

MODELING AND SIMULATION OF SOLAR MODULE PHOTOVOLTAIC WAAREE WSM 330 USED BY THE CENTRAL SOLAR 7MW OF MALBAZA (NIGER)

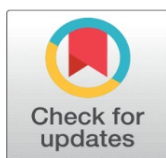
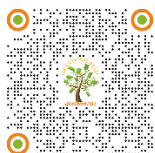
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ABSTRACT

In order to study the behavior of the solar photovoltaic 7MW Malbaza depending on the irradiation and temperature, modeling of the various components of the system is essential. It is in this context that we have done modeling of a PV module comprising the solar field of the said plant. In this article, we initially presented the basic mathematical model of the photovoltaic cell, reported the equations models with two diodes and a diode, and later considered the case of the model with a diode to perform modeling PV of the central module. Secondly, we implemented the model developed in MATLAB Simulink to study the current-voltage characteristics for different irradiations considering the constant temperature and then for different temperature keeping constant light. The results are similar to the current-voltage characteristics provided by the manufacturer. This allowed us to conclude that the model developed is reliable. Finally, we will study the influence of radiation and temperature on the production of the module.

Keywords: Electricity Spot Market, Energy, Photovoltaic, PV 7 MW, Modeling, Simulation, Matlab, Malbaza

1. INTRODUCTION

In a context of energy shortage, Nigerien authorities have focused on improving the production and distribution of electric energy. The use of renewable energy is a viable alternative to meet the energy needs of the population. It is in this context that the construction project of a 7 MW solar photovoltaic power plant connected to

the grid in Malbaza (Tahoua Region in Niger). The plant consists of a twenty two thousand one hundred seventy-three (21 273) type modules Waaree WSM 330. In order to perform an optimization of production, we will establish a modeling of this plant to study the influence of parameters weather on production. The model will be simulated on Matlab Simulink. We will initially make a literature review on models of PV cell, in a second time exposing the materials and methods used to develop the solar module and then present the results of the simulation on Matlab.

2. MATHEMATICAL MODEL OF THE PHOTOVOLTAIC CELL

A photovoltaic cell is described by its current-voltage characteristics ($I = f(V)$). This modeling is typically used to approximate the output of the cell (voltage, current) as a function of two inputs which are the temperature and the illumination received. Many mathematical models have been developed to represent the behavior of the photovoltaic cells; these models are generally nonlinear resulting from that of the semiconductor junctions which form the basis of their achievements. They derive said reference model or model n diodes [Ayachi & Hamdoud \(2012\)](#).

2.1. THE REFERENCE MODEL

The principle of the photovoltaic effect is identical to the operating principle of a diode, and is illuminated when the PN junction is observed the occurrence of a reverse current I at a forward voltage V . A photovoltaic cell in darkness behaves like a conventional diode and it obeys the law Shockley is as follows [Ayachi & Hamdoud \(2012\)](#).

$$I_d = I_s \left[\exp\left\{\frac{q.v}{k.T}\right\} - 1 \right] \quad (1)$$

With

q: charge of the electron

K: Boltzmann constant

T: Temperature

N: The ideality factor ($N = 2$ for a silicon diode).

In the presence of illumination, this characteristic is modified so as to provide a maximum current which is equal to the short-circuit current (I_{sc}) and maximum voltage which is equal to the open circuit voltage (V_{oc}). The nonlinear part involves several phenomena that will divert part of the current picture generated. These phenomena may be represented by one or more diodes in parallel and optionally a resistor. This allows to achieve a reference model for the photovoltaic cell is:

Figure 1

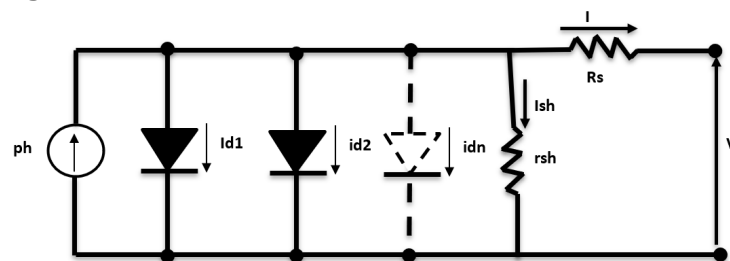


Figure 1 Basic Model of the Photovoltaic Cell [Petrone et al. \(2017\)](#), [Wasilla \(n.d.\)](#)

The first diode corresponds to a recombination "band to band" (Shockley model). It reflects the properties of the semiconductor of the cell and is characterized by a short circuit in forward bias. In the case of a small injection (cell concentrations without light), this recombination is limited by the minority carriers and the ideality factor of the diode is $N1 = 1$. In the case of a large injection (cells with high light concentration), this recombination is limited by the two types of carriers and $N1 = 2$ [Petrone et al. \(2017\)](#), [Wasilla \(n.d.\)](#).

The second diode corresponds to a recombination of two carriers in the depletion region due to the presence of defects (creating intermediate energy levels). It is characterized by an open circuit in forward bias. The diode $N2 = 2$ ideality factor if the faults are evenly distributed and matches an energy level located in the middle of the band gap (model-Noyce-Sah Shockley). If we deviate from these assumptions, we $1 \leq N2 \leq 4$.

In the case of large injection (cells with high light concentration), there also appears the Auger recombination: a majority carrier is combined with a minority by transferring the energy released at another majority carrier. This phenomenon gives rise to a third diode ideality $N3 = 2 / 3$, etc.

But generally the most used models are the two diodes and the model for a diode.

2.2. THE TWO DIODES MODEL

Indeed, the two diodes model takes into account the power transmission mechanism of the charges within the cell [Petrone et al. \(2017\)](#).

The cell a PN junction photovoltaic subjected to illumination, connected to a load can be schematized by a current generator I_{ph} (the intensity of which depends on the solar irradiance) in parallel with two diodes and a resistance R_{sh} parallel delivering a current through a series resistance R_s as shown in [Figure 2](#).

Figure 2

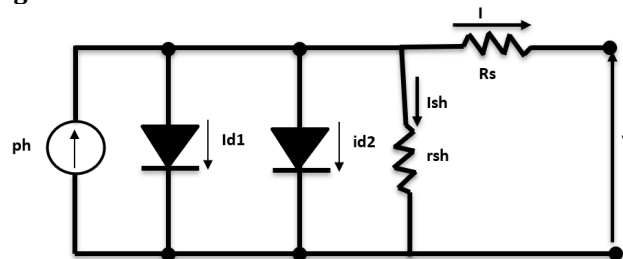


Figure 2 Model Two Diodes of the Photovoltaic Cell [Petrone et al. \(2017\)](#).

In this model, the two diodes representing polarization phenomena of the PN junction. The diode $d1$ represents a short-circuit forward biased and diode $D2$ is open circuit in reverse bias).

Resistance R_s characterizes the resistivity of the material, that the electrodes and the semiconductor / metal contact. It represents the resistive losses and should ideally be as low as possible to limit its influence on the course of the cell. This can be achieved by optimizing the semiconductor / metal contact, and reducing the resistivity of the material used.

Resistance r_{sh} : parallel resistance, called 'Shunt', comes from the recombination losses due mainly to the thickness, surface effects, as well as non-

ideality of the junction. She translated in turn, the presence of a leakage current between the upper grid and the back contact. This value will be as high as possible [Petrone et al. \(2017\)](#), [Wasilla \(n.d.\)](#).

By applying Kirchoff's laws, the charging current is obtained (I) by [Ayachi & Hamdoud \(2012\)](#), [Nassim & Ouazar \(2015\)](#), [Belkhier & Ait \(2017\)](#), [Bilal \(2012\)](#), [Back & Hoffmeister \(1991\)](#), [Olivier Gergaud \(2002\)](#), [Houda & Badache \(2008\)](#):

$$I = I_{ph} - I_{d1} - I_{d2} - I_{sh} \quad (2)$$

the current Id1 and id2 two diodes are given by equations (3) and (4) respectively [Ayachi & Hamdoud \(2012\)](#), [Nassim & Ouazar \(2015\)](#), [Belkhier & Ait \(2017\)](#), [Bilal \(2012\)](#), [Back & Hoffmeister \(1991\)](#), [Olivier Gergaud \(2002\)](#), [Houda & Badache \(2008\)](#):

$$I_{d1} = I_{s1} \left(\exp \left(\frac{V + I \cdot R_s}{n_1 \cdot V_t} \right) - 1 \right) \quad (3)$$

$$I_{d2} = I_{s2} \left(\exp \left(\frac{V + I \cdot R_s}{n_2 \cdot V_t} \right) - 1 \right) \quad (4)$$

With

- n_1 and n_2 the respective ideality factors of diodes D1 and D2.
- V: the voltage across the PV cell.
- I_{s1} et I_{s2} : The respective reverse saturation currents of the diodes D1 and D2.
- V_t = thermal voltage. It is given by:

$$V_t = \frac{K \cdot T}{q} \quad (5)$$

Or:

- $K = 1.38 \times 10^{-23}$ J / K is the Boltzmann constant;
- $q = 1.602 \times 10^{-19}$ C the elementary charge of an electron;
- T: the nominal temperature of the cell.

The current flowing in the shunt resistor and defined by:

$$I_{sh} = \frac{V + I \cdot R_s}{R_{sh}} \quad (6)$$

By replacing the current Id1, Id2 and Ish by these expressions in equation (1), the characteristic I(V) And is described by [Nassim & Ouazar \(2015\)](#), [Belkhier & Ait \(2017\)](#), [Bilal \(2012\)](#), [Back & Hoffmeister \(1991\)](#), [Olivier Gergaud \(2002\)](#), [Houda &](#)

Badache (2008), Khatib & Wilfried (2016), Petrone et al. (2017), Piazza & Vitale (2013):

$$I = I_{ph} = I_{s1} \left(\exp\left(\frac{V + I \cdot R_s}{n_1 \cdot V_t}\right) - 1 \right) - I_{s2} \left(\exp\left(\frac{V + I \cdot R_s}{n_2 \cdot V_t}\right) - 1 \right) - \frac{V + I \cdot R_s}{R_{sh}} \quad (7)$$

2.3. MODEL WITH A DIODE

The model with a diode is obtained by neglecting the recombination of carriers in the depletion zone ($I_{S2} = 0$) Petrone et al. (2017). This leads to a "standard" model to a diode. This model, also called four-parameter model was proposed by Townsend and Beckmann. It will therefore have a dependent current source of illumination and a diode in parallel and a series resistance R_s and parallel (shunt) R_{sh} to consider dissipative phenomena at the cellular level.

Figure 3

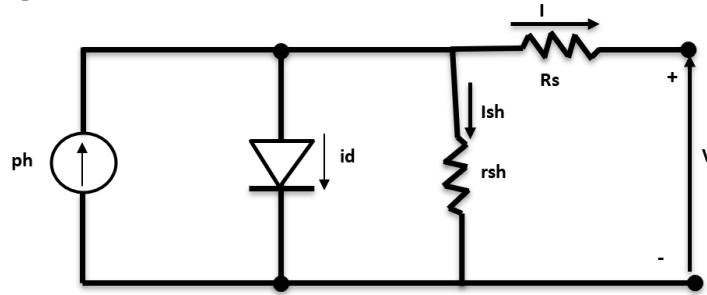


Figure 3 Model for a Cell Diode PV Petrone et al. (2017).

By applying Kirchhoff's laws determines the current I supplied by the cell by:

$$I = I_{ph} - I_d - I_{sh} \quad (8)$$

With:

- I_{ph} : The picture-current varying as a function of irradiating, it is determined with respect to data values at standard conditions Khatib & Wilfried (2016), Petrone et al. (2017), Piazza & Vitale (2013), Wasilla (n.d.), Louzazni & Aroudam (2014), Bensaci (2012), Abdelaziz & El Ghzizal (2015), Tati & Ben Lamoudi (2018), Belkhier & Ait (n.d.), Eddine & Slimane (2015), Chohraoui & Ratiba (2016):

$$I_{ph} = \frac{G}{G_{ref}} \left[I_{sc} + \alpha \cdot (T - T_{ref}) \right] \quad (9)$$

- I_d : current through the diode gives the Shockley law Khatib & Wilfried (2016), Petrone et al. (2017), Piazza & Vitale (2013), Wasilla (n.d.), Louzazni & Aroudam (2014), Bensaci (2012), Abdelaziz & El Ghzizal (2015), Tati & Ben Lamoudi (2018), Belkhier & Ait (n.d.), Eddine & Slimane (2015), Chohraoui & Ratiba (2016).

$$I_d = I_s \cdot \left[\exp\left\{ \frac{q \cdot V_d}{N \cdot K \cdot T} \right\} - 1 \right] = I_s \cdot \left[\exp\left\{ \frac{V - I \cdot R_s}{N \cdot V_t} \right\} - 1 \right] \quad (10)$$

And Is the saturation current varies with temperature and is given by Khatib & Wilfried (2016), Petrone et al. (2017), Piazza & Vitale (2013), Wasilla (n.d.), Louzazni & Aroudam (2014), Bensaci (2012), Abdelaziz & El Ghzizal (2015), Tati & Ben Lamoudi (2018), Belkhier & Ait (n.d.), Eddine & Slimane (2015), Chohraoui & Ratiba (2016).

$$I_s = I_{sref} \cdot \left(\frac{T}{T_{ref}} \right)^3 \cdot \exp\left[\left(\frac{E_g}{K} \right) \left(\frac{1}{T_{ref}} - \frac{1}{T} \right) \right] \quad (11)$$

Where the saturation current at standard conditions (Is-ref) is given by Khatib & Wilfried (2016), Petrone et al. (2017), Piazza & Vitale (2013), Wasilla (n.d.), Louzazni & Aroudam (2014), Bensaci (2012), Abdelaziz & El Ghzizal (2015), Tati & Ben Lamoudi (2018), Belkhier & Ait (n.d.), Eddine & Slimane (2015), Chohraoui & Ratiba (2016)

$$I_{sref} = \frac{I_{sc}}{\exp\left(\frac{q \cdot V_{ocref}}{N_s \cdot N_p \cdot N \cdot K \cdot T_{ref}} \right) - 1} \quad (12)$$

- Ish: The current through the parallel resistance given by:

$$I_{sh} = \frac{V + I \cdot R_s}{R_p} \quad (13)$$

Or:

- G and: Irradiance actual and reference [W / m²]. G_{ref}
- T and T_{ref} : Actual temperature and reference [K].
- I_{sc} : short-circuit current
- a : coefficient of photocurrent temperature (or short circuit current), it is often given by the manufacturer, it is generally positive but very weak.
- $K = 1.38 \times 10^{-23}$ J / K is the Boltzmann constant;
- $q = 1.602 \times 10^{-19}$ C the elementary charge of an electron;
- T : the nominal temperature of the cell in Kelvin.
- N : the ideality factor
- V : the voltage at the cell terminals
- V_{ocref} : the open circuit voltage at the reference temperature.
- R_s : series resistance

- V_t = thermal voltage given by equation (4).
- E_g : Energy "gap" of the cell. (Crystalline silicon $E_g = 1.12$ eV, amorphous Si $E_g = 1.7$ eV, copper indium diselenide $E_g = 1.03$ eV, cadmium telluride $E_g = 1.5$ eV).
- T_{ref} : Actual temperature and reference [K].

By replacing the current I_{ph} , I_d and I_{PR} by their expressions in equation (8), the characteristic I (V) is described as follows by:

$$I = I_{ph} - I_d - I_{PR}$$

$$I = \frac{G}{G_{ref}} \cdot [I_{sc} + \alpha \cdot (T - T_{ref})] - I_s \left[\exp\left\{ \frac{V - I \cdot R_s}{N \cdot V_t} - 1 \right\} \right] - \frac{V + I \cdot R_s}{R_p} \tag{14}$$

Several comparative studies have shown that the model gives a diode peak power values that the two diodes model. So, for the rest of our work, we will consider the model to a diode of the PV cell.

3. MATERIALS AND METHODS

3.1. MATERIALS

As material we used the software Matlab Simulink and characteristics of modules provided by the manufacturers.

Indeed, 7 MWc solar photovoltaic Malbaza consists of solar modules Waaree type WSM 330 whose characteristics are the following (standard conditions):

Table 1

Table 1 Characteristics of Waree Module WSM 330.	
Nominal Maximum Power (Pm) in watts	330
Tolerance for power	0 / + 5W
Open circuit voltage (Voc) in Volts	45.60
short-circuit current (Iso) in Ampere	9.65
Maximum operating voltage in volts	36
Overcurrent operation (Imp) in Ampere	9.17
Maximum system voltage Volts	1000
Module Efficiency (%)	17.01
Number of cells per module (serial)	72
Temperature coefficient α for the current (a) in% / ° C	0.0118
Temperature coefficient β for the voltage (b) in% / ° C	-0.2627
Temperature Coefficient for the γ power in% / ° C	-0.3677
Number of Parallel Module	1

3.2. METHODS

We used the model to a diode of the photovoltaic cell to develop a mathematical model of the solar module WSM 330 Malbaza. This model is then implanted on Matlab simulation using the features the manufacturer.

3.2.1. MATHEMATICAL MODEL OF A SOLAR MODULE SOLAR POWER MALBAZA

Because of its small thickness, a photovoltaic cell produces a very low electrical power of the order of 1 to 3W. Thus, to increase the power, are assembled these cells either in series or in parallel to form a photovoltaic module and achieve the desired power. A series combination of cells used to add tension, while the interconnection of cells in parallel makes it possible to add the output current of the generator.

The wiring diagram of the solar module may be represented by the following figure: [Louzazni et al. \(2014\)](#)

Figure 4

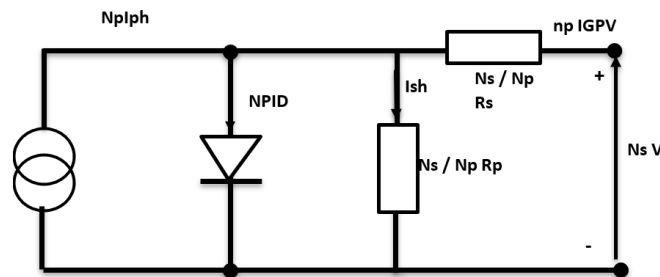


Figure 4 Equivalent Diagram of the Mathematical Model of the PV Module [Louzazni et al. \(2014\)](#).

The current supplied by the PV module is given by [Guingane et al. \(2016\)](#), [Louzazni et al. \(2014\)](#):

$$I_{pv} = N_p \cdot I_{ph} - N_p \cdot I_d - I_{sh} \quad (15)$$

with:

- I_{ph} : The photocurrent varies with the radiant and given by equation (9):

$$I_{ph} = \frac{G}{G_{ref}} \cdot [I_{sc} + \alpha \cdot (T - T_{ref})] \quad (16)$$

- I_d : current through the diode gives the Law Shockley [Guingane et al. \(2016\)](#), [Louzazni et al. \(2014\)](#):

$$I_d = I_s \left[\exp \left\{ \frac{q \cdot V_d}{N \cdot K \cdot T} \right\} - 1 \right] = I_s \left[\exp \left\{ \frac{V^*}{N \cdot V_t^*} \right\} - 1 \right] \quad (17)$$

$$\text{Or } \begin{cases} V^* = N_s \cdot V = V_{gpv} \\ R_s^* = N_s \cdot R_s \\ V_t^* = N_s \cdot V_t \end{cases} \quad (18)$$

From where:

$$I_d = I_s \left[\exp \left\{ \frac{N_p \cdot N_s \cdot V - I \cdot N_s \cdot R_s}{N_p \cdot N_s \cdot N \cdot V_t} \right\} - 1 \right] = I_s \left[\exp \left\{ \frac{N_p \cdot V_{gpv} - I \cdot N_s \cdot R_s}{N_p \cdot N_s \cdot N \cdot V_t} \right\} - 1 \right] \tag{19}$$

And Is the saturation current given by equation (11):

$$I_s = I_{sref} \cdot \left(T / T_{ref} \right)^3 \cdot \exp \left[\left(\frac{q \cdot E_g}{N \cdot K} \right) \cdot \left(\frac{1}{T_{ref}} - \frac{1}{T} \right) \right]$$

- Ish: The current through the parallel resistance given by:

$$\begin{aligned} I_{sh} &= \frac{V^* + I \cdot R_s^*}{R_p^*} = \frac{N_s \cdot V + I \cdot (N_s / N_p) \cdot R_s}{(N_s / N_p) \cdot R_p} \\ &= \frac{N_p \cdot N_s \cdot V + I \cdot N_s \cdot R_s}{N_s \cdot n_p} = \frac{N_p \cdot V_{gpv} + I \cdot N_s \cdot R_s}{N_s \cdot R_p} \end{aligned} \tag{20}$$

Id and replacing Ish by their values in Equation (15) was obtained in the current of the solar module by:

$$I_{pv} = N_p \cdot I_{ph} - N_p \cdot I_s \left[\exp \left\{ \frac{N_p \cdot V_{gpv} - I \cdot N_s \cdot R_s}{N_s \cdot N_p \cdot N \cdot V_t} \right\} - 1 \right] - \frac{N_p \cdot V_{gpv} + I \cdot N_s \cdot R_s}{N_s \cdot R_p} \tag{21}$$

3.3. IMPLEMENTATION OF MATLAB SIMULINK MODEL

3.3.1. IMPLANTATION OF THE CURRENT EQUATION PROVIDED BY THE PHOTOVOLTAIC MODULE

The photovoltaic current implementation scheme given by equation (15) on Maltab Simulink is represented by the following figure:

Figure 5

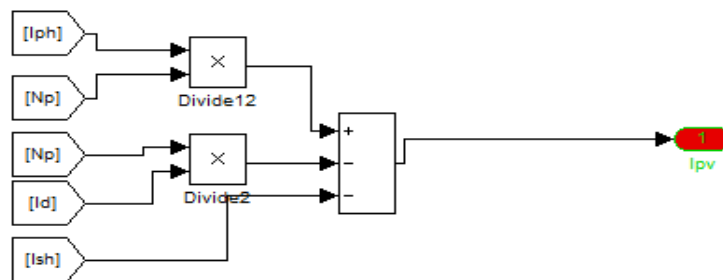


Figure 5 Photovoltaic Power Block Diagram Simulink

3.3.2. IMPLEMENTATION OF THE PHOTON CURRENT EQUATION PH

The layout diagram on Matlab Simulink, the photon current given by Equation (9) is represented by the following figure:

Figure 6

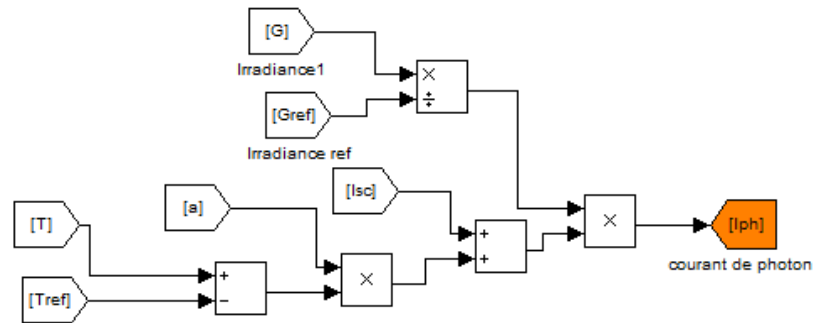


Figure 6 Photon Stream Block Diagram Simulink

3.3.3. CURRENT LOCATION OF THE DIODE

The layout diagram on Matlab Simulink, the diode current given by Equation (19) is represented by the following figure:

Figure 7

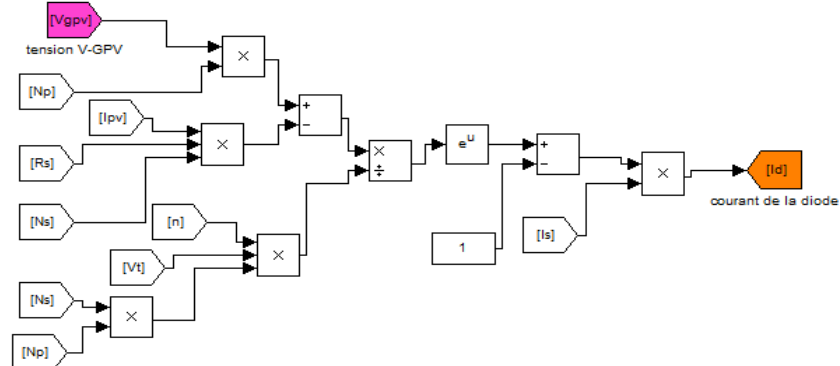


Figure 7 Photovoltaic Power Block Diagram Simulink

3.3.4. IMPLANTATION OF THE THERMAL VOLTAGE VT

The layout diagram on Matlab Simulink, thermal voltage given by equation (5) is represented by the following figure:

Figure 8

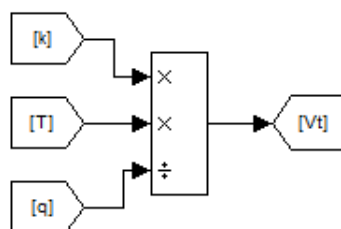


Figure 8 Block Diagram of the Thermal Voltage on Simulink

3.3.5. IS IMPLANTATION OF THE SATURATION CURRENT

The layout diagram on Maltab Simulink, the saturation current given by the equation (11) is represented by the following figure:

Figure 9

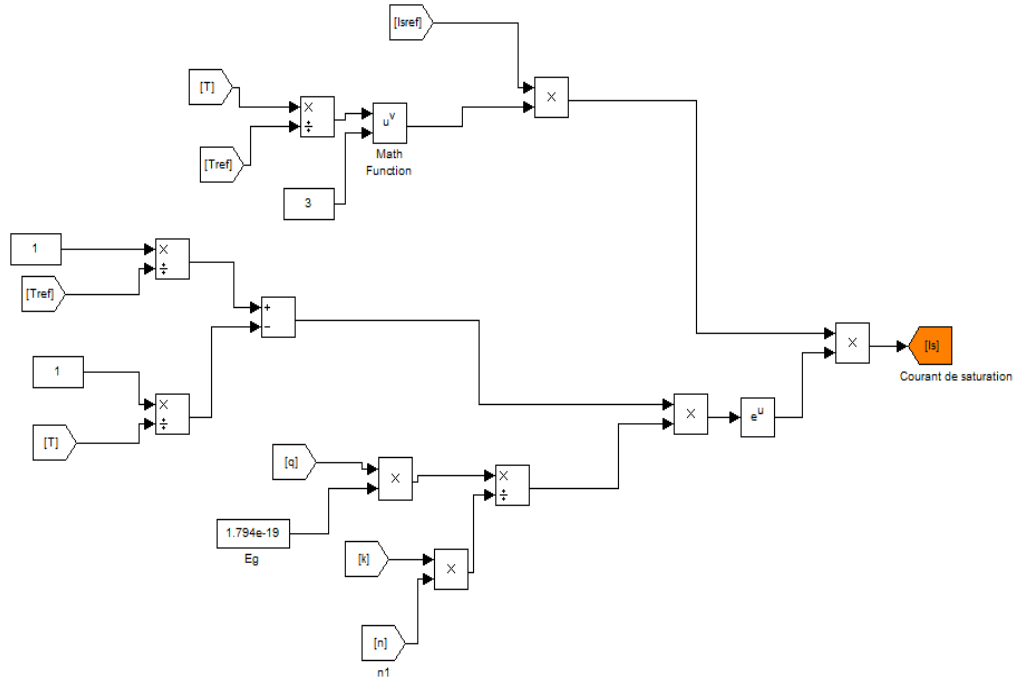


Figure 9 Photovoltaic Power Block Diagram Simulink

3.3.6. IMPLANTATION OF THE SATURATION CURRENT AT THE REFERENCE TEMPERATURE IS-REF

The layout diagram on Maltab Simulink, the saturation current at the reference temperature given by equation (12) is represented by the following figure:

Figure 10

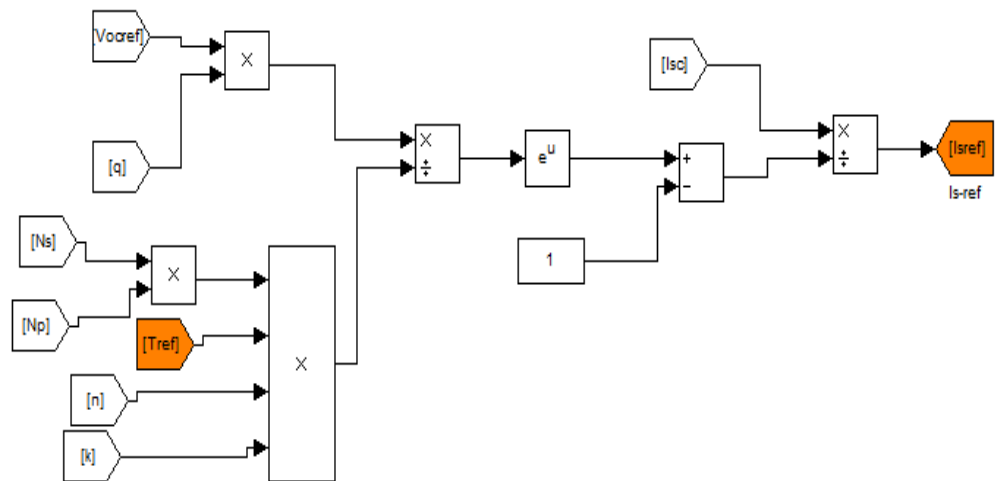


Figure 10 Saturation Current of the Block Diagram at the Reference Temperature on Simulink

3.3.7. SHUNT CURRENT IMPLANTATION (ISH)

The layout diagram on Matlab Simulink, current shunt given by equation (20) is represented by the following figure:

Figure 11

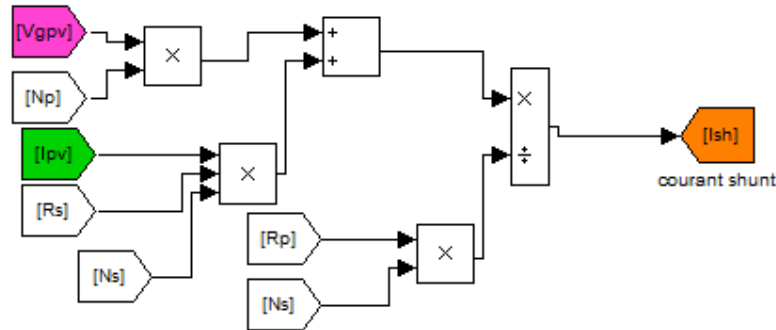


Figure 11 Schematic Block Current in the Shunt Resistance on Simulink

3.3.8. IMPLANTATION SERIES RESISTORS (RS) AND PARALLEL (RP)

Series resistance can be calculated at the point V_{co} :

$$dI_{pv} = 0 - I_{sc} \left(\exp \left(\frac{V_{gpv} + R_s \cdot I_{pv}}{n.K.T} \right) \right) \left(\frac{dV_{gpv} + R_s \cdot dI_{pv}}{n.K.T} \right) \quad (22)$$

The series resistance influences largely on the slope of the characteristic curve (IV) in the vicinity of V_{co} . It can therefore be calculated by the following formula [Khatib & Wilfried \(2016\)](#), [Piazza & Vitale \(2013\)](#), [Bensaci \(2012\)](#):

$$R_s = - \frac{dV_{gpv}}{dI_{pv}} - \frac{n \cdot V.T}{I_s \cdot \exp \left(\frac{V_{pv} + R_s I_{pv}}{n.K.T} \right)} \quad (23)$$

An approximate value was determined for the first time [Petrone et al. \(2017\)](#), [Freddy \(n.d.\)](#) and [Petrone et al. \(2017\)](#), [Skoplaki et al. \(2008\)](#). They applied for assessing PV cell parameters in Standard conditions. Their approach was later extended to extract the parameters of the cells for any environment.

The hypothesis is to consider $R_h \rightarrow \infty$ to the series resistance. Thereby neglecting the current in the branch R_h simplifying the equation of the current.

A further simplification can be made for when the PV panel is in operating condition in a short circuit, the diode included in the model is reversed biased and current is considerably lower than the current photoinduced I_{ph} . The following approximation is valid for environmental operating condition [Petrone et al. \(2017\)](#):

$$I_{ph} = I_{sc} \tag{24}$$

The series resistance can then be calculated by [Petronne et al. \(2017\)](#):

$$\begin{cases} R_s = \frac{x \cdot N_c \cdot V_t - V_{mpp}}{I_{mpp}} \\ N_c = \frac{V_{ocT}}{V_t \cdot \ln\left(\frac{I_{sc}}{I_s} + 1\right)} \text{ et } V_{ocT} = V_{ocref} + b(T - T_{ref}) \\ X = \frac{V_{mpp} + R_s \cdot I_{mpp}}{N_c \cdot V_t} \end{cases} \tag{25}$$

Or:

V_{mpp} and I_{mpp} respectively represent the voltage and current at the point of maximum operation.

b: Temperature Coefficient voltage

implanting R_s , N_c , X and V_{ocT} in Simulink is represented by the following figures:

Figure 12

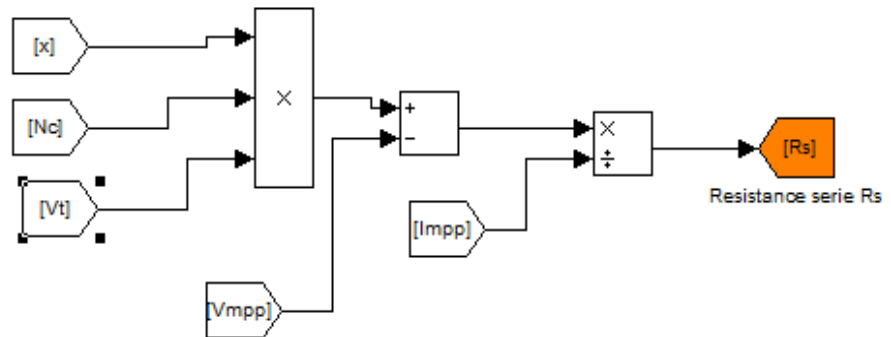


Figure 12 Series Resistance R_s Block Diagram Simulink

Figure 13

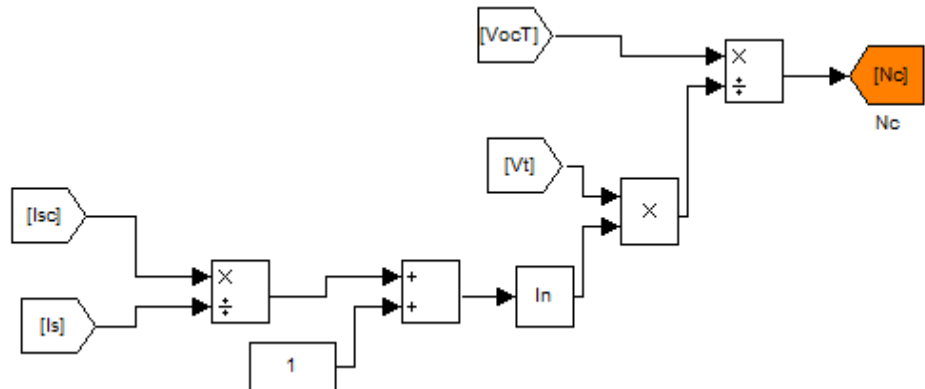


Figure 13 Ideality Factor of the Block Diagram of N_c Diode on Simulink

Figure 14

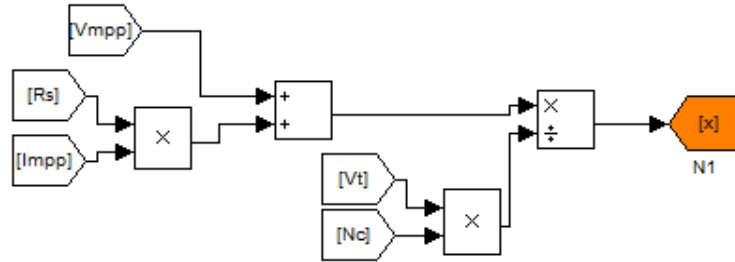


Figure 14 Block Diagram of the Parameter X Simulink

Figure 15

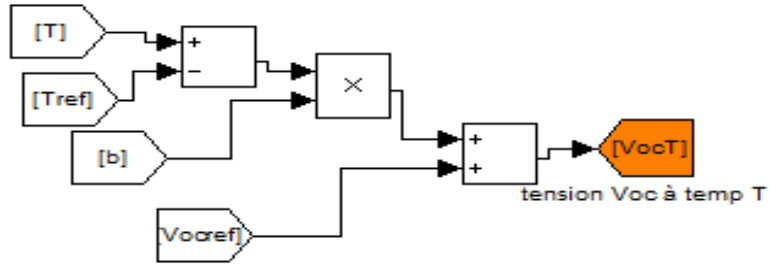


Figure 15 Block Diagram VocT Voltage on Simulink

3.3.9. IMPLANTATION OF THE PARALLEL RESISTANCE RP

The parallel resistance R_p is given by [Petrone et al. \(2017\)](#), [Tati & Ben Lamoudi \(2018\)](#)

$$R_p = \left[\frac{G_{ref}}{G} \right] \left[\frac{V_{mpp} + I_{mpp} \cdot R_s}{I_{ph} - I_{mpp} - I_s \left[\exp\left(\frac{V_{mpp} + I_{mpp} \cdot R_s}{N_c \cdot V_t} - 1\right) \right]} \right] \quad (25)$$

The diagram implantation in Matlab Simulink is given by the following figure:

Figure 16

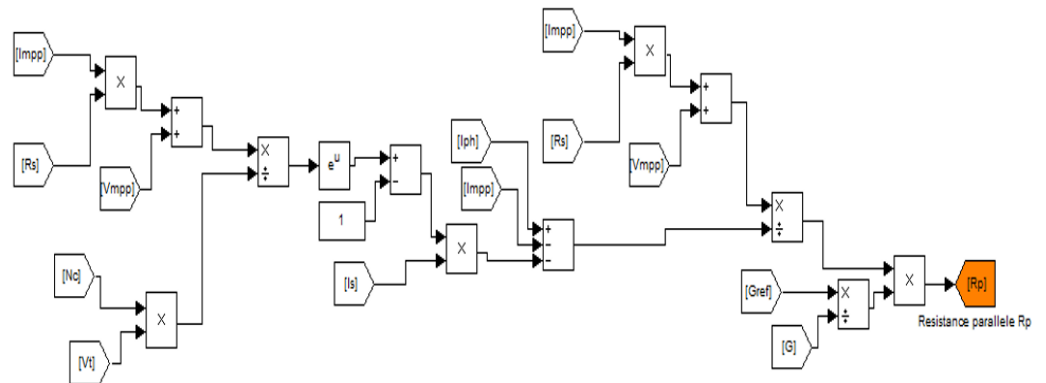


Figure 16 The Parallel Resistor Block Diagram Simulink

4. RESULTS, INTERPRETATION AND COMPARISON OF THE SIMULATION

4.1. STUDY OF THE CURRENT-VOLTAGE CHARACTERISTIC DEPENDING ON THE IRRADIATION VARIABLE AND CONSTANT TEMPERATURE

The influence of the illumination on the module at a constant temperature of 25 °C is shown in Figure 16.

Figure 17

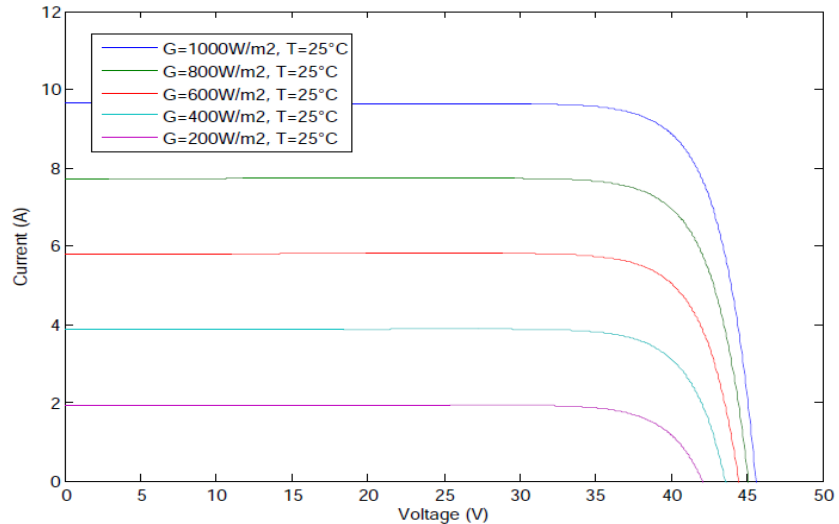


Figure 17 Characteristic Current Voltage at T = 25 °c and G Module Variable Simulink

The characteristic data by the manufacturer is shown in Figure 18

Figure 18

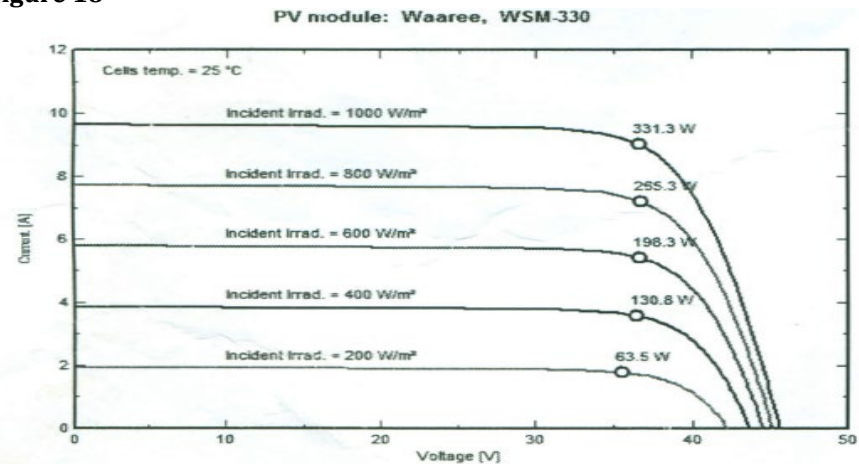


Figure 18 Characteristic Current Voltage at T = 25 °C and G Variable Given by the Manufacturer

The simulation results show that the characteristic of the PV module is directly dependent on the illumination. Indeed, the variations of current versus voltage for different levels of illumination at a temperature kept constant 25 °C show a significant change, whereas the voltage slightly changes with the illumination. On the other hand by making a comparison with the characteristic curve of the

manufacturer, found almost the particular points (SAI, Voc, Im, Vm). Which is that the model is reliable and matches the pattern of a WSM330 module.

4.2. STUDY OF THE CURRENT-VOLTAGE CHARACTERISTIC TEMPERATURE VARIABLE AND CONSTANT IRRADIATION ($G = 1000W / M2$)

The influence of temperature on the module at a constant irradiation ($G = 1000W / m2$) is represented by Figure 19.

Figure 19

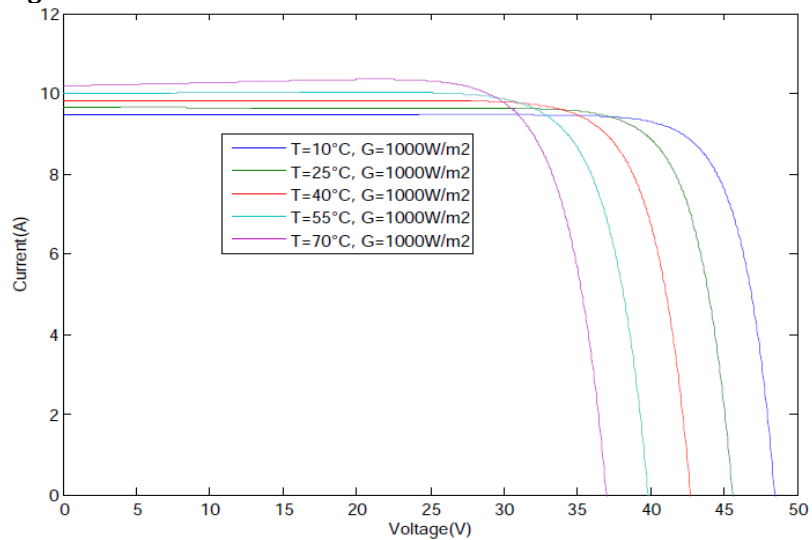


Figure 19 Characteristic Current Temperature Voltage Constant Variable and G of Simulink

The characteristic given by the manufacturer is shown in Figure 20

Figure 20

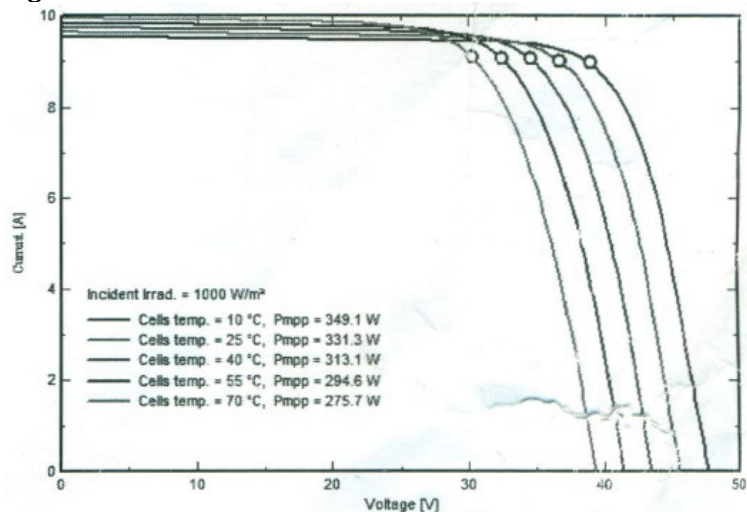


Figure 20 Voltage Current Curve (at Constant Temperature Variable and G) the Manufacturer.

The simulation results show that the characteristics of the PV module is directly dependent on the temperature. Indeed, the variations of current versus voltage for different temperature levels maintained constant irradiance $1000 W / m^2$, showed

a slight change, while the voltage changes slightly with temperature. On the other hand by making a comparison with the characteristic curve of the manufacturer, found almost the particular points (SAI, Voc, Im, Vm). Which is that the model is reliable and matches the pattern of a WSM330 module.

4.3. STUDY OF THE INFLUENCE OF IRRADIATION ON THE PHOTOVOLTAIC MODULE OUTPUT

The influence of the irradiation on the output is shown in [Figure 21](#):

Figure 21

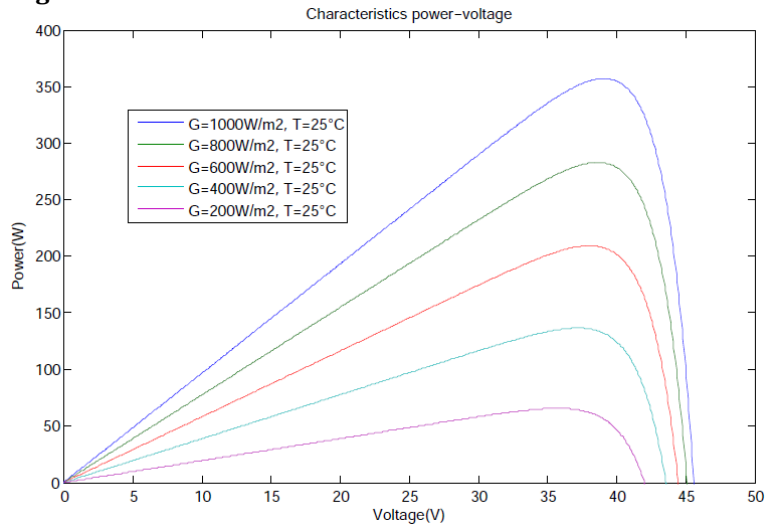


Figure 21 The Influence of the Irradiation on the Production of Modules

The simulation results show that more radiation increases more the operating point moves upward. So, the increase of irradiation greatly increases production.

4.4. THE INFLUENCE OF TEMPERATURE ON PV PRODUCTION

The influence of the irradiation on the output is shown in [Figure 22](#):

Figure 22

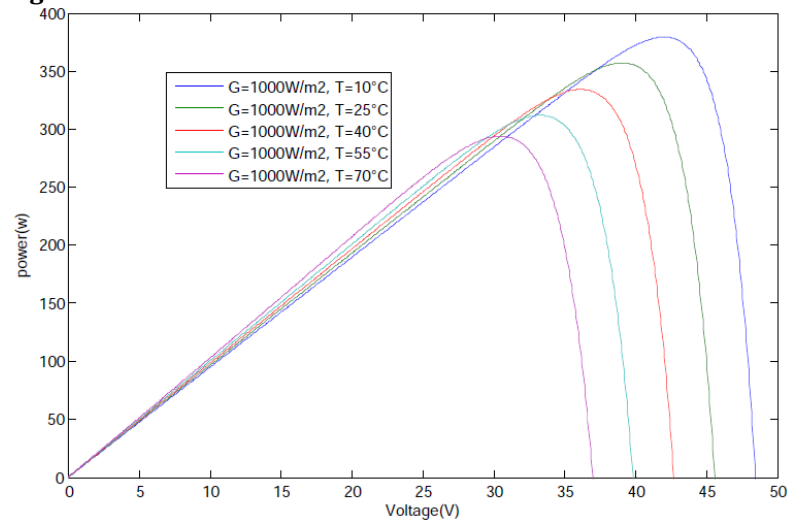


Figure 22 The Influence of Temperature on the Production of Modules

The simulation results show that the higher the temperature the more the operating point moves down. So, the increase in temperature induces negative module production

5. CONCLUSION

We have presented in this work, a model of the PV module to explain its electrical operation depending on climatic factors. The simulation module based on mathematical equations showed that the characteristics are strongly influenced by temperature and irradiation. It is observed that the temperature at a slight effect on the current, but an increase in temperature causes an apparent decrease in the short-circuit voltage. Further comparisons made with the characteristic curves given by the manufacturer with those obtained by simulation shows the curves are similar. This proves the reliability of the model developed and can be considered the model of a PV module solar power Malbaza. We show that to increase radiation induced positively on production while the temperature rise induced negatively on production.

CONFLICT OF INTERESTS

None.

ACKNOWLEDGMENTS

None.

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