ABOUT MODELLING OF MEDIUM BEHAVIOUR OF A PHOTOVOLTAIC CELL FROM A SOLAR MODULE

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Modeling of photovoltaic cells is an essential topic of research. Photovoltaic cells models are usually drawn from the equivalent electrical circuit as either four or five parameters [1]. Some other models that describe the behavior of a photovoltaic module or the energy produced from it are based on empirical approaches. The technical data provided by the manufacturers may not describe the performance of photovoltaic modules at a particular site because the climatic conditions can differ from the standard test conditions [2].

This paper presents researches in order to establish a simulating model for a SM 1236/2 photovoltaic panel, fabricated in Romania. The photovoltaic system has 36 Si cells with a diameter of 5.08 cm each one, in a serial circuit. The system of cells is delivered with experimental characteristics at three temperatures (0 ^{o}C, 25 ^{o}C, 50 ^{o}C) and three insolations.

A photovoltaic cell is a p-n jonction which produces a voltage when is iluminated. The cell can be replaced by an equivalent circuit which consists in a current source shunted through a diode.

The current-voltage characteristic I_c-U_c for a Si cell is:

$$I_c = I_L - I_o[\exp(qU_c / kAT) - 1] \qquad (1)$$

where: I_c – the cell current, I_L – light-generated current (photocurrent, I_L = •E for solar irradiance up to E= 1 kWm^{-2}), • – constant depending of cell type, I_o – diode reverse saturation-current, U_c – voltage of cell, q – elementary electrical charge, k –Boltzmann’s constant, A –additional curve factor. The short-circuit current I_{sc} (for U_c = 0) is just the light-generated current I_L, that is I_{sc} = •E.

Taking into account the proper resistances of the diode (R_s – series resistance and R_{sh} – shunt resistance) in (1), the theoretical characteristic curve is different, but they can be neglected in a first approximation.

For U_c = 0, the diode contribution is neglected and the short-circuit photocurrent I_{sc} is proportional with solar irradiance up to 1 kW/m^2.

For a panel having the voltage U_p , made by N_s series photovoltaic cells, the characteristic I_c-U_c of a photovoltaic cell reads:

$$I_c = aE - I_o[\exp(qU_p / N_s kAT) - 1] \qquad (2)$$

The system modelling is based on some results presented in [3,4,5], but considering the curve factor A, too.

The average value of parameter • is obtained from the characteristics of the panel, given for solar irradiances E'= 1kWm^{-2}, E'' = 0.75 kWm^{-2} , E'''= 0.5 kWm^{-2} and the corresponding values for short-circuit currents. One obtains three appropriate values for •, wich give an average value •$_m$ = 5$\cdot$ 10^{-4} Am^{2}W^{-1}.

In order to find the factor A we consider the power for a single cell:

$$P_c = I_L U_c - I_o U_c[\exp(qU_c / kAT) - 1] \qquad (3)$$

When U_c has a value which optimizes the power U_c=$U_{c,opt}$, from the condition of maximum power (dP_c/dU_c)=0, and I_L=I_{sc}, one obtains:

$$I_o \exp(qU_{c,opt} / AkT) = AkT(I_{sc} + I_o)/(AkT - qU_{c,opt}) \qquad (4)$$

Introducing the left part of (4) in (1) and taking into account that $I_0 << I_{sc}$, one obtains:

$$A = (q / kT)(U_{c,opt} - R_{c,opt} I_{sc}) \qquad (5)$$

where q/kT = 38.9 V^{-1} , at 298 K and the optimal resistance $R_{c,opt}$=$U_{c,opt}$/I_c.

Using equation (5) and the given characteristic curves of the photovoltaic panel, for three solar irradiances, one obtains three values for the parameter A: $A'=1.517$, $A''=1.590$, $A'''=1.653$. The average value $A= 1.587$ is considered from now on.

So, equation (1), which describes the cell characteristic, becomes:

$$U_c = 0.0408 \ln \frac{5 \cdot 10^{-4} E - I_c}{1.25 \cdot 10^{-6}} \qquad (6)$$

Applying equation (6) for the photovoltaic module, we obtain a considerable deviation from the experimental characteristics. This imposes to take into account of series resistance of the cell. In agreement with the method described in [6], the I_c-U_c photovoltaic characteristics will match at different light intensities if the voltage axis is shifted by an amount • $I_L.R_s$ and the current axis is shifted by an amount • I_L. Therefore, by matching I_c-U_c curves at various intensities and measuring the axis shifts required for the match, Rs may be determined.

By calculating for a pair of characteristics of panel, the found resistance of photovoltaic module is R_p=4.82 • . The average series resistance for a cell is R_{sc} = 4.82/36 = 0.134 • and so the relation (6) receives a supplementary term:

$$U_c = 0.0408 \ln \frac{5 \cdot 10^{-4} E - I_c}{1.25 \cdot 10^{-6}} - 0.134 I_c \qquad (7)$$

This relation represents the mathematical model for a "typical" cell from the panel (the average behaviour of a cell from the photovoltaic panel).

The optimal working point for a cell is very important for photovoltaic panel. The cell power is maximally when $d(U_c I_c)/dI_c = 0$.

Plotting the derivative of the power (fig.1), obtained by multiplying relation (7) by Ic, for three solar irradiances (E', E'', E'''), can be found three curves which give us the optimal working point for "typical cell", that is $I_{c,opt}$ at intersections of curves with abscissa, respectively 0.443 A, 0.334 A, 0.223 A.

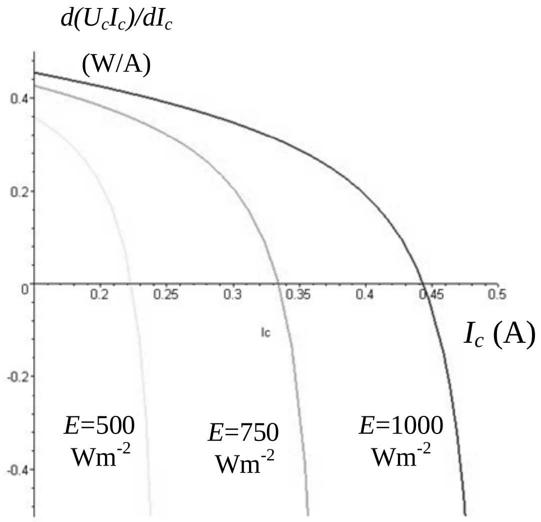

Figure1. Derivative of the typical cell power versus cell current

By introducing these values in (7), we obtain values $U_{c,opt}$ are 0.378 V, 0.379 V, 0.376 V. By using average value $U_{c,opt,av.}$ = 0.378 V, the voltage of photovoltaic panel results $U_{p,opt}$ = 0.378 $\cdot$ 36 = 13.61 V, value that is in agreement with experimental data.

The mathematical model proposed by us represents the behaviour, at a constant temperature, of a "typical photovoltaic cell" from the photovoltaic panel SM 1236/2, made by series Si cells.

This allows us to establish the optimal working point for different values of solar radiations and temperatures for "typical cell", and for a photovoltaic system made by their association

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