Experimental analysis of I–V characteristics of solar cells

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This paper describes a simple experiment that can be performed by undergraduate students to derive the values of solar cell parameters from the plot of the output load current versus the voltage at the terminals of the cell.

I. INTRODUCTION

Photovoltaic cell characteristics are often described by the junction diode model,[1] with a photoelectronic current I_{ph} generated by the incident light:

$$I = I_{ph} - I_0[\exp\beta(V + R_s I) - 1], \quad (1)$$

where I is the load current, V is the terminal voltage, I_0 is the reverse diode saturation current, $\beta = e/AkT$, A being the diode factor, and R_s is the internal series resistance of the solar cell.

These macroscopic parameters are interesting because they are related to internal properties of the components of the solar cell: Equation (1) shows that I is very sensitive to some of these parameters since they appear in the exponential term. It is worthwhile to point out that the parameters I_0, A, and R_s depend on the temperature and the illumination of the cell;[2,3] thus they have to be determined for a given illumination and temperature. Several methods have been presented which do not satisfy this requirement; they consider the difference between the dark and various illuminated characteristics.[2,4,5]

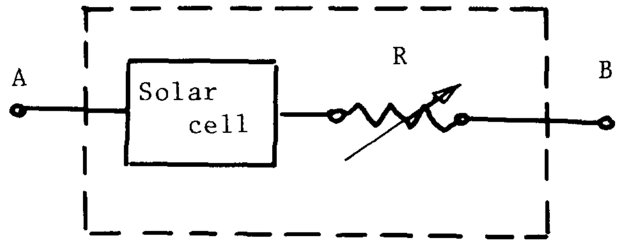

Fig. 1. New solar cell.

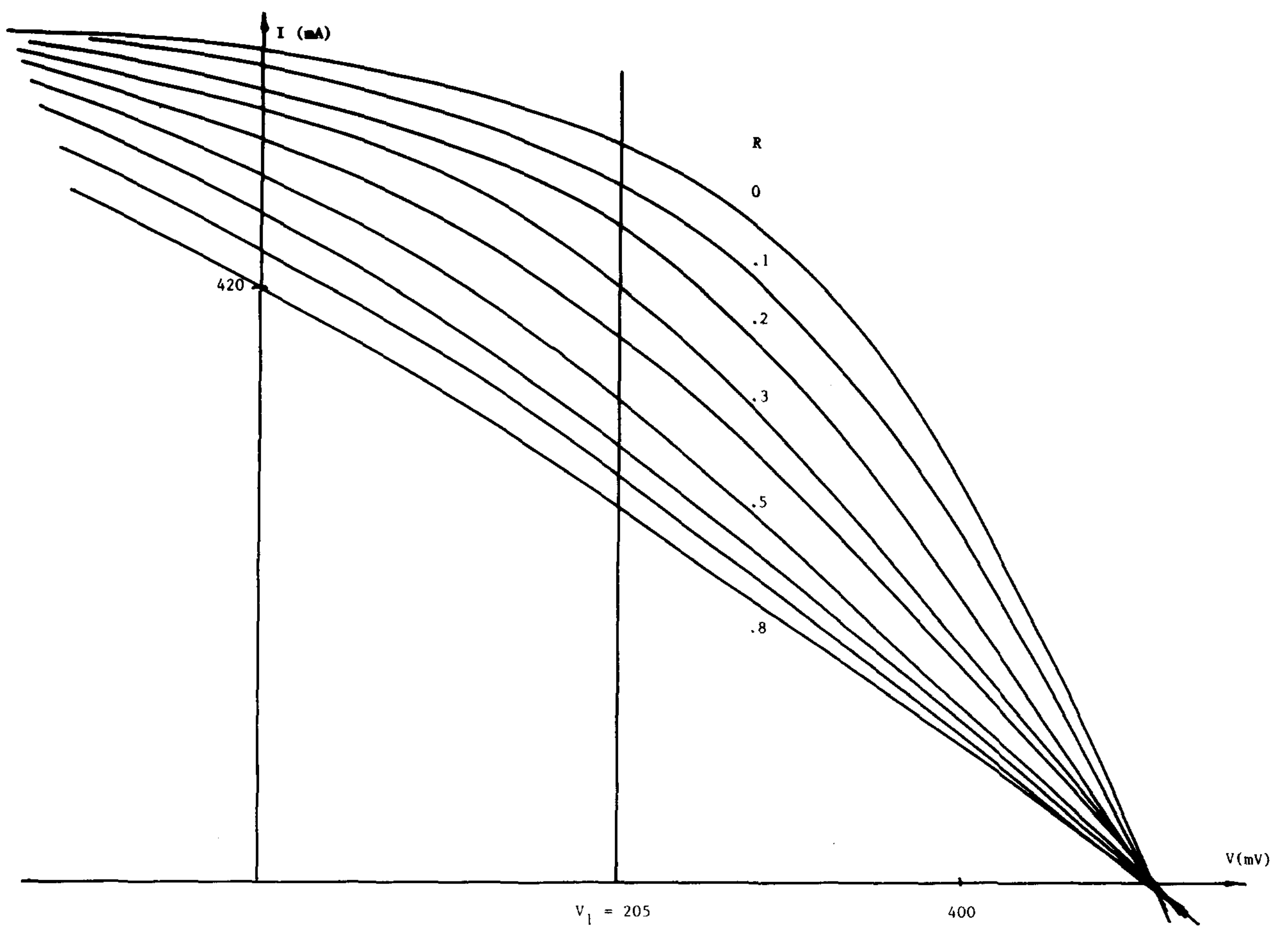

Fig. 2. Characteristics of the (AB) new solar cell for different values of R. Solar illumination $(AM\ 1)$; $T = 330$ K.

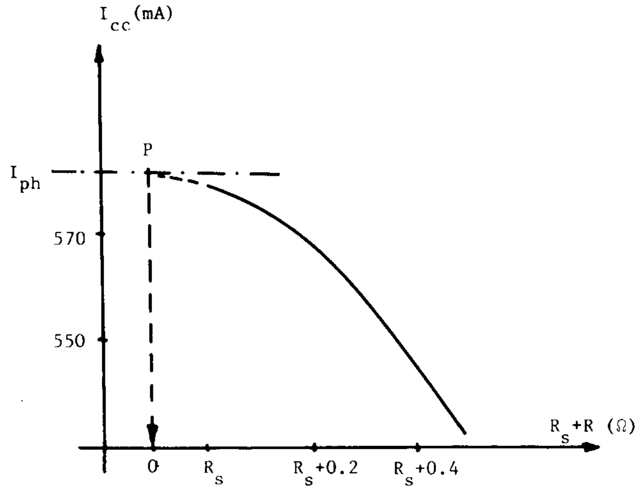

Fig. 3. Plot of the short circuit current I_{cc} versus $(R_s + R)$.

We present here an experimental method applied to a solar cell driven as a generator only, under illumination, which allows the determination of all parameters of this cell.

II. EXPERIMENTAL METHOD

The first step of the method is to put a variable resistor R in series with the solar cell and to consider the new (AB) solar cell with an internal series resistance value of $(R_s + R)$ as shown in Fig. 1. The characteristics of this cell are then recorded under constant solar illumination on a X-Y recorder (using a power supply in a simple circuit described elsewhere[6,7]) for different values of R: 0 Ω,0.1 Ω,...,0.9 Ω. Figure 2 shows the characteristics with the indication of the values of R.

From Eq. (1) with $V = 0$, the short circuit current I_{cc} is obtained as

$$I_{cc} = I_{ph} - I_0[\exp\beta(R_s + R)I_{cc} - 1] . \quad (2)$$

We can see that the limit of I_{cc} when $(R_s + R)$ approaches zero is I_{ph}. The large variation of I_{cc} with R shown in Fig. 2 is beneficial for the determination of R_s. Let us plot I_{cc} as a function of $(R_s + R)$ with the origin unknown (Fig. 3). Since I_{ph} is determined from Fig. 2, it is possible to determine graphically the point P where the I_{cc} curve reaches the value I_{ph}. This gives the origin on the $(R_s + R)$ axis and hence the value of R_s. This method gives $R_s = (0.10 \pm 0.02)\Omega$. It is then possible to plot $(I_{ph} - I)$ mea-

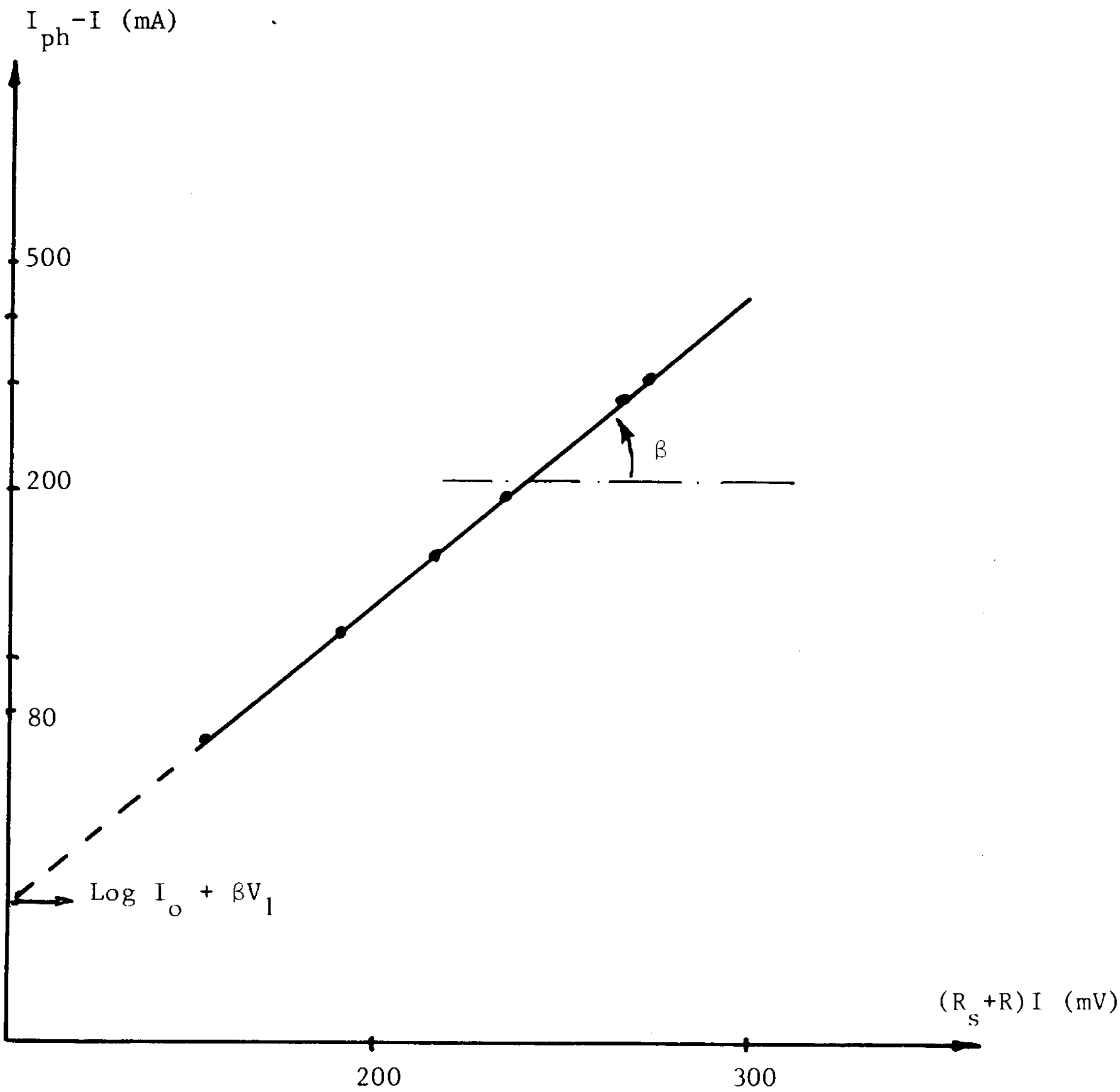

Fig. 4. Plot of Log$(I_{ph} - I)$ verus $(R_s + R)I$ for an arbitrary fixed voltage $V = V_1$.

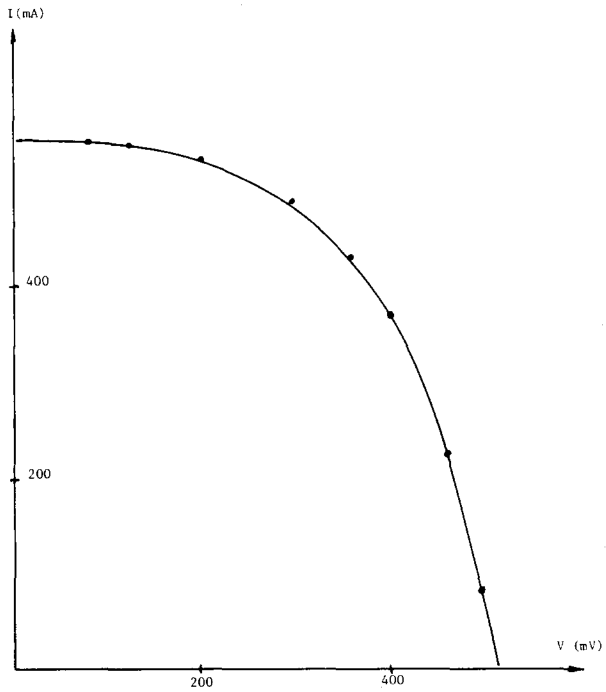

Fig. 5. Real cell experimental characteristic, solar irradiation ($T = 330$ K); the points are computed values from Eq. (1) with $I_0 = 8 \times 10^{-4}$ A; $A = 2.8$; $R_s = 0.1\ \Omega$.

sured on Fig. 2 for a fixed V value ($V = V_1$) against $(R_s + R)I$ on a semilogarithmic scale (Fig. 4). The slope of the approximately linear plot is β and the intercept with the vertical axis gives $\mathrm{Log}\, I_0 + \beta V_1$; therefore, we can derive A and I_0:

$$A = 2.80 \pm 0.15,$$

$$I_0 = (8 \pm 0.5)10^{-4} A .$$

III. DISCUSSION

The test of validity for an experimental method of determination of cell parameters is the accuracy with which they reproduce the experimental values of the I–V characteristics. Figure 5 shows the experimental characteristics of our solar cell; the points obtained using Eq. (1) with the above values of the parameters show good agreement with the experimental curve. A variation of the parameters within their interval of precision does not affect the fit. The precision indicated is estimated from the experimentally recorded curve and from the graphical plots. The method described is of simple practical use, in addition to the fact that all required measurements are made using only one illumination level.

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