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New approach modeling and a maximum power point tracker method for solar cells

M.T. Benmessaoud *, F.Z. Zerhouni, M. Zegrar, A. Boudghene Stambouli, M. Tioursi

Department of Electrical Engineering, Faculty of Electrical Engineering, University of Science and Technology of Oran, BP 1505, EL M'Naouer, Oran (31000), Algeria

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ABSTRACT

In this work, we present a generic model based on universal of mathematical equations to model the operation of a solar cell. We analyze the output current and the electric power supplied by a solar cell according to the output voltage, temperature and power. The results obtained show that the model is very effective in treating the simulation model of a solar cell on the one hand and secondly the ability to model in an efficient manner a photovoltaic field with fewer errors. This allows operating the photovoltaic generators in optimal conditions, and consequently with a better exploitation of energy.

1. Introduction

Photovoltaic cells have been widely studied for over 30 years. In these models the parameters are set arbitrarily and without constraint and which reduce the model's efficiency. Several types of models exist to simulate the behavior of a photovoltaic cell. The model was developed Largely by Townsend [1] and was detailed by Duffie and Beckaman (1991). It is currently a model for the modeling of cells. This model is empirical, empirical models are preferred to theoretical models insofar as they allow a simplification of the problem and reduce the number of parameters. In this paper, the model of one exponential of the solar cell is used for the reconstitution of the I–V characteristics and the estimation of the power supplied by photovoltaic solar cells. The reconstruction of the current–voltage characteristics is obtained by the method of three points (short circuit current, open circuit voltage, maximum power) which are provided by the manufacturer. The estimation of parameters (saturation current, series resistance, photonic current) was established by neglecting the shunt resistance and considering the ideality factor of an ideal diode. Expressions of power as a function of current and as a function of voltage have been set by neglecting the shunt resistance. The expression of the power as a function of the voltage has required the introduction of numerical analysis. The I–V characteristics curves and power depending on the current and voltage were derived and graphically represented enabling to estimate the power delivered by the photovoltaic generator under the conditions of its operation. We propose in the second work the MPPT algorithm developed in our laboratory, based on an inspired approach of P&O [2] method, has greatly improved the further optimal operating point of PV systems.

2. Model description of a photocell—electrical model (I–U characteristic)

The relationship between the current I and voltage U of the equivalent circuit in Fig. 2 can be found by equating the light current I_L, diode current I_D, and shunt current I_{sh} to the current operation. The junction used as the basis for the solar cell is a diode; when lit the LED emits a photocurrent I_L (A) which depends on the amount of incident light G (W/m^2) [3] (Fig. 1).

Indeed, the electrical equivalent of the solar cell is based on a diode, adding two resistors to account for internal losses. R_S is the series resistance which takes into account the ohmic losses of the material, the metallization and the contact

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* Corresponding author. Tel.: +213 07 76 07 52 71; fax: +213 041 33 39 64.
E-mail address: benmessaoudtarik@yahoo.fr (M.T. Benmessaoud).

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Nomenclature

A	ideality factor parameter
$\mathbf{A}$	effective area of the PV cell/module (m^2)
C_{PV}	the overall heat capacity per unit area of the PV cell/module [$J/(°C\,m^2)$]
ε_G	energy band gap (eV)
G	solar radiation ($W\,m^{-2}$)
$G_{e,Ref}$	$G_{e,Ref}$ ($1000\,Wm^{-2}$)
I	current module (A)
I_L	light current (A)
$I_{L,Ref}$	light current at SRC (A)
I_{MP}	current at maximum power point (A)
$I_{MP,Ref}$	current at maximum power point at SRC (A)
I_o	diode reverse saturation current (A)
$I_{o,Ref}$	diode reverse saturation current at SRC (A)
$I_{sc,Ref}$	short circuit current at SRC (A)
k	Boltzmann's constant (1.38066E−23 J/K)
NCS	number of cells connected by module
V_{MP}	voltage at maximum power point (V)
$V_{MP,Ref}$	voltage at maximum power point at SRC
$V_{oc,ref}$	open circuit voltage at SRC (V)
Ns	number of cells in series
P	predicted power (W)
P_{MP}	maximum power (W)
q	electron charge (1.60218E−19 C)
R_S	series resistance (Ω)
$R_{S,Ref}$	series resistance at reference condition (Ω)
R_{Sh}	shunt resistance (Ω)
T_C	temperature cell (K)
$T_{C,ref}$	temperature of reference (K)
Ta	overall heat loss coefficient [$W/(°C\,m^2)$]
U	voltage Module (V)
U_L	overall heat loss coefficient [$W/(°C\,m^2)$]
$\mu_{V,OC}$	temperature coefficient for open circuit (V/K)
$\mu_{I,SC}$	temperature coefficient for short circuit current (A/K)
$\tau\alpha$	transmittance–absorption product of PV cells

metal/semiconductor; R_P represents resistance leakage current from currents between the top and bottom of the cell, by the board in particular and within the material by irregularities or impurities. Applying the law of Kirchhoff, the output current of the cell is given by the following equation:

$$I = I_L - I_D - I_{Sh}. \tag{2.1}$$

The light current I_L (A), depends on solar radiation and temperature, calculated in relation to the SRC.

$$I_l = \frac{G}{G_{Ref}}\left[I_{l,Ref} + \mu_{I.sc}\left(T_C - T_{C,Ref}\right)\right]. \tag{2.2}$$

The current of the diode is defined by Shockley equation [1]:

$$I_D = I_0\left[\exp\frac{q\,(U + IR_s)}{\gamma k T_C} - 1\right]. \tag{2.3}$$

The relationship between the current I and voltage U can be expressed:

$$I = I_L - I_0\left[\exp\frac{q\,(U + IR_s)}{\gamma k T_C} - 1\right] - \frac{U + IR_{Sh}}{R_{Sh}}. \tag{2.4}$$

The effect of parallel resistance is negligible ($R_P \ll R_S$), the relationship between the current I and voltage U can be expressed:

$$I = I_L - I_0\left[\exp\frac{q\,(U + IR_s)}{\gamma k T_C} - 1\right]. \tag{2.5}$$