calculate maximum power points and also behaviour under different temperatures" (Green Rhino Energy, (n.d.)).

In a module, a number of cells are put in series into a string, and a number of strings in parallel. Putting cells in series adds to the voltage, whereas putting cells in parallel adds to the current, so that:

$$I = N_p I_{Cell} \quad (3)$$

$$U = N_s U_{cell} \quad (4)$$

3 Methodology

The design of any solar power installation requires a careful assessment of the solar radiation pattern at a particular site. Several radiation data have been recorded for many location around the world but they have to be analysed before a good estimate of the available solar radiation can be made. To ensure accuracy of design calculations, every photovoltaic system must rely on the measured data close to the site of installation. The experimental setup for determination of the I-V characteristics of a solar panel requires the use of high precision voltmeters and ammeters with the solar panel placed horizontally under direct sunlight, measurement taken within the hours of 11am and 1pm when the sun is directly overhead and the atmosphere is clear. On a clear day at sea level the radiation from the sun at zenith corresponds to air mass 1(AM1) (Kammer & Ludington, 1977). The test requires the use of an ammeter with zero internal resistance in series with the load and a high resistance voltmeter across the solar panel. The solar panel used for the test is rated 100W whose short circuit current is about 6.12 A. The resistance required to allow for measurement of its characteristics should allow for variation of the current from the panel from about 0.2A to its maximum value.

$$R_{max} = \frac{V_{omax}}{I_{min}} = \frac{20}{0.2} = 100\Omega \quad (5)$$

This calculation led to the choice of a variable 100W resistor to be connected in series with the solar panel as shown below

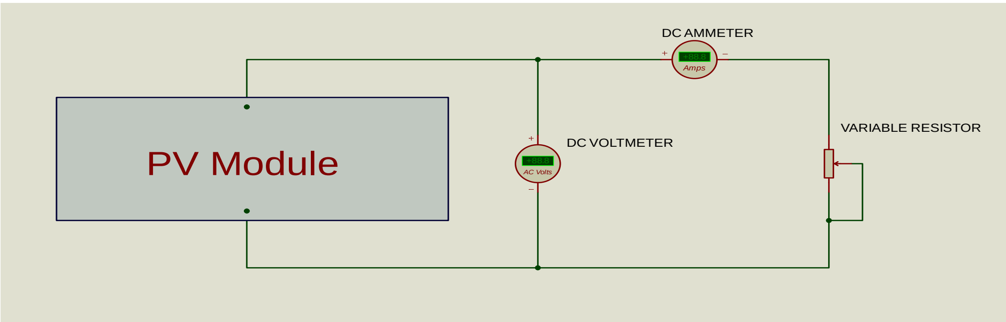

Figure 1: Circuit diagram for determining the I-V characteristics of a solar panel

4 Result

The voltage and current were measured strictly under AM 1 levels. The measurement were repeated for 5 days to confirm the measurement results are correct and eliminating possibilities of gross and instrument errors. Table 1 shows the results obtained at different voltage level and figure 2 & 3 is the graph of current against voltage and power against voltage respectively.

Table 1: Voltage, current and power measured in I-V test

Voltage	Current	Power
0	8.13	0
2	7.45	14.90
4	7.18	28.72
6	6.91	41.46
8	6.63	53.11
10	6.36	63.68
12	6.23	74.79
14	5.96	83.46
16	5.69	91.05
18	5.55	99.99
20	4.60	92.14
22	1.35	29.81

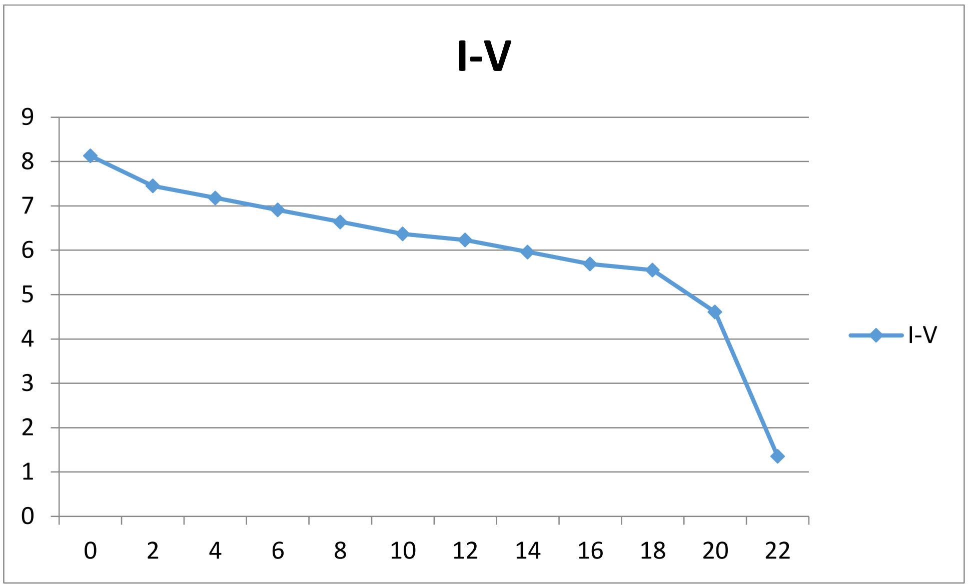

Figure 2: I-V characteristics obtained from the table 1

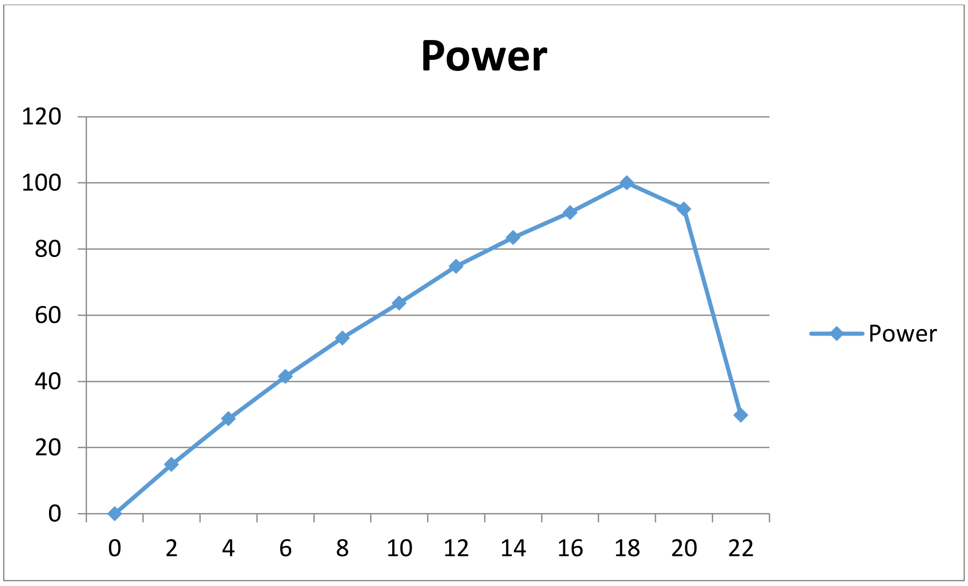

Figure 3 Graph of power against voltage

5 Discussion of result

The result obtained provides information on the behaviour of the solar panel under varying load levels and it also reflects the variation of the power levels obtainable at different voltage at the output of the solar panel. As shown in figure 3 the peak power is attained at ~18V. Solar installations are usually operated at 12V because of the battery bank voltage used. This forces the panel to be operated at approximately 12V while charging the installed battery bank, power at this level therefore is equivalent to P=12 X 6.23 = 74.76W.

$$\% \text{ loss in energy} = \frac{100-74.76}{100} \times 100\% = 25.24\% \tag{6}$$

A loss of 25.24 W is expected for a 100W system as observed in this test.

Total energy wasted is therefore modelled as

$$\%Loss\ on\ 12\ V\ instalation = 0.2524 \times Total\ installed\ solar\ panel\ power\ rating \tag{7}$$

This result therefore informs any solar panel installer or user of the inherent loss expected when deploying the system for 12V installation, therefore the user can calculate the requirement based on an oversized power requirement to about 1.25 above the actual need, to ensure full power is delivered. The solution to eliminate this loss is to use d.c.to d.c. converting charging circuits that can convert the input voltage from the panel to the required dc level for charging without altering the peak input voltage level.

6 Conclusion

Maximum efficiency can only be obtained when solar panel are installed and allowed to operate at its peak voltage, this allows for maximum power transfer and total conversion of the light energy to electrical energy. Design calculations for new solar installation using pulse width modulated charge controllers which forces the panel voltage to the battery level must include the loss factor presented in equation (7) to make up of for the loss level in the system.

7 References

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