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Research Article

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Variation of I-V and P-V characteristics under the effect of temperature and sunlight

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Abstract In this paper we study the impact of excess carrier on the recombinaison rate and effective lifetime. We study two types of dopand species the Boron and the phosphorus. Considering the all types of recombinaison (Auger, radiative and SHR recombinaison). The model used for these types of recombinaison is Niewelt 2022. In indirect band gap semiconductors such as silicon (Si), the carrier lifetime strongly depends on the concentration of recombination centers. The simulation was done under the temperature of 300 K. The results show that, the effective lifetime depends on the the types of dopand species and the excess carrier density.The lifetime decreases as the excess carrier density increases.

Keywords Silicon Doped p and n, silicon (Si)

1. Introduction

A variety of performance indices have been employed by the photovoltaic community to assess the performance of cells and modules. The physical mechanisms of the influence of temperature and irradiance on the performance of a cell (module) are well known, so that in principle the prediction of module output can be incorporated into models physical [1]. However, this is impractical. Researchers and designers report different more complex approaches. In reality, the performance on real-site photovoltaic modules or systems is greatly influenced by orientation, total incident irradiance, solar spectral distribution, wind speed, air temperature and other loss factors. In real operation (outdoor), the operating conditions of the module are not necessarily identical to those of the laboratory test.

Then that the current-voltage and power-voltage characteristics of a photovoltaic module depend on the solar irradiation and the temperature [2], it becomes essential to prevent researchers and users from adjusting the current conditions to maximize the efficiency.

We carried out a characterization and a simulation in the MATLAB environment. The main objective of this study is to simulate the performance of the CS-PS-COWIN SOLAR 50 module as a function of sunshine and temperature. The simulation model will be validated from the experimental data of the module.

2. Presentation and choice of the four-parameter simulation model

Many mathematical models have been developed to simulate the operation of a photovoltaic generator **[3]**, **[4]**. These models differ between them by the mathematical procedures and the number of parameters involved in the current-voltage characteristic of the photovoltaic module.

To reproduce the operation of a module, we will need two input variables which are the sunshine in the plane of the modules and the junction temperature of the cells.
Also we need output variables: the current supplied by the PV generator and the voltage at the terminals of the PV generator **[5]**, **[6]**.
The modeling of photovoltaic modules passes necessarily by a judicious choice of equivalent electrical circuits, taking more or less detail.
In general, the choice of a model always depends on the use we want to make of it, but also on the information available to determine the parameters. If only the data provided by the manufacturer is available, usually only four parameters can be determined. In this case, the easiest way is to take a 4-parameter L4P model **[7]**, **[8]**.

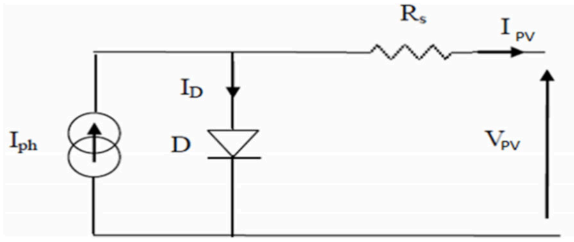

Figure 1: Equivalent circuit of the four-parameter model

The four parameters of this model are **[9]**, **[10]**:
IL, Iph = the photon current
I0 = reverse saturation current
γ = quality factor
RS = series resistance
In fact, several researchers have studied this model and compared it with other models **[11]**. In their results, they showed that it is the most used and the most appropriate model for the long-term estimation of the performance of a photovoltaic system. Their results showed that this model provides the best agreement with the experimental data, requires less calculations and the data necessary for its implementation are available in the technical data sheets.
This model treats the PV cell as a current source, which depends on irradiance, connected in parallel with a diode and in series with a serial resistance RS(4), the effect of the parallel resistance (Rp) is very small in a single module, so the model does not include it.
The characteristic I-V is thus described by:

$$I = I_{ph} - I_0\left(exp\left(\frac{q(V+IR_S}{\gamma_1 kT_c}\right) - 1\right) \quad (1)$$

For a given irradiance, temperature and cell parameters, the relationship of current versus voltage is given by equation (1), which by definition is an implicit equation and nonlinear, therefore must be solved numerically to extract the photovoltaic parameters from this equation [12].
These parameters are not generally measurable quantities or included in manufacturing data. Consequently, they must be determined from the systems of the voltage-intensity equations at various operating points given by the manufacturer or resulting from direct measurement on the module. In this context, we will hereafter study the method of identification of the different parameters of the current-voltage characteristic of a photovoltaic module.

Identification Methods of Parameters

The four parameters appearing in the voltage-intensity equation are:
- The photonic current (or photocurrent) Iph;
- The junction leakage current (or saturation current) I0;

- The imperfection coefficient of the diode (or ideality factor);
- The series resistance of the cell Rs.

After the choice of a model, another problem arises on the choice of methods to determine the different parameters. In the literature, several methods have been proposed for the extraction of parameters, each of these methods has drawbacks, either in terms of the complexity of use and accuracy, or in terms of convergence and **speed [13].**

Extraction method of parameters: Iterative method

These parameters are to be determined from the measurement of the voltage-intensity characteristic for an illumination couple and reference temperature (E_{ref}, T_{ref}) given at the STC ("Standard Test Conditions", 1000 W/m^2, 25 °C, spectrum $AM_{1.5}$) by the manufacturer, or from direct measurement on the module using the iterative method [14], [15].

From the figure, the output current is deduced by Kirchhoff's law [16]:

$I = I_{ph} - I_d$ (2)

I_{ph} is the photocurrent, Id is the diode current which is proportional to the diode saturation current.

The photocurrent is related to the illumination (E), to the temperature (T) and is given by the following expression:

$I_{ph}(E, T) = I_{ccref} * \left(\frac{E}{E_{ref}}\right) * [1 + \alpha(\Delta T)]$ (3)

With E, Eref: the actual illumination and the illumination at the reference condition (W/m^2)

α current temperature coefficient, (A/°C)

$\Delta T = T_{mod} - T_{mod\ ref}$ (4)

T_{mod} , $T_{mod\ ref}$: Cell temperature, actual and at reference condition (°C)

T_{mod} varies according to the ambient temperature and the illumination according to the following relationship:

The diode current is given by the Shockley equation (no.)

$I_d = I_0\left[exp\left(\frac{V + I.R_S}{A.N_S.V_T}\right) - 1\right]$ (5)

V is the voltage imposed on the diode

$V_T = {k.T_c}/{q}$ (6)

I_0 is the reverse saturation current of the diode (A),

Tc is the current cell temperature (°C),

k is the Bolztmann constant (k = 1.38×10^{-23}),

q is the charge of the electron.

V_T is called thermal voltage because of its exclusive dependence on temperature

N_S is the number of cells connected in series.

A is the ideality factor

It is necessary to underline that A is a constant which depends on the technology of the photovoltaic cells. All terms by which V is divided in equation (6) under the exponential function are inversely proportional to the cell temperature and therefore vary with conditions.

$a = \frac{N_S.\ A.k.T_C}{q} = N_S.\ A.V_T$ (7)

Rs is the series resistance (Ω)

The reverse saturation current is expressed as a function of the characteristics of the material and the temperature and is given by [17]:

$$I_0 = I_{0,ref} * \left(\frac{T_{mod}}{T_{ref}}\right)^n * exp\left[\frac{q.E_g.\left(\frac{1}{T_{ref}} - \frac{1}{T_{mod}}\right)}{k.n}\right] \quad (8)$$

$$I_{0,ref} = \frac{I_{sc,ref}}{\left[exp\left(\frac{V_{OC,ref}}{n.V_T}\right) - 1\right]} \quad (9)$$

With:

Voc,ref is the open circuit voltage of the solar cell at the reference condition

Eg is the Gap energy of the solar cell

$$dI = d\left(I_{ph} - I_0 * exp\left[\left(\frac{q(V+IR_S)}{n.kT}\right) - 1\right]\right) \quad (10)$$

$$dI = 0 - I_0 * q\left(\frac{dV + R_S * dI}{nkT}\right) * exp\left(q\left(\frac{V+IR_S}{nkT}\right)\right) \quad (11)$$

The series resistance (Rs) of the PV module has a great impact on the slope of the I-V curve, therefore the value of Rs is calculated by evaluating the dI/dV slope of the I-V curve at the point Voc [18].

So the series resistance is given by:

$$R_s = -\frac{dI}{dV} - \frac{nkT/q}{I_0 * exp\left(q\left(\frac{V+IR_S}{nkT}\right)\right)} \quad (12)$$

If I = 0, then V = Vco

So, the value of Rs is determined from the previous equation as a function of this point:

$$R_s = -\frac{dI}{dV}\bigg| V_{co} - \frac{nkT/q}{I_{0.exp\left(\frac{qV_{co}}{nkT}\right)}} \quad (13)$$

A PV module is an association of PV cells connected together to give a much higher voltage. In normal operation, all the cells of the PV module are assumed to be identical and subject to the same operating condition (insolation and temperature).

The equations of the characteristic relating to a module or to a field of modules formed by the series connection of Ns modules and Np modules in parallel are extrapolated from those of a cell and given by [19]:

$$I_{cc\,(mod)} = N_p.I_{cc\,(cel)} \quad (14)$$

$$V_{oc\,(mod)} = N_s.V_{oc\,(cel)} \quad (15)$$

$$R_{s\,(mod)} = \frac{N_S}{N_p} \quad (16)$$

3. Simulation of the module by the four-parameter diode model

Module overview

In our work, we used the photovoltaic module type COWIN SOLAR CS-SP-50. The characteristics of this module, under standard conditions (1000w/m^2, 25°C and Air mass 1.5), are presented in this table.

Table 1: Characteristics of the module given by the manufacturer

Maximum power, Pm	50 w (±3%)
Voltage at maximum power point, Vm	18, 2 V
Current at maximum power point, Im	2, 75 A
Open circuit voltage, V_{oc}	22,7 V
Short-circuit current, I_{cc}	2, 99 A
Current temperature coefficient	

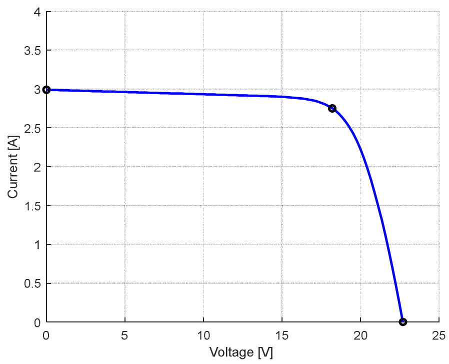

Figure 2: Experimental I-V characteristic of the COWIN SOLAR CS-SP-50 module

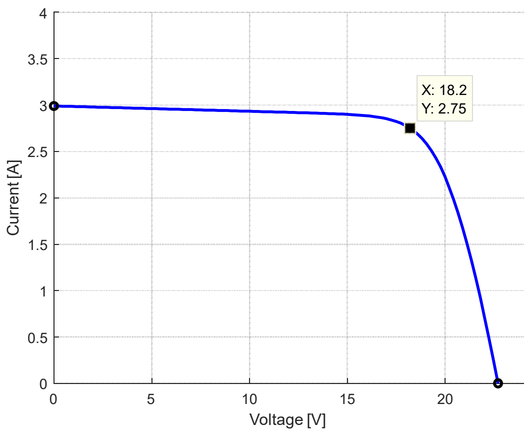

Figure 3: Modeled I-V characteristics of the COWIN SOLAR CS-SP-50 module

The experimental I-V and P-V characteristics and those compared with the results of the simulation model are presented in the following figures.

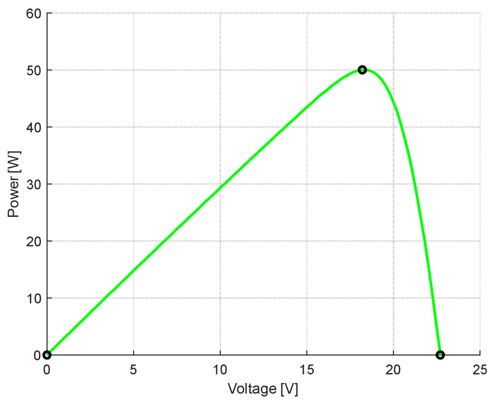

Figure 3: Experimental P-V characteristic of the COWIN SOLAR CS-SP-50 module

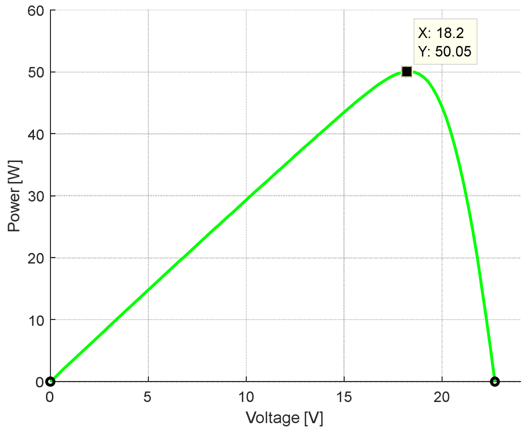

Figure 4: Modeled P-V characteristics of the COWIN SOLAR CS-SP-50 module

The comparison of the curves between the experimental and modeled I-V and P-V characteristics does not give any appreciable difference for a sunshine of 100w/m^2 and a temperature of 25°. We observe a very good correlation between the simulation results and the experimental data delivered by the manufacturer (figure 10).

4. Influence of the various parameters on the on the characteristics of the solar cell

To reproduce the influence of environmental parameters on the characteristics of a solar cell, we have simulated the IV and PV characteristics for different values of illuminations and temperatures for the use of our flowchart executed under Matlab, and this is obtained at using equations (1) to (13) and the data in table1.

Influence of irradiation on I-V and P-V characteristics

Irradiation has a very remarkable impact on the current Isc. The figures below show the influence of irradiation on the I-V and P-V characteristics. These fluctuations are obtained by varying the sunshine for a constant temperature equal to 25°.

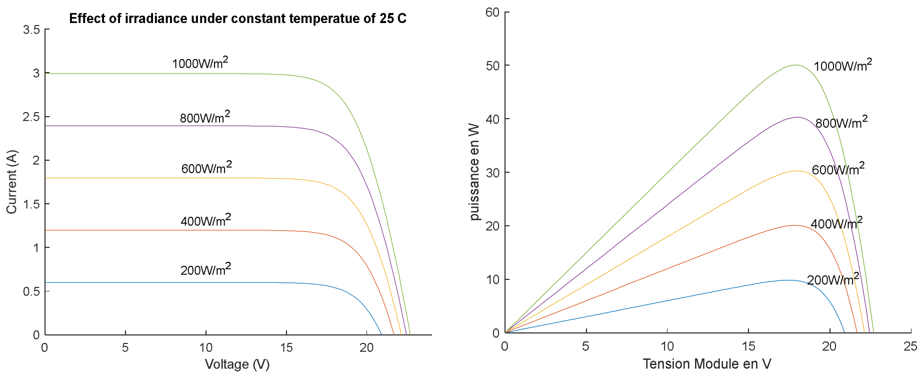

Figure 5: Influence of sunshine on I-V and P-V

Figure 5 shows the variation of the I-V and P-V characteristics of the COWIN SOLAR module depending on the insolation.

When the sunshine increases, the intensity of the photovoltaic current increases, the I-V curves shift towards increasing values allowing the module to produce greater electrical power. The current-voltage characteristic of the module shows a maximum power point whose voltage is close to 17-18 Volts at 25°C and 1000 W/m^2, in accordance with the manufacturer's data. The photo-current is therefore directly linked to the luminous flux (we put the equation number of Icc according to Iph, Rsh and Rs). Thus we can conclude that the efficiency of a PV module increases considerably with the increase in irradiation G.

Influence of temperature on I-V and P-V characteristics

Temperature is a very important and often overlooked parameter in the behavior of solar cells. For this purpose, it is essential to know the effect of changing the temperature of a solar cell on the I-V and P-V characteristics. The following figures show the effect of temperature on the I-V and P-V characteristics. These simulation results are obtained by varying the temperatures over a range of 0°C to 75°C in steps of 25°C on a sunshine of 1000w/m^2.

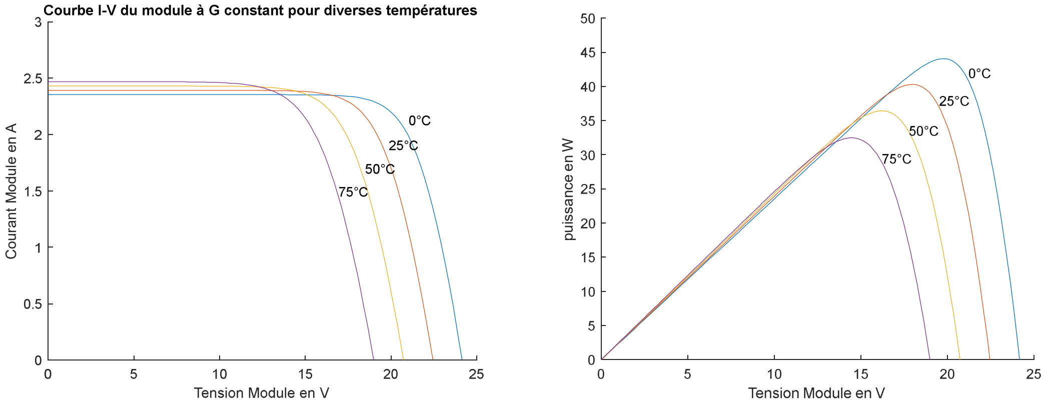

Figure 6: Influence of temperature on I-V and P-V

Figure 6 shows the temperature variation on the I-V and P-V characteristics of the module. It was found that module current parameters increase with increasing temperature, but module voltage parameters decrease with increasing temperature.

The evolution of the I (V) characteristic as a function of temperature shows that the current increases very rapidly when the temperature rises and generates a less pronounced decrease in the open circuit voltage, figure 12. It can be noted from the results that the temperature has a crucial impact on the voltage parameters of the solar module rather than the current parameters [20], [21], [22].

Thus we can conclude that the temperature has a negative impact on the performance of a PV module.

Conclusion

The performance of a PV generator is strongly influenced by climatic conditions, particularly solar irradiation and the temperature of the PV module. In this study, we used the empirical four-parameter diode model to simulate the operation of CS-SP-50 COWIN SOLAR PV modules for different insolation and temperature conditions. The main advantage of this model lies in its simplicity and ease of implementation based on the technical characteristics given by the manufacturer. From the results we found that increasing the series resistance results in degradation of the I-V curve.

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