Modelling Photovoltaic Panels (Tandem) In Matlab-Simulink

A.Talhi*,[1], Dennai Benmoussa[2]

[1]University Center Ali Kafi Tindouf – Algeria

[2]University Tahri Mohammed Bechar – Algeria

Abstract

At the stage of development of solar photovoltaic; the direct conversion of energy carried by the solar radiation into electricity, but before consuming, it took to produce using solar panels. Modeling of solar cells is based on their electrical characteristics (relationship voltage / current) under various conditions of radiation and temperature obtained by the equivalent circuit model, we consider associations with cells semiconductors respectful individuals such as: if, AlGaAs, Tandem, we integrate this model with Matlab simulink. The aim of this work is modeled solar panels; Tandem (coupled AlGaAs / Si). This modeling is an essential step to evaluate the characteristics of photovoltaic solar panels.

Keywords: Tandem Solar Cells, Photovoltaic Panels, Matlab Simulink. Algaas / Si.

Introduction:

In photovoltaic conversion of solar energy, we can reduce losses by excess energy and non-absorption of photons by combining several photovoltaic (solar cell tandem) of different materials as shown by various authors [1, 2]. One embodiment, said tandem «stacked ", is produced in advance, each on its own substrate, two (or more) different cells that are superposed and then fixing them by a transparent adhesive. This adhesive can be either conductive each of these portions is sent to a different type of solar cell is optimized for given photon energy (Fig. 1).

The choice of materials for the production of a dichroic structure is guided by the optical and electrical properties of the two materials, in particular the values of their band gap [3]. The two cells are associated optically and electrically. In this case, when the two cells electrically connected in series, the current through the device is dictated by the cell, which provides the least. The open circuit voltage Voc is the sum of the open circuit voltages of each cell.

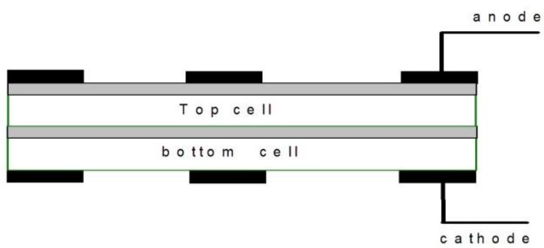


Fig. 1 Equivalent diagram of a solar cell Tandem

A photovoltaic panel is constituted by a set of photovoltaic cells of the same technology in series to increase the voltage and / or parallel to increase the current to achieve the desired electrical characteristics such as power, the short-circuit and the open-circuit voltage [4]. By connecting M cells (C) in series and N columns of cells in parallel Fig. 2 gives a PV panel. Voltage (V_{pv}) and current (I_{pv}) issued by the latter are functions of the characteristics of a basic PV cells [5].

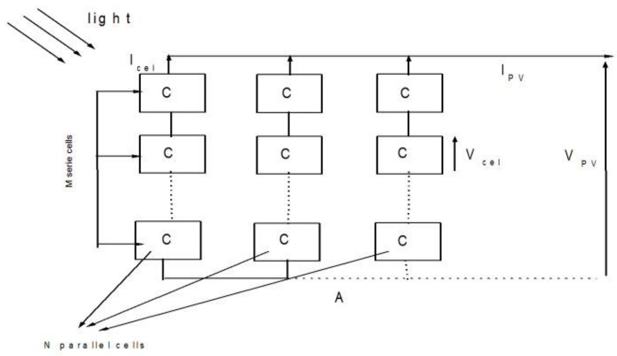


Fig. 2: Photovoltaic Panel

Mathematical Model:

A solar cell modeled by the equivalent circuit well known in Fig.3 [1-2]. This circuit introduces a current source and a diode in parallel and series resistors Rs and parallel (shunt) to take account of R_{sh} phenomena.

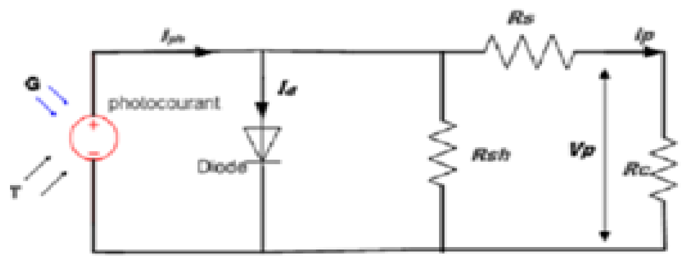


Fig 3 Equivalent circuit of a solar cell

The series resistance is due to the contribution of the base resistors and the junction of the front and front and back contacts. The parallel resistance includes the effects, such as the leakage current through the edges of the cell; it is reduced by the penetration of the metal impurities in the joint (especially if the penetration is deep). This circuit can be used both for an individual cell, for a module or panel consists of several modules [1, 3, 2].

The equation relating the current supplied by a photovoltaic cell and the voltage at its terminals given by:

$$I = I_{ph} - I_0\left(\exp\left[\frac{q}{nkT}(V + IR_S)\right] - 1\right) - \frac{V + IR_s}{R_{sh}} \qquad (01)$$

Where:

I_{ph} and I_0 respectively designate the photocurrent and the reverse saturation current of the diode. n the ideality factor of the diode; q the electron charge; K is Boltzmann's constant and T the temperature of cell. From this equation, we can determine the characteristics of a photovoltaic cell. Such as the short-circuit I_{sc} and the voltage V_{oc} Open Circuit.

Calculation of Multi Spectral Efficiency Solar Cell:

A. Photo-current:

In the tandem mode the solar spectrum is cut each solar cell receives a portion of the solar spectrum. Taking one hand the quantum efficiency of absorption and secondly, the collection efficiency (Q) of minority carriers through the barrier of the PN junction, both easily obtained equal to 1. The table base [5] giving the photo-current calculated from the number of photons N_{ph} and the gap E_g the semiconductor.

For the cell (1):

$$I_{ph1} = Qq\int_{E_{g1}}^{\infty} N_{ph}(E_{ph})dE_{ph} \qquad (02)$$

For the cell (2):

$$I_{ph2} = Qq\int_{E_{g2}}^{E_{g2}} N_{ph}(E_{ph})dE_{ph} \qquad (03)$$

B. characteristic photovoltaic

The power supplied to the external circuit by the solar cell under illumination depends on the load resistor R_L (external resistor placed across the cell). This power is maximum (denoted $P_{\max}$) for an operating point P_m (I_m, V_m) the current-voltage curve. To this point we can write:

This equation allows expressing the tension V_{mp} operating point:

$$V_{mp} = V_{CO} - \frac{K.T}{q}.\log\left(1+\frac{q.V_{mp}}{K.T}\right) \qquad (04)$$

It looks like by:

$$I_{mp} = I_{ph} - I_0\left(e^{\frac{q}{kT}(V_{mp}+R_s I_{mp})} - 1\right) - \frac{V_{mp}+R_s I_{mp}}{R_{sh}} \qquad (05)$$

Were: $R_S <<< \Rightarrow V_{mp} + R_S.I_{mp} \approx V_{mp}$

$$I_{mp} = \left[I_{ph} - I_0\left(e^{\frac{qV_{mp}}{kT}} - 1\right) - \frac{V_{mp}}{R_{sh}}\right] \Big/ \left(1+\frac{R_s}{R_{sh}}\right) \qquad (06)$$

C. Performance:

The efficiency of cell number k is:

$$\eta_{mk} = \frac{P_{\max k}}{P_{in}} = \frac{I_{mk}.V_{mk}}{\phi_k.S_k} \qquad (07)$$

.is the total power incident light per unit area P_{in}

When the cells are connected together by a transparent cole. This adhesive can be either conductive. Should be noted that the same current flows through all the cells and the total voltage across the device is simply the sum of the voltages across each cell. After determining the operating point I_{mk} , V_{mk} independent cells, we impose a power series I equal to the smallest of the currents I_{mk} whether $I = \inf\left(I_{mk}\right)$. We obtain an operating voltage V_{mk} and useful power:

$$P_k = V_{mk}.\inf\left(I_{mk}\right) \qquad (08)$$

The overall performance will :

$$\eta = \frac{\sum_{k=1}^{n} P_k}{P_{in}} \qquad (09)$$

Matlab – Simulink:

The equations used above can be modeled in Matlab-Simulink from basic math blocks present in the catalog Simulink. Simulink program proceeds in two steps. In the first system to be studied is defined by a mathematical model developed for this purpose, then the model developed is then introduced into the program in the form of blocks.

While the second phase is to analyze the behavior of the system previously defined after specifying the simulation parameters, it starts with the MATLAB command.

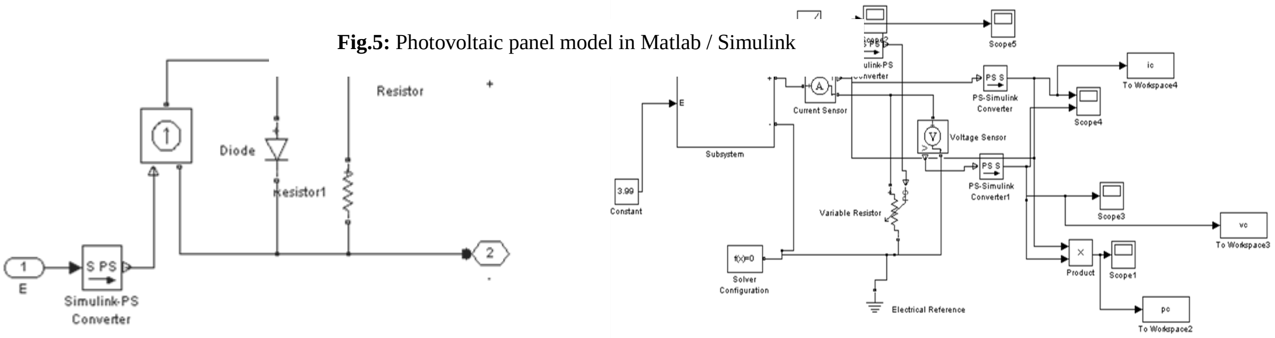


Fig.5: Photovoltaic panel model in Matlab / Simulink

Results:

Photovoltaic conversion is the conversion of light energy into electrical energy. Devices capable of performing this transformation are called solar cells. Yields were relatively very low, which gave motivation to the study of factors limiting the conversion efficiency [6]. For this reason, we studied the influence of factors (light, temperature, parallel resistance, and series resistance) on the characteristics $I\left(V\right)$, $P\left(V\right)$ of panel. We chose for this study a panel of solar cells consists tandem combination of two cells AlGaAs $\left(E_{g1} = 1.798eV\right)$ and Si $\left(E_{g2} = 1.127eV\right)$ A temperature $T = 300K$ and irradiance $G = 1000W/m^2$ with the following values of the series resistors and parallel: $R_s = 0.5\Omega$ and $R_{sh} = 700\Omega$.

A. Effect of illumination:

To see the influence of light i fixed at room temperature (300K) and the illumination varied in a sufficient range. By varying the illumination between 400 and 1000 with a step 200, the characteristic I(V) is given by the fig.6.

From fig.6, there is a sharp decrease in short-circuit current versus illumination and a small decrease in the open circuit voltage.

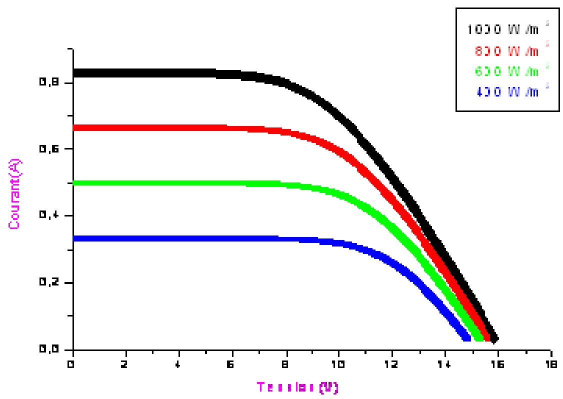


Fig.6: The influence of illumination on the characteristic I (V)

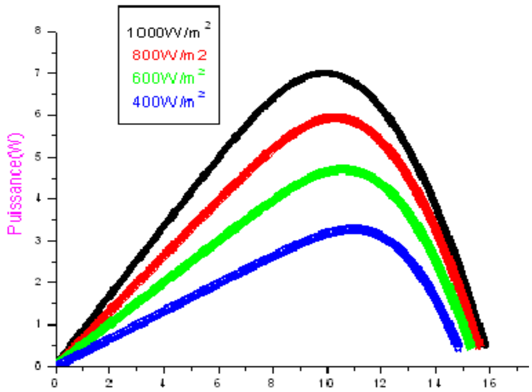


Fig.7: The influence of illumination on the characteristic P (V) for the panel tandem

We also note in Fig.7 that the illumination affects proportionally the power and open circuit voltage of the photovoltaic panel. We also note that the voltage Vco corresponding to the maximum power varies only slightly depending on the light, unlike the current Icc, which increases strongly with illumination.

B. Effect of temperature:

The influence of temperature very significant and will require choices. The size of the band gap E_g provides important electrical characteristics to each semiconductor. These variations can be described approximately by the following universal function bearing system design [11].

$$E_g(T) = E_g(0) - \frac{\alpha_g . T^2}{T + \beta_g} \qquad (10)$$

By varying the ambient temperature (T_a between 300 K and 325K) the influence of the latter on the characteristic I(V) is given in Fig.8 with a constant illumination is found from Fig.7. The effect of the rise in temperature lowers the open circuit voltage of the photovoltaic panel, unlike the short-circuit current remains constant. The characteristic I(V) of the photovoltaic panel is given in Fig.8:

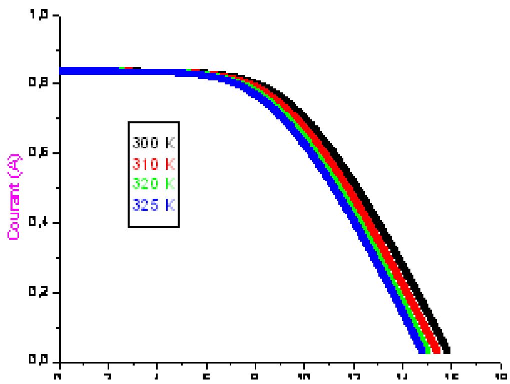


Fig.8: The influence of temperature on the characteristic I (V) for the panel Tandem

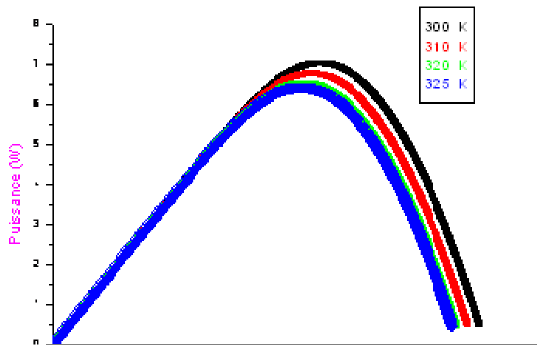


Fig.9: The influence of temperature on the characteristic P (V) for the panel Tandem

From Fig.9, the effect of increasing temperature on the characteristic P (V) is slightly decreasing power and open circuit voltage of the photovoltaic panel.

C. Effect of series resistance:

Series resistance losses characterized by Joule effect of the inherent resistance of the semiconductor and losses through the gates of collections and bad ohmic contacts of the cell. Contacts semiconductor electrode high strength appreciably lower voltage and output current, which will limit the conversion efficiency [7].

Fig.9 and Fig.10 show the variation of current with the voltage and the variation of power as a function of the voltage at various values of the series resistance. We will vary the series resistance in a range between 0.5Ω to 2.5Ω. The shunt résistance is considered constant is $1M\Omega$.

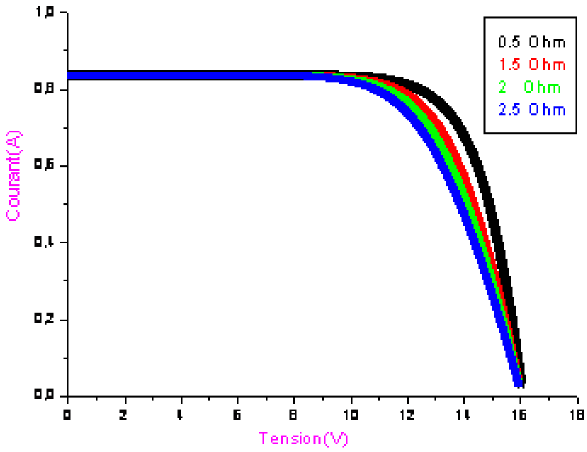


Fig.10: the influence of the series resistance on the characteristic I (V) for the panel tandem

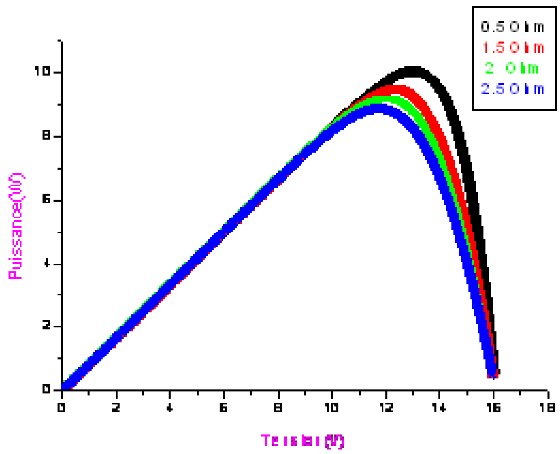


Fig.11: the influence of the series resistance on the characteristic P (V) for the panel tandem

The

rge

..npact on the slope of the curve $I = f(V)$. Effect of R_s is visible in the $I(V)$ characteristic decay or R_s increases the slope of the curve as shown in the diagram above.

D. Effect of shunt resistance:

Fig.12 and Fig.13 show the variation of current density as a function of the voltage and the change in power as a function of the voltage of the solar panel to different values of R_{sh}. We will R_{sh} vary in a range between 700Ω to 80Ω

Fig.12: The influence of the series resistance on the characteristic P (V) for the panel tandem

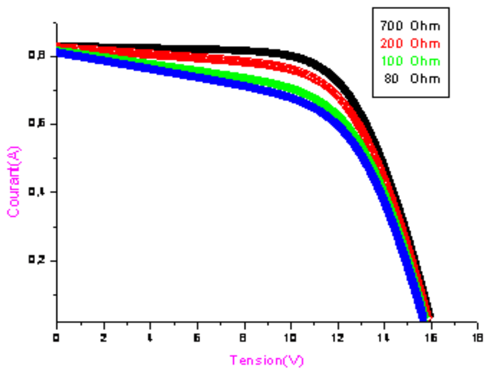
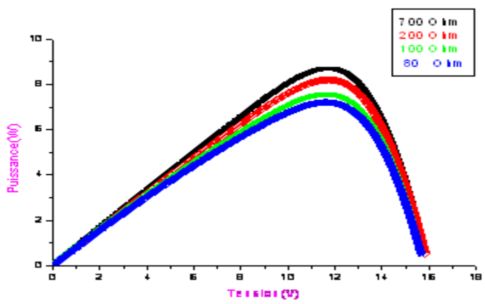


Fig.13: The influence of the series resistance on the characteristic P (V)



The effect of the shunt resistor is light on the characteristic curve of the panel. We will note that there is a slight variation of I_{sc}. On physically R_{sh} interpreter carrier recombination, that is to say the decrease in the phenomenon of recombination depends on the increase of R_{sh} .

Conclusion:

The influences of lighting, temperature and series resistors and shunt characteristics $I(V)$ and $P(V)$ are important. When the irradiation varies for a given temperature, the short-circuit current I_{sc} varies proportionally to irradiation. At the same time, the open circuit voltage V_{co} varies very little. By cons, if the temperature increases at constant irradiation, the voltage V_{co} decreases whereas current I_{sc} increases slightly. From these data, we can estimate that depending on the operating conditions we will submit the panel, it can be deduced that the power will be able to deliver. It should, however, take some precautions for the use of these data to estimate the amount of energy delivered by a generator.

References

1. B. Beaumont, G. Nataf, F. Raymond, and C. Verie, 'A Four-Cell Photovoltaic System Based on InP and GaAs,' Proceedings 16thIEEE photovoltaic Specialist Conference, pp. 595 - 600, 1982.

2. M. Orgeret, 'Les Piles Solaires, le Composant et ses Applications', Edition Masson, 1985.

3. T. Zdanowicz, T. Rodziewicz and M. Zabkowsk-Waclawek 'Theoretical Analysis of the Optimum Energy Band Gap of Semiconductors for Fabrication of Solar Cells for Applications in Higher Latitudes Locations', Solar Energy Materials and Solar Cells, Vol. 87, N °, pp. 757 – 769, 2005

4. M..F.Sharaif, « Optimisation et mesure de chaine de conversion d'énergie photovoltaique en énergie électrique »Thèse de l'université Paul Sabatier, LAAS/CNRS, N° 02569, Tolouse-France,2002.

5. A. Mabrouk, «Etude et conception d'une stratégie de commande d'un onduleur connecté au réseau électrique». Mémoire de magister en électricité solaire de l'école Nationale Polytechnique El Harrach, ALGER, 2008.

6. T. Zdanowicz, T. Rodziewicz, M. Zabkowsk-Waclawek "Theoretical analysis of the optimum energy band gap of semiconductors for fabrication of solar cells for applications in higher latitudes locations" Solar Energy Materials & Solar Cells 87 (2005) 757–769.

7. Sze S, Physics of Semiconductor Devices, John Wiley & Sons, New York, NY (1981).