Modeling and study the photovoltaic system, with the influence of internal and external operating conditions

Aicha Djalab
Applied Automation and Industrial Diagnostics Laboratory
Djelfa University, Algeria.
d.aicha1@yahoo.fr

Mohamed Mounir Rezaoui
Applied Automation and Industrial Diagnostics Laboratory
Djelfa University, Algeria.
mm.rezaoui@univ-djelfa.dz

Noureddine BESSOUS
Faculty of Science and Technology, El Oued University, Algeria
nbessous@yahoo.fr

Imad MERZOUK
LAADI Laboratory, Faculty of Science and Technology, Djelfa University, Algeria.
imadmer@yahoo.fr

***Abstract*—Photovoltaic systems operates to generate electricity. In Algeria is used as a source of alternative electric power connected to the electricity grid. Because of its many benefits, this photovoltaic energy source can be a good replacement or addition to conventional sources of supply of electricity. In this paper, a model of a photovoltaic generator is proposed, where generator uses directly the voltage and current of the photovoltaic panel to search for the operating point corresponding to the maximum power of system photovoltaic studied to proposed control strategy adopted for this system.**

The objective of this work is to model the photovoltaic system in a way intelligible and understandable to see the influence of the metrological conditions such as illuminance and temperature and the operating parameters internal to photovoltaic system. This allows the development of an on-board system in order to control the point of maximum power despite the variation of the temperature, irradiation and the electrical characteristics of the load.

Keywords - Photovoltaic system, electricity generation, electricity grid, maximum power, MPPT control.

I. INTRODUCTION

Today electrical energy production covers a very important part in the world due to the energy needs of the industrialized societies that increase regularly. On the other hand, developing countries will need more and more energy to complete their development. Large parts of their production of energy are from fossil fuels. However, the disadvantage of using these sources cause gas emissions to greenhouse with an increase in pollution; more the additional dangers of excessive consumption of natural resources stock, reducing the reserves of this type of energy in a dangerous way for nature in the future [1].

Renewable energy means the energy of the sun, the wind, the heat of the earth, water or biomass is considered a source of clean alternative energy. The direct exploitation of solar energy using sensors is based on two distinct technologies: one produces calories, and one thermal energy, the other produces solar electricity, which is the subject of this article.

Solar energy comes directly from the sunlight. The sun is a constant source energy and available worldwide.

Because of the electrical characteristics strongly not linear photovoltaic cells and their associations, the performance of PV systems can be improved by using the maximum power point research techniques (MPPT) [2].

Concerning this work, the objective is proposed an electrical mathematical modeling of the I-V characteristic of the PV module and the influence of its internal and external operating conditions. We use the MATLAB software.

II. PHOTOVOLTAIC CONVERSION SYSTEM

Photovoltaic effect used in solar cells to directly convert light energy from the Sun's rays into electricity through the production and transport in a semiconductor material of positive electric charges and negative under the effect of light. This material has two parts, one with an excess of electrons and the other a deficit of electrons, say respectively doped type "n" and boosted type 'p '. When we have contact with the second, the electrons in excess in the "n" material broadcast in the material « p » [3] [4].

The "n" initially doped area becomes charged positively, and the initially doped area 'p' negatively charged it creates between them an electric field which tends to repel the electrons in the n box and holes to the area 'p '. A junction (known as 'p' - 'n') was formed [5] [6].

By adding metal contacts on "n" and "p" areas, a diode is obtained. When the junction is lit, the photons of energy equal to or greater than the width of the bandgap communicate their energy to the atoms, each move an electron from the valence band into the conduction band and also leaves a hole capable of is move, thus generating a pair of electron - hole. If a charge is placed across the cell, the electrons of the zone n join the zone p via the external connection holes, giving rise to a potential difference [5] [6] [7]. See Figure 1**.**

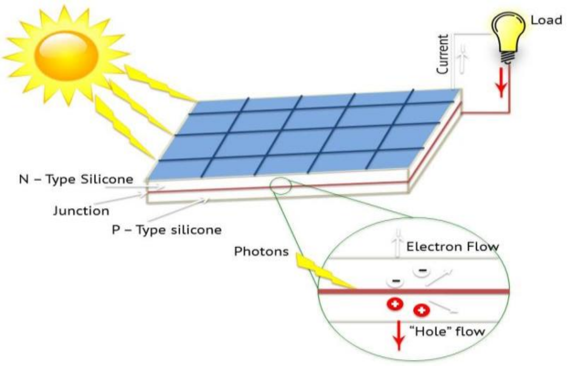


Fig.1: Principle of the photovoltaic effect

III. MODELING OF THE PHOTOVOLTAIC SYSTEM

Considering a system delivers a continuous output voltage. This photovoltaic conversion system is based on modular, as in figure 1shows a represented block [5]:

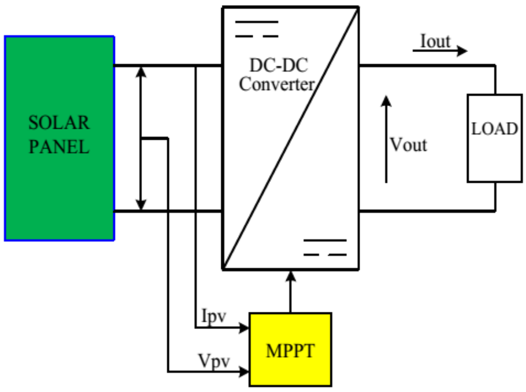


Fig.2 : system photovoltaic.

to obtain electrical features desired such as the power, the current short - circuit or voltage in open circuit [8] [9], the photovoltaic system (SPV) which consist of a set of basic photovoltaic cells connected in series and/or parallel, where the Photovoltaic cells are the main components of the module.

A. *Model of a photovoltaic cell*

The simplest circuit of the photovoltaic cell model is represented by a current source in parallel with an ideal diode, which will be adopted in this study [10].

The equivalent circuit of a solar cell is given in Figure 3. The basic PV cell model consists of four basic components, a current source, diode, shunt resistor, and series resistor [3]. The current source, i_{ph}, represents the photonic current formed from light generating excess carriers in the depletion region. The diode represents the p-n junction in the PV cell. The shunt resistance, R_p, is due to leakage in and around the depletion region and edges of the cell. The series resistance, R_s, is due to internal and external resistances to the PV cell. [11].

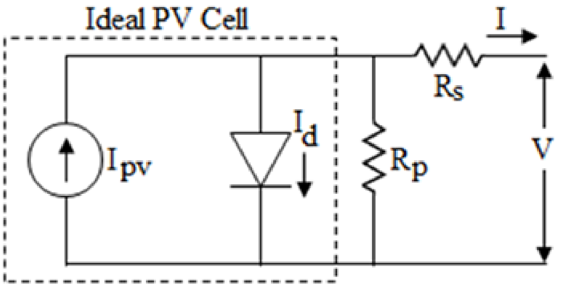


Fig.3: Equivalent circuit of a solar cell.

The equivalent circuit gives the following relationship:

$$I_{ph} = I_d + I_p + I \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(1)}$$

The current in the diode Id is given by [11]:

$$I_d = I_0 \left[\exp\left(\frac{V + R_s I}{V_t a} \right) - 1 \right] \quad \ldots\ldots\ldots\text{(2)}$$

The current in the RP resistance is given by:

$$I_p = \left(\frac{V + R_s I}{R_p} \right) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(3)}$$

From equation (1), we obtain the expression of current I:

$$I = I_{ph} - I_d - I_p \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(4)}$$

Replacing (4) in the equations (2) and (3), the characteristic equation becomes:

$$I = I_{ph} - I_0 \left[\exp\left(\frac{V + R_s I}{V_t a} \right) - 1 \right] - \left(\frac{V + R_s I}{R_p} \right) \ldots\ldots \quad \text{(5)}$$

Where:

V : The cell voltage
R_s: The resistance series cell [Ω]
R_p is the parallel resistance
I_0: Saturation current (A)
Vt : the thermal voltage of the module : Vt=Ns kT/q, with Ns the number of cells connected in series
T : The temperature of the cell [°K]
q : electron's charge e = 1.6 *10^{-19} C
K: The Boltzmann constant (1.3854*10^{-23} J°K^{-1})
a : a constant of the diode,

The source of current in Figure 2 is controlled by the solar RADIUS and temperature:

$$I_{ph} = \left(I_{phn} + K_I \Delta_T \right) \frac{G}{G_n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(6)}$$

Where:

$I_{ph,n}$: rated current (given in nominal conditions: T=25°C and G=1000W/m^2),

K_I : The short circuit current/temperature coefficient,

Δ_T =T-Tn : (T and Tn are the current and nominal temperature respectively)

G and G_n are the Sun's rays current and nominal.

With the saturation of the diode current I_0:

$$I_0 = \frac{I_{sc,n} + K_I \Delta_T}{\exp\left(\frac{V_{oc,n} + K_V \Delta_T}{aV_t}\right) - 1} \quad \text{..........................(7)}$$

$I_{sc,n}$: rated short-circuit current,
$V_{oc,n}$: nominal open voltage.
K_V : the open circuit voltage/temperature coefficient,

B. *Essential characteristics of the photovoltaic module*

In order to evaluate the influence of temperature, irradiation and the resistance series on the characteristics of the photovoltaic module, tests is made up on the module BP SX 150 of 72 solar cells connected in series to produce a maximum power of 150 W [12].

The technical details of this module show the information summarized in table [12]:

Table I: Electrical characteristics of the BP SX 150 PV module s

Caractéristiques électriques	
Voltage in open circuit (Vco)	43.5 V
Optimal operation voltage (Vmp)	34.5V
Short circuit current (Isc)	4.75 A
Optimal operating current (Imp)	4.35 A
Maximum power on STC (Pmax)	150 Wp
Operating temperature	De - 40 C° à +85 C°
Power tolerance	+/- 5%

C. *Results and interpretations*

Figures from (4) to (9). Shows the Simulation of the photovoltaic module results which represent the characteristics of current-voltage and power-voltage for different temperatures, different Photonic rays, the association in parallel, series, mixed modules and the influence of the series resistance.

Current-voltage/power-voltage characteristics in standard test conditions (STC) standard irradiation, internationally accepted, to measure the response of the photovoltaic module is a radiant intensity of 1000 W/m² and a Tempe temperature of 25 ° C.) Electrical characteristics IV and the PV curve are nonlinear characteristics and have a single point of maximum power as shown in Figures 4 and 5:

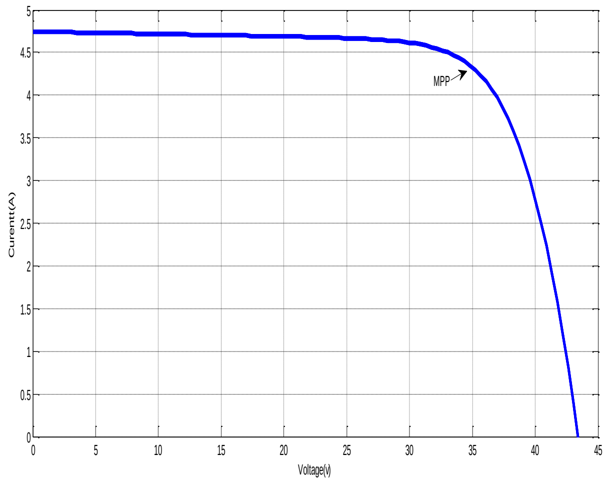


Fig.3: Electrical characteristics of a photovoltaic module I (V)

Charged by the PV module power dependent on the operating point of the MPP; It is the product of current and voltage between its terminals (Figure 5). The "MPP" represents the maximum power output by the photovoltaic generator [13].

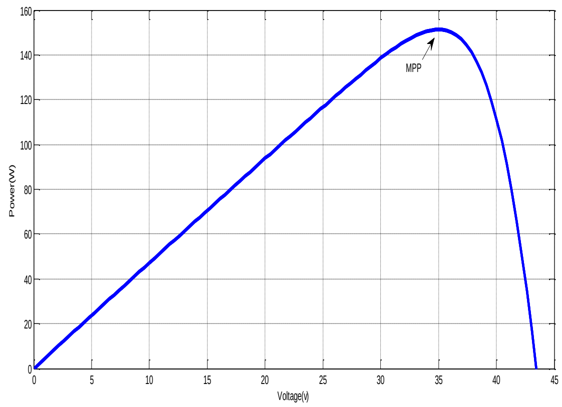
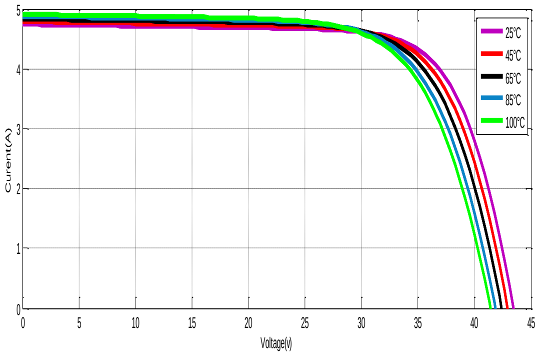


Fig.5: Electrical characteristics of a photovoltaic module P (V)

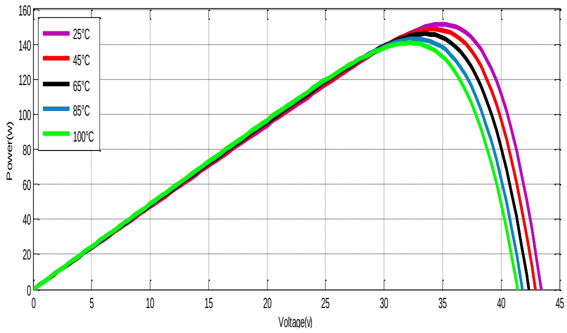
1) *The effect of temperature:*

We obtained a simulation results where we maintained illumination constant (G=1000W/m2) to different temperature (25 ° C, 50 ° C, 75 ° C, 100 ° C).

Figure 6 shows the effect of temperature on the characteristic I (V), P (V). It is essential to understand the effect of the temperature changes of a solar cell on the characteristic I (V).
In figure 6 - (a), we note that the current depends on the temperature; thus as the current increases slightly, the temperature increases, but the temperature has a negative impact on the open circuit voltage. When the temperature increases the open circuit voltage drops.



(a)



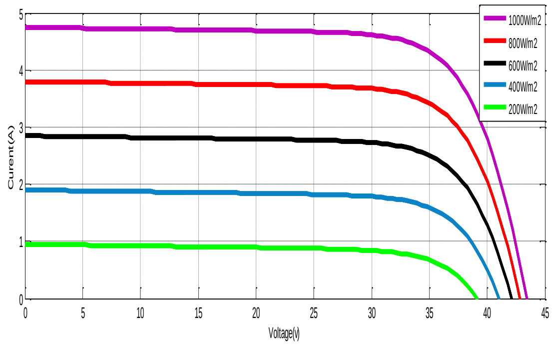
(b)

Fig.6: (a), (b) effect of temperature on the characteristics I (V) - (V) P of the BP SX 150 S module

And in figure 6 - (b), we notice that the temperature increases the maximum power of the module.

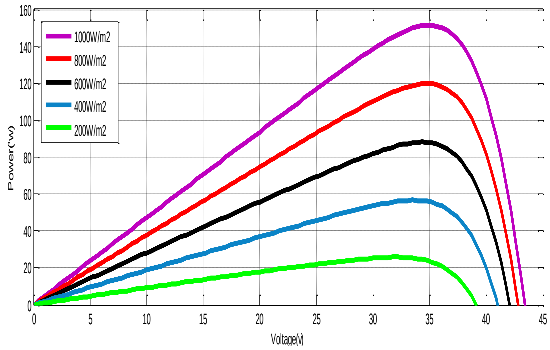
2) Effect of illuminance :

Figure 7 shows the effect of illumination on the characteristic I (V) and P (V). At a constant temperature (25 ° C), we see in figure 7 (a) as the light increases, the intensity of the current increases, the growing allows the module to produce more electric power, however the voltage light change.



(a)

And the same for the characteristic P (V) in figure 7 (b)



(b)

Fig.7: **(a) , (b)** The effect of illumination on I (V) - P (V)

3) The effect of the association in parallel, series, mixed modules:

We usually use this type of association to get a voltage important since the association of series of solar cells delivers a voltage equal to the sum of individual voltages and current equal to that of a single cell.

The characteristic of a grouping of two solar modules shown below (figure 8), which can be generalized over a range of Ns solar modules in series. As it is shown in figure (8), this kind of grouping increases the current; the equivalent feature will be that of a cell. To obtain the powers of a few W, under proper tension, it is necessary to combine modules in panels and mount the panels in rows of series and parallel panel to form what is called a photovoltaic generator.

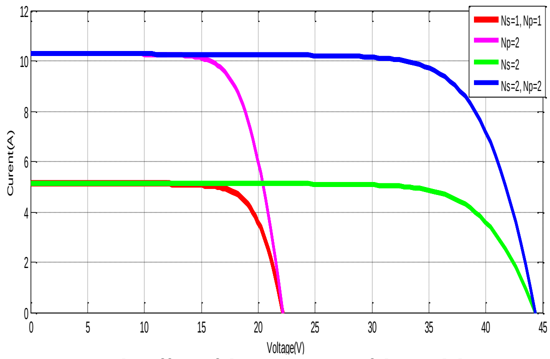
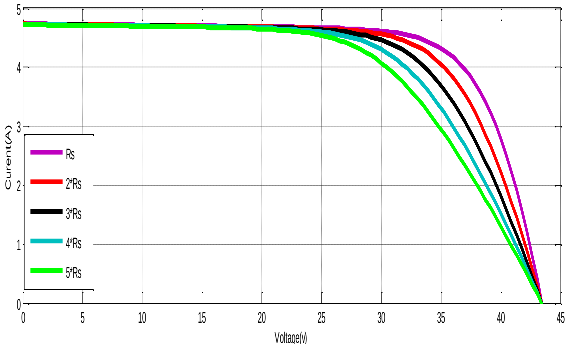


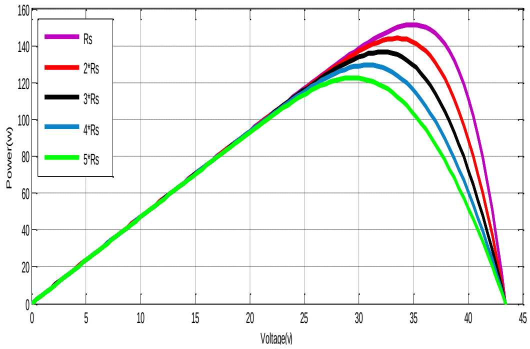
Fig.8: The effect of the association of the modules.

4) The effect of the resistance series:

The series resistance is on the slope of the characteristic in the area where the photodiode that behaves like a generator voltage, and when it is high, it decreases the value of the short-circuit current (Icc) shown in figure (9).



(a)



(b)

Fig.9: (a).(b) The effect of the resistance series on I (V) - P (V)

IV. CONCLUSION

In this paper, we introduce some principle of photovoltaic conversion. Then, we have described the main elements of the PV system. Finally, we finished by a modeling and simulation of the electric operation of a system of photovoltaic simple.

From the results we conclude that the PV cell has a non-linear characteristic and can be modeled by a simple electric circuit. Subsequently, we studied the design of the module, its modeling and its technical characteristics. The effect of the different climate and other parameters such as the Photonics irradiation and temperature on the characteristics I (V) and P (V) has been addressed. The modules can also be connected in series or in parallel to build a photovoltaic field in order to increase the voltage and intensity of use.

REFERENCES

[1] Touil Nacer Eddine, Ghenbazi Slimane. Modélisation et Simulation d'un Système Photovoltaïque, Mémoire de master Université de Echahid Hama Lakhder d'El-Oued. (2015)

[2] Andrianarimanana N. Dona, Commande MPPT d'un système photovoltaïque, Mémoired'ingéniorat, ES Polytechnique d'Antsiranana, (2014).

[3] Debili Narimene, Etude et optimisation en environnement Matlab /Simulink d'un système de pompage Photovoltaïque, Thèse de magister. Université Constantine I, (2015).

[4] Bouzidi Ali, Diagnostic et contrôle des systèmes de conditionnement de l'énergie photovoltaïque. Cas d'un système connecte au réseau électrique, Mémoire de magister. Université Hadj Lakhdar Batna, 2016.

[5] B.Chaouki , B.Tarek .Optimisation floue neuronale et génétique d'un système photovoltaïque connecté au réseau, Mémoire d'ingénieur. Université de Biskra, (2007).

[6] Nabil Kahoul, Mounira Mekki, Adaptive P&O MPPT Technique for Photovoltaic Buck- Boost Converter System, International Journal of Computer Applications (0975 – 8887) Volume 112 – No 12, February 2015

[7] J.Royer, T.Djiako, E.Schiller, B.Sada Sy, Le pompage photovoltaïque: manuel de cours à l'intention des ingénieurs et des techniciens, IEPF, Université d'Ottawa, EIER, CREPA, 1998.

[8] BENSACI Wafas. Modélisation et simulation d'un système photovoltaïque adapté par une commande MPPT, Thèse de doctorat, Université Kasdi Merbah–Ouargla, (2012).

[9] Bun, L. Détection et Localisation de Défauts pour un Système PV, Thèse de Doctorat en Génie Electrique, Université de Grenoble,(2011).

[10] Xing Wu. Fault detection and diagnosis of photovoltaic systems, Thesis master. University of southern California. (2011).

[11] T. Salmi, M. Bouzguenda, A. Gastli, A. Masmoudi, » MATLAB/Simulink Based Modelling of Solar Photovoltaic Cell, nternational journal of renewable energy research, vol.2, no.2, February 2012.

[12] SX 150s module datasheet, BP Solar.(www.bpsolar.com).

[13] Yassine LASMI, Optimisation de la poursuite du point de puissance maximale (MPPT) d'un système photovoltaïque par les techniques intelligentes, Thèse de Magister, Université Sétif -1, Algérie, (2013).