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Topic

PARAMETERS IDENTIFICATION OF A PHOTOVOLTAIC MODULE USING OPTIMIZATION METHOD

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In front of the jury

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Dedication

Dedication

finally, we have reached the end of our academic journey. However, it is the gleam that shall open doors for a greater future. Besides, for our merciful the one and only "Allah," we are thankful, We dedicate this success to our parents who strongly were present with us throughout this journey in the joyful moments as well as the sad ones. Nevertheless, we do not forget our generous teachers who stood up with us and guided us from the start to the final .line. With hearts full of love we Thank you all for being with us.

Lah. Assia

Dedication

We thank God who has guided us to work. I dedicate this humble work, especially to my mother the patient woman who has given us love and care, believed in me, and supported me. Also, to my dear father, the one whose name , I bear and who possesses a big heart and a radiant face, the one I leaned on during my moments of weakness , To my dear siblings, my companions, and my unwavering support in this world, my sisters and brothers.

This work it dedicated to every person who helped me, even if with a word, for everyone who motivated me from the beginning until the day of my graduation, for every person who contributed to raising my moral. For every person who told me you can do it, for family, friends and cousins.

I dedicate this research to every student who open it and read it, I hope you find what you want. And the most important thing that this work will become as an ongoing charity for us.

Ne. Zineb

ملخـــــص:

الاعتماد على الطاقات الشمسية في العشرية الأخيرة أثبت إمكانية مساهمتها وبشكل كبير في حلول المشاكل الطاقوية، ليس من الناحية الإيكولوجية فحسب، بل أيضا بفضل بناها اللامركزية .

في هذا العمل، دراسة لبعض نماذج الانظمة الشمسية وطريقة تعريفها بالاعتماد على خوارزمية التحسين ممثلة بـ PSO .الموضوع واسع ولذلك في دراستنا اعتمدنا على تجربة تمثلت في استخراج التيار و التوتر لنوع خاص من الانظمة الشمسية. النتائج المتحصل عليها تثبت فعالية الخوارزمية المطبقة وخاصة للقيم القريبة من الشروط النظامية.

كلمات مفتاحية : الطاقة الشمسية ، النمذجة، المحاكاة، خوارزمية PSO

Résumé

La dépendance croissante aux énergies solaires au cours de la dernière décennie a démontré sa capacité à contribuer de manière significative aux solutions aux problèmes énergétiques, non seulement du point de vue écologique, mais aussi grâce à sa nature décentralisée. Dans cette étude, nous avons examiné quelques modèles de systèmes solaires et leur définition en utilisant l'algorithme d'optimisation des essaims particulaires (PSO). Le sujet est vaste, et dans notre étude, nous avons basé notre expérience sur l'extraction du courant et de la tension pour un type spécifique de systèmes solaires. Les résultats obtenus confirment l'efficacité de l'algorithme appliqué, en particulier pour les valeurs proches des conditions du système.

MOTS CLES : Energie photovoltaïque, Modélisation, Simulation, Algorithme PSO

ABSTRACT

Over the past decade, relying on solar energy has demonstrated its significant potential in addressing energy-related problems, not only from an ecological perspective but also thanks to its decentralized nature.

In this study, an examination of certain solar system models and their definition using the optimization algorithm represented by PSO is conducted. The subject matter is extensive, and in our research, we relied on an experiment involving the extraction of current and voltage for a specific type of solar system. The results obtained affirm the effectiveness of the applied algorithm, especially for values close to the system conditions.

Key-Words: Photovoltaic energy, modeling, simulation, algorithm PSO.

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PSO: Particle Swarm Optimization

General introduction

Life is but a continuous process of energy conversion and transformation Energy is an essential component of human development and economic growth. Adequate and affordable energy supplies are necessary to improve people's well-being and standard of living.

Energy should be considered an important component of economic development because most production processes involve energy inputs. Energy consumption increases with economic growth and development. Therefore, energy demand must be met adequately and economically. There has been significant development in the past 50 years.

Living standards have improved and people are healthier and living longer. Science and technology have greatly improved social welfare. The abundant and cheap energy resources of the Middle East have contributed particularly to these developments.

The sufficiency of the world's energy resources has major implications for the sustainable development, economic governance, and social welfare of the world and its countries.

Solar energy is an environmentally friendly technology, an excellent source of energy supply and one of the most important renewable green energy sources. It plays a major role in achieving energy solutions for sustainable development.

This makes it a very attractive resource for power generation due to the large amount of solar energy available every day. Both concentrating solar thermal and photovoltaic technologies are under constant development to meet our energy needs.

The large installed capacity of solar energy applications worldwide meets, in the same context, the job market to support the energy sector and obtain adequate development. Thus, this publication provides insights and analysis on the sustainability of solar energy, including environmental and economic development.

Furthermore, it highlights the contribution of solar energy applications in sustainable development by providing energy demand, creating employment opportunities, and enhancing environmental protection. Finally, draws on the prospects of solar energy technology in energy sector applications and offers perspectives for future developments in this field.

Photovoltaic power generation has the potential for effective and sustainable development. As a result, scientific research is moving towards mainstreaming, refining and improving the operation of the solar system.

Solar system improvements are based on energy measurements and maximizing criteria for good performance

Modeling solar cells necessarily requires the judicious selection of equivalent electrical circuits. Developing an accurate equivalent circuit for a solar cell requires an understanding of the physical configuration of the cell elements.

As well as the electrical characteristics of each element. Several mathematical models have been developed to describe the highly nonlinear behavior of these based semiconductor junctions. These models differ in the number of mathematical procedures and parameters used to calculate the voltage and current of the solar module.

The overall objective is to ensure that photovoltaic modules operate at their highest efficiency and reliability, contributing to the success of solar energy systems and reducing the cost of renewable energy production.

This project is organized as follows:

In the first chapter, we explored the broad scope of photovoltaic systems. We delved into the various categories and constituents of photovoltaic cells, as well as the diverse models available for these cells. We will be discussing the one-diode and two-diode models and their real-world applications. Furthermore, we will examine how solar cell characteristics can be influenced by both light and temperature.

In the second chapter we learn about the photovoltaic system identification. Formulate problem of the ideal model, the simple and the double diode. we represented Newton Raphson method and the Particle swarm optimization method (PSO).

In third Chapter, we introduce the types of solar illumination, followed by a general definition of solar radiation with its properties and measurement devices.

In the simulation part , we apply the commands to our system after visualizing the obtained results.

CHAPTER I

Photovoltaic systems representation

I.1 Introduction:

We will present in this chapter the principle of photoelectric conversion and we will give a description of photoelectric cell, its performance and also its types, as well as a model of the cell.

Photovoltaic (PV) solar energy is one of the most widely used and renewable forms of energy since the sun is an unlimited source of energy .for the production of electrical energy,solar systems rely on photovoltaic which convert photons of light into electricity , since the energy is provided by photons (component of light)which collide with electrons and release them which cause an electric current .this direct current can be converted into other currents.

I.2 Renewable energy:

Renewable energies are natural energies that renew themselves at the human level. They are natural and available energies, because they are very diverse [1].

- ✓ Sun: thermal, photovoltaic, thermodynamic.
- ✓ Wind: wind turbine.
- ✓ Biofuel.
- ✓ Biodegradation: biomass.
- ✓ Water: hydroelectric, tidal.
- ✓ Terrestrial heat: geothermal energy.

I.3 Solar energy:

Solar energy comes from nuclear fusion that takes place in the center of the sun, it is composed of 75% hydrogen, 23% helium and 2% other molecules. Hydrogen atoms are converted into helium by a large-scale thermonuclear fusion reaction. Moreover, according to Einstein's formula $\boldsymbol{E = mc^2}$**,** the mass is converted into energy. This reaction keeps the surface of the sun at a temperature of about 5800°K. The sun's energy is uniformly converted into radiation in all directions in space. When it traveled 150 million miles from the sun to earth, its total extraterrestrial density fell to 1367/m^2. This value is called the solar constant. In one hour, the energy the earth gets from the sun is enough 1.2×1017, which is enough to sustain itself for almost a year. Photovoltaic panels can use this free energy by converting it into electricity [2].

I.4 Solar radiation:

Our sun is a dwarf star, composed of 74% hydrogen and 25% helium And for some heavier elements, the surface temperature is around 5530 [3].

a. Direct radiation: direct radiation is the difference between global radiation and diffuse radiation.

b. The global radiation: global radiation is subdivided into direct, diffuse and ground-reflected radiation. In the figure below is schematized all the solar radiation received on a terrestrial surface.

c. Diffuse radiation: this is due to the absorption and scattering of part of the global solar radiation by the atmosphere and its reflection by clouds and aerosols.

d. Reflected radiation or ground albedo: It is the radiation that is reflected by the ground or by objects on its surface. This albedo can be significant when the ground is particularly reflective (water, snow, etc.).

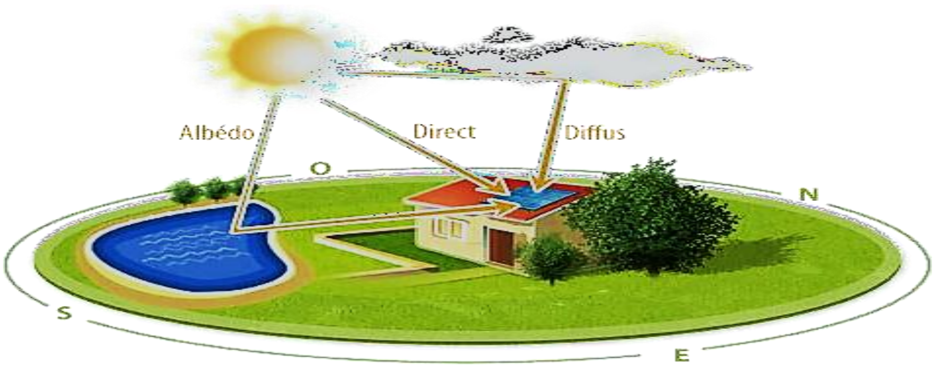


Figure I.1: Types of solar radiation received on the ground [3].

I.5 the solar panels:

A solar panel is a flat technological device of approximately 1 m2 intended to recover energy from solar radiation to transform it into heat and heat sanitary water via thermal collectors or produce electricity thanks to photovoltaic cells composed of part of semiconductor materials. The solar panel can also combine both thermal and electrical technologies. It is installed on the roof or the ground.

I.5.1The photovoltaic cell:

Photovoltaic cells can be directly converted into solar energy (light) is converted into electricity. This conversion method is based on the well-known principle of the photoelectric effect. To pass from the photovoltaic effect to the practical applications, it is necessary research of semiconductor materials being able to optimize the two basic stages this principle consists in absorbing the incident light and collecting surface electrons. Photovoltaic cells are made of semiconductor materials, Can conduct electricity or transmit electricity. Over 90% of the solar cells that are made today are crystalline silicon, a type of semiconductor. One of the battery faces is N-doped (eg, phosphorus). The other is P-doped (e.g., boron). Metal electrodes are placed on both sides to collect electrons and make the circuit. Treat the top surface of the battery Through surface treatment, the amount of light entering the cell is optimized in the following ways: Applying an anti-reflective layer and another layer of waterproof glass Cell protection. Finally, the upper and lower sides are equipped with electrodes recover the electronics [4].

I.5.2 Principle of operation of the photovoltaic cell:

The PV cell consists of two layers of silicon, one layer is doped with boron (P-doped silicon), and the other layer is doped with phosphorus (N-doped silicon), thus forming a PN junction with a potential barrier. 1.8. When the photons are absorbed by the semiconductor, they transfer energy to the atoms in the PN junction, thus releasing the electrons from these atoms and generating electrons (negative charge: N) and holes (positive charge: P) . Then, it creates a potential difference between the two layers. This potential difference can be measured between the terminal connections.

Positive and the negative terminal of the battery. By placing a resistive load outside the unit, we can also harvest carriers.

The maximum cell voltage is about 0.6 V for zero current (open circuit). This voltage is called open circuit voltage V_{c0}.

The maximum current occurs when the cell terminals are short circuited, it is called short circuit current (I_{cc}) [5].

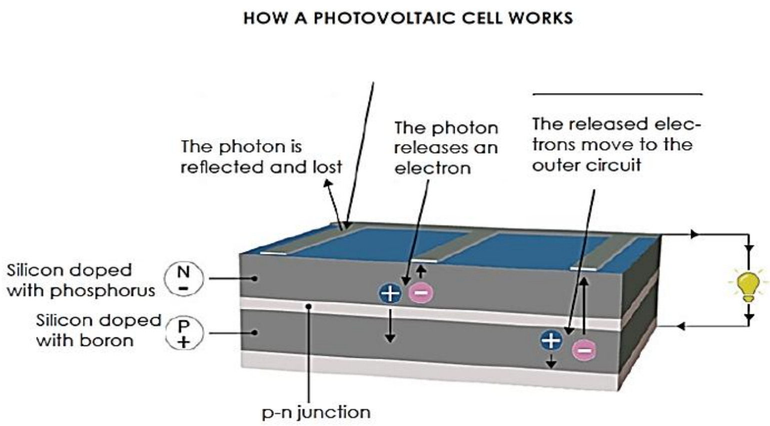


Figure I.2: Operating principle of a photovoltaic cell [5].

I.5.3 Cell technologies:

The most common material in photovoltaic cells or solar cells is silicon, a type IV semiconductor. It is said to be tetravalent, which means that a silicon atom can bond with four other atoms of the same nature. Composite materials such as gallium arsenide and thin layers such as CdTe (cadmium telluride) and CIS (copper-indium-diselenium) and even CIGS are also used [6].

There are several types of solar cells:

- Mono crystalline cells.
- Polycrystalline cells
- Amorphous cells, etc.

I.6 the different types of solar cells (photovoltaic cells):

There are different types of solar cells or photovoltaic cells. Each type of cell is characterized by its own efficiency and cost. However, whatever the type, the efficiency remains quite low: between 8 and 23% of the energy that the cells receive. Currently, there are three main types of cells.

I.6.1 Mono crystalline cells:

- First generation solar cell.
- Obtaining pure crystals requires a lot of energy.
- Laborious and difficult manufacturing method, therefore very expensive.
- The direct sunlight yield rate (12-16%) (23% in lab).

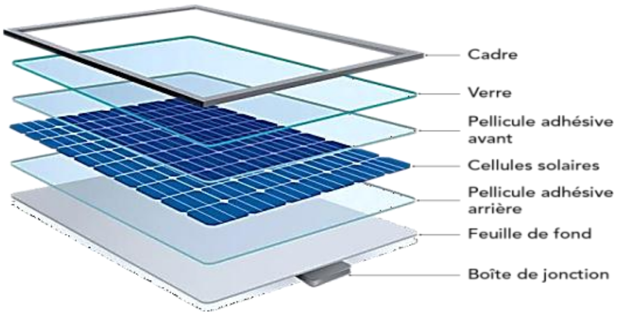


Figure I.3: Mono crystalline photovoltaic cell [6].

I.6.2 Polycrystalline cells:

Their design is easier and their manufacturing cost is lower.

- The yield is 11-13% (18% in the laboratory).
- Process requiring less energy.
- Constitute small single crystal silicon, which can reduce the manufacturing cost.

Figure I.4: Polycrystalline photovoltaic cell [6].

I.6.3 The cells Amorphous:

They have a low yield (5% to 8%, 13% in the laboratory), but only require very small thicknesses of silicon and have a low cost. They are commonly used in small consumer products such as solar calculators or watches.

The advantage of this last type is that it works with low lighting (even on cloudy days or inside a building).

Figure I.5: Amorphous photovoltaic cell [6].

I.7 the PV field:

The photoelectric field is the unit of direct current generation in the system, it is a group of interconnected photovoltaic solar modules intended to produce electricity, either independently or as part of a connection to a grid, audience [7].

Figure I.6: Photovoltaic field [7].

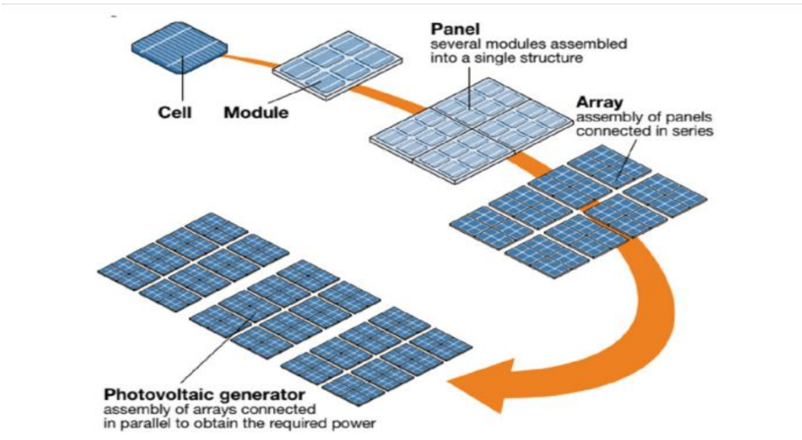


Figure I.7: Cell to module to photovoltaic generator.

I.8 Different types of PV system:

a. Autonomous system:

Autonomous systems are completely independent of other energy sources. They are usually used to power homes, cabins or camps in remote areas as well as for applications such as remote monitoring and water pumping. Depending on whether or not electrochemical storage is used, stand-alone photovoltaic systems are classified as follows:

- Autonomous photovoltaic systems with storage.
- Photovoltaic systems without storage (over the sun) [8].

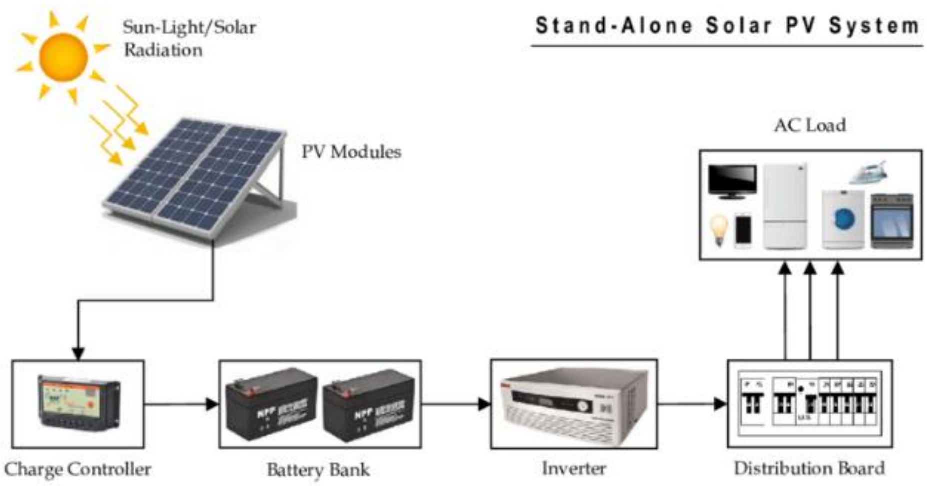


Figure I.8 :Stand-alone or isolated PV system[8].

b. Grid-connected PV system :

Such a system is installed on a site connected to the network (Sonelgaz in Algeria). Generally, on homes or businesses that wish to use a form of renewable energy and that benefit from good sunshine.

A distinction can be made between grid-connected PV systems with and without storage batteries.

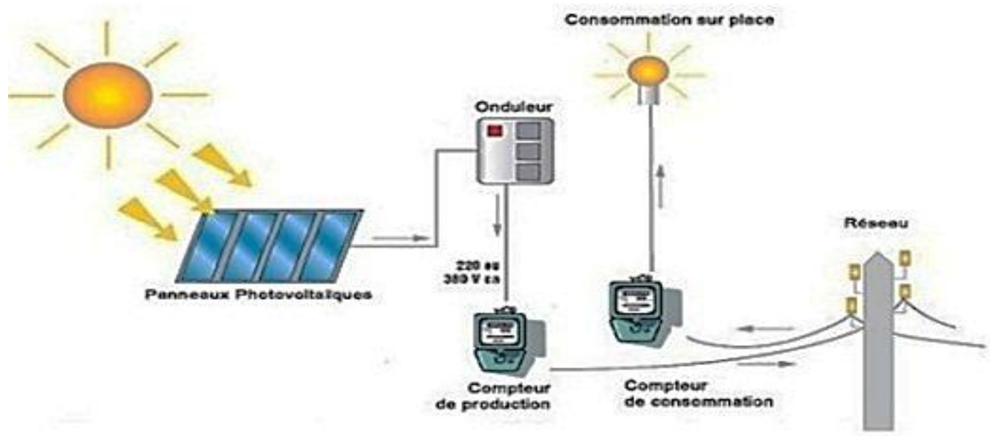


Figure I.9: Grid-tied PV system without battery [8].

c. Hybrid PV system

Hybrid photovoltaic systems integrate a photovoltaic generator and another generator: wind turbine, generator and sometimes even the public electricity network. In general, a battery system stores energy and thus allows not losing energy from random sources such as solar or winding.

The difficulty with this type of system is to balance the different energy sources so as to optimize them all, it being understood that the thermal sources (diesel, gas, etc.) and the public network are always the back-up of last resort [8].

I.9 Connecting of photovoltaic cells:

1. Regrouping in series:

In a series group , the cells are crossed by the same current and the resultant characteristic of the series group (index S) is obtained by the addition of the voltages at the given current .the figure shows the resulting characteristic (Vs, I_{cc}) obtained by associating in series Ns identical cells .

$$V_s = N_s . V_{C0} \quad \textbf{(1.1)}$$

To for general expression :

$$I_{cc} = I_c \quad \textbf{(1.2)}$$

With V_C : voltage supplied by a cell. For this grouping, the current is common to all the cells.

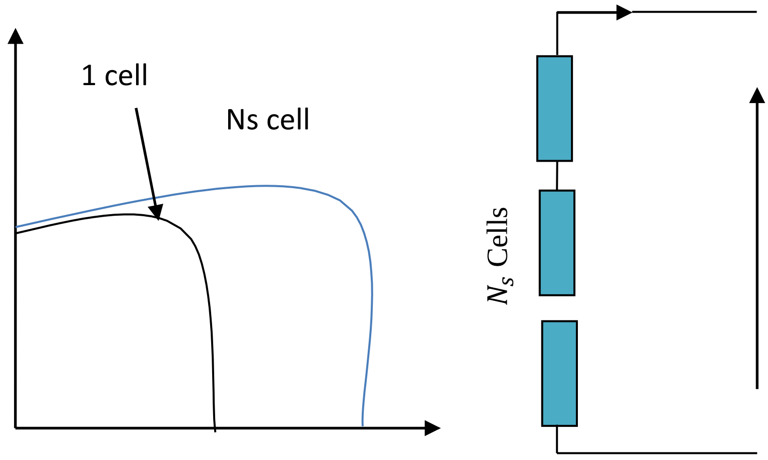


Figure I.10 : Current voltage characteristic of (N_s) cells in series [8].

2. **Regrouping in parallel:**

Paralleling allows the output current to be increased. For a group of cells connected in parallel, the output current has the general expression:

$$\boldsymbol{I_s = N_p . I_{cc}} \qquad \textbf{(1.3)}$$

With $\boldsymbol{I_{cc}}$: current supplied by a cell.

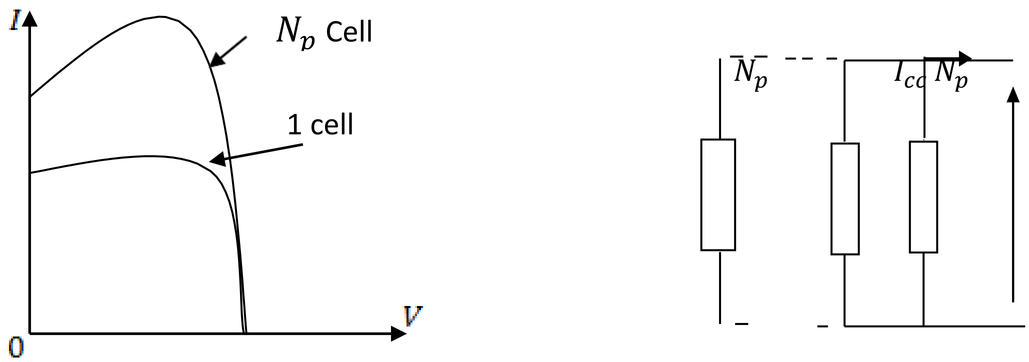


Figure I.11: Current voltage characteristic of (Np) cell in Parallel [8].

I.10 Advantages and disadvantages of solar PV energy Benefits:

a. Advantages:

- High reliability. The installation has no moving parts which makes it particularly suitable for remote areas. This is the reason for its use on Spacecraft.
- The operating cost is very low given the reduced maintenance and it does not require fuel, transportation or highly specialized personnel.
- Photovoltaic technology has qualities from an ecological point of view because the finished product is non-polluting, silent and causes no disturbance of the environment.
- The production of this renewable electricity is clean and non-toxic.
- Photovoltaic electricity is produced as close as possible to its place of consumption, in a decentralized way, directly at the user.
- Its modular components lend themselves to an innovative and aesthetic architectural integration (installed on or roof or roof elements or façade , in the from of a sun – breaker , glass roof , etc). [9]

Facade structure Integrated bi-glass modules Structure in sun breeze

b. The inconvenient:

- Energy production that depends on sunlight is always variable. Industry pollution
- The actual unit conversion efficiency is low. Electrical efficiency decreases over time (decreases by 20% after 20 years).
- The storage of electrical energy continues to pose many problems.
- Manufacturing the PV module with high technology and requires high investment costs.

Despite the disadvantages, the photovoltaic market continues to find applications, and expand in addition PV technology is in a process of maturation in which the disadvantages could soften , especially with regard to manufacturing cost.

I.11 Modeling of PV cells:

- Model has a diode (or simple exponential).
- Model has two diodes (or double exponential)

The photovoltaic system consists of an electrical generator and several electrical components that adapt the electrical energy produced to the receiving devices. In this chapter, we will model a photoelectric cell by a model of a diode and two diodes. This model must be modeled in such a way that all the parameters are easily calculated and avoiding complex equations as much as possible [10].

I.11.1 Photovoltaic conversion principle:

The light energy from the sun's rays is converted into electricity by the photoelectric effect used in solar cells, by the production and transfer of positive and negative electrical charges under the influence of light. This is how the photoelectric conversion process takes place.

- Absorption of light and creation of an electron/hole pair.
- Electron/hole pair separation under the effect of an induced field
- Transport of charges to the electrodes.

I.11.2 Photovoltaic panel modeling:

There are two possible models: the ideal photovoltaic cell and the real photovoltaic cell where one can model a photovoltaic cell through an equivalent electrode which reproduces its behavior. We have these models the ideal PV cell and the actual PV cell.

I.11.3 Equivalent diagram of a photovoltaic cell:

A) Simple diode:

A.1 Ideal photovoltaic cells (Real model):

The solar cell is a semiconductor component which delivers a current by exciting it with photons, so as a first approximation we have a current source short-circuited by a diode (because the solar cell is a PN junction) [11].

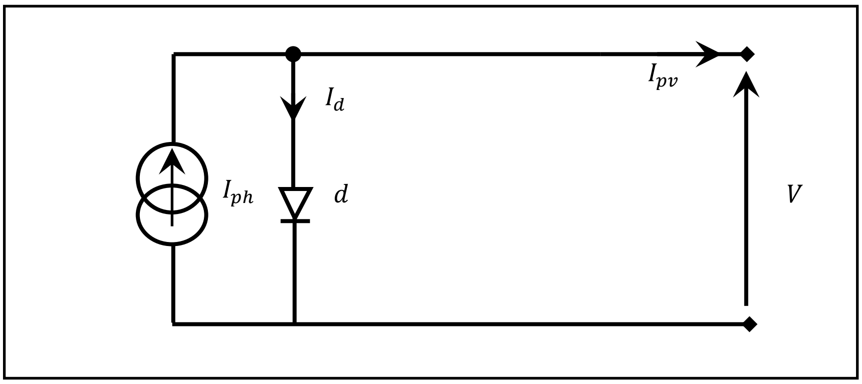


Figure I.12: Model of an ideal photovoltaic cell [12].

The current delivered by the photovoltaic cell according to the law of knots:

$$I_{pv} = I_{ph} - I_d \tag{1.4}$$

I_{pv}: Current supplied by the cell.

I_{ph} : The photon current which is estimated by I_{cc}.(generated photo-current).

I_d: The parallel current through the diode (Current through the diode).

For an ideal P_v generator, the voltage across the load resistor is equal to the voltage across the diode:

$$V = V_d \tag{1.5}$$

$$I_d = I_s(\exp(V_d / V_t) - 1) \tag{1.6}$$

I_s: The reverse saturation current of the diode **[A].**

V_d : The voltage across diode **D.**

V_t: Thermal potential. According to the replacement of I_{pv}

$$I_{pv} = I_{ph} - I_s(\exp(V_d /V_t) - 1)$$

(1.7)

A.2 Solar cell with series resistance:

This model is called (1M4P)

Add the series resistance R_s as 4th parameter

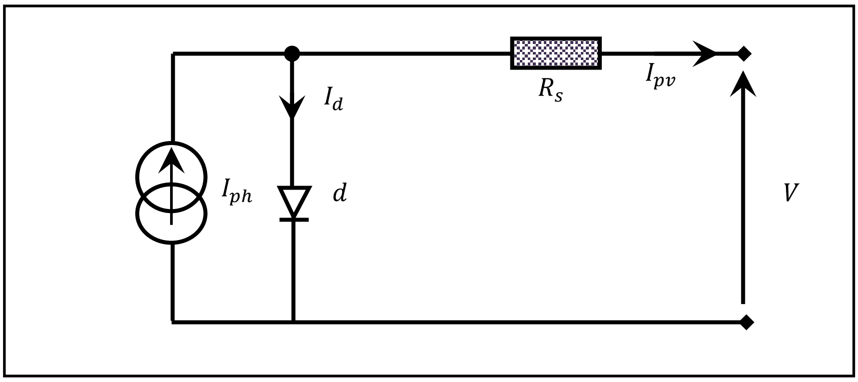


Figure I.13: Model (1M4P) [13].

$\boldsymbol{R_s}$**:** represents the resistance of the connections and $\boldsymbol{V_d}$ will be:

$$\boldsymbol{V_D - V + R_s I_{Rs} = 0} \quad \textbf{(1.8)}$$

$$\boldsymbol{I_d = I_s(e^{q\frac{Vpv+RsIpv}{nkt}} - 1)} \quad \textbf{(1.9)}$$

In normal conditions of illumination **(1000 W/m²)** and temperature **(25 c).**

$$\boldsymbol{\frac{KT}{q} = 26mv}$$

$$\boldsymbol{K = 1.38 * 10^{-23} J.K^{-1}}$$

$$\boldsymbol{T = 25 + 273 = 298k}$$

$$\boldsymbol{e = 1.16 * 10^{-19} c}$$

So the relationship becomes:

$$\boldsymbol{I_{pv} = I_{Ph} - I_{sat}(e^{q\frac{V+Irs}{nkt}} - 1)} \quad \textbf{(1.10)}$$

A.3 modeling of the photovoltaic generator of a simple diode:

Many mathematical models have been proposed to simulate the current voltage characteristic of a solar cell. In order to find a model of PV generator, it is first necessary to find the equivalent electrical circuit for this source. The distinction is made between these models by the calculation procedure, precision and number of parameters involved. Usually, photovoltaic solar cells are designed as an electrical circuit like in the diagram below which contains a diode in addition to a power supply and two resistors.

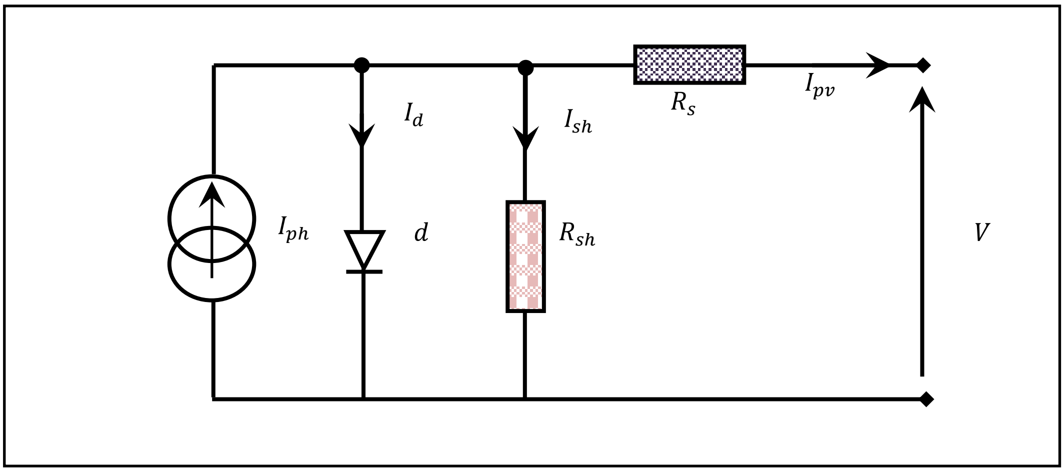


Figure I.14: Model of single diode solar cell with series and shunt resistances (1MSP) [12].

D: Diode materializing the fact that the current only flows in one direction.

$\boldsymbol{R_s}$: Series resistance which is due to the different electrical resistances that the current encounters on its way;

$\boldsymbol{R_{sh}}$**:** Shunt resistor which takes into account the inevitable current leakage which occurs between the opposite positive and negative terminals of a cell;

G: Current source that models the conversion of luminous flux into electrical energy.

We then obtain the current equation for a photovoltaic module deduced from the equivalent electrical diagram:

$$\boldsymbol{I_{pv} = I_{ph-}\, I_d - I_{sh}} \qquad \textbf{(1.11)}$$

$\boldsymbol{I_{pv}}$: The current delivered by the module (the output current)

$\boldsymbol{I_{ph}}$: The photo-current (represents the current generated by the solar cell when it is exposed to sunlight.)

$\boldsymbol{I_{sh}}$: Represents the current flowing through the resistor (the shunt current).

$\boldsymbol{I_d}$: The current of the diode.

The diode current expression $\boldsymbol{I_d}$ is given by the Schrockley equation

$$\boldsymbol{I_d = I_s\left[(e^{q\frac{Vpv+Rs1c.Ipv}{nkt}} - 1\right]} \qquad \textbf{(1.12)}$$

$\boldsymbol{K}$: $constante\ de\ Boltzmann$ ($\boldsymbol{K = 1{,}380662.10^{-23}\,J.K^{-1}}$).

n: is the ideality factor of the diode it varies between 1 and 2.

$\boldsymbol{q}$: charge of the electron **(q = 1.602.10^{-19} VS).**

The expression for the current flowing through the resistor in parallel $\boldsymbol{R_{sh}}$, **1c** is given by:

$\boldsymbol{R_{s,1c}}$**:** The output shunt resistance of the cell.

$\boldsymbol{R_{sh,1c}}$: The output series resistance of the cell.

$\boldsymbol{V_{pv}}$: Cell output voltage.

So, in the end, the 5-parameter model of a cell is given by the equation next :

$$\boldsymbol{I_{pv} = I_{ph} - I_s \left[e^{q\frac{Vpv+Rs,1,c.Ipv}{nKT}} - 1\right] - \left[\left(V_{pv} + R_{s,1,c}.I_{pv}\right)/\left(R_{sh,1c}\right)\right]}$$

(1.13)

The following table is the various electrical volumes used in the above expressions in addition to their corresponding value. In our work, the modeling of the real behavior of a cell is ensured.

B) Double –diode model:

We will present a two-diode model for the effect of partial shading on the energy production of photovoltaic (PV) panels. For this purpose, a complete study of all available PV module configurations the model is presented as follows:

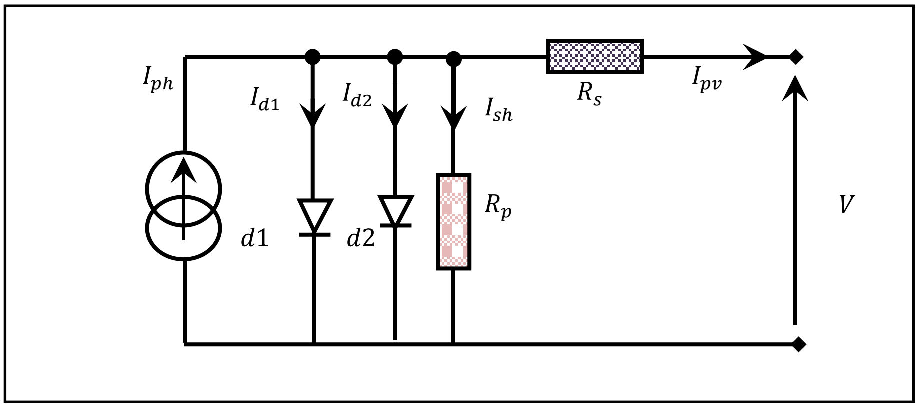


Figure I. 15: Model electric diagram of a cell in crystalline silicon-model [13].

The following equation describes the photovoltaic cell output current for the two-diode model:

$$\boldsymbol{I_{pv} = I_{ph} - I_{d1} - I_{d2} - I_{sh}} \quad \textbf{(1.14)}$$

$$\boldsymbol{I_{pv} = I_{ph}I_s - I_s\left[-1 + e^{q\frac{Vpv+Rs,Ipv}{A1.Vr1}}\right] - I_s\left[-1 + e^{q\frac{Vpv+Rs.Ipv}{A1.Vr2}}\right] - \frac{V_{pv}+R_s.I_{pv}}{Rp}} \quad \textbf{(1.15)}$$

$\boldsymbol{I_{d1}}$: Reverse saturation current of diode **D1.**

I_{d2} : Reverse saturation current of diode **D2**.

V_{r1} : Thermodynamic potential of diode **D1.**

V_{r2} : Thermodynamic potential of diode **D2.**
A_1: The ideality factor of the junction of diode **D1.**
A_2: The ideality factor of the junction of diode **D2.**

I.12 Characteristics I(V) and P(V) (influence of illumination and temperature):

I.12.1 The influence of light:

The decrease in illumination will inevitably lead to a decrease in the generation of electron/hole pairs. However, in the absence of any illumination, the current generated by the cycle of minority carriers is still very low (it is the reverse current in the diode). This current is called dark current. Of course, the solar current generated by the solar panel is equal to the difference between the current I_{ph} generated by illumination and the dark current inherent in the diode. Consequently, it is undeniable that the reduction in the illumination of the photovoltaic cell will cause the solar current I_{SC} .

To decrease proportionally, which will be accompanied by a very slight reduction in the voltage, therefore in the long term, the point P_m *of* the solar cell panel will move at lower power [14].

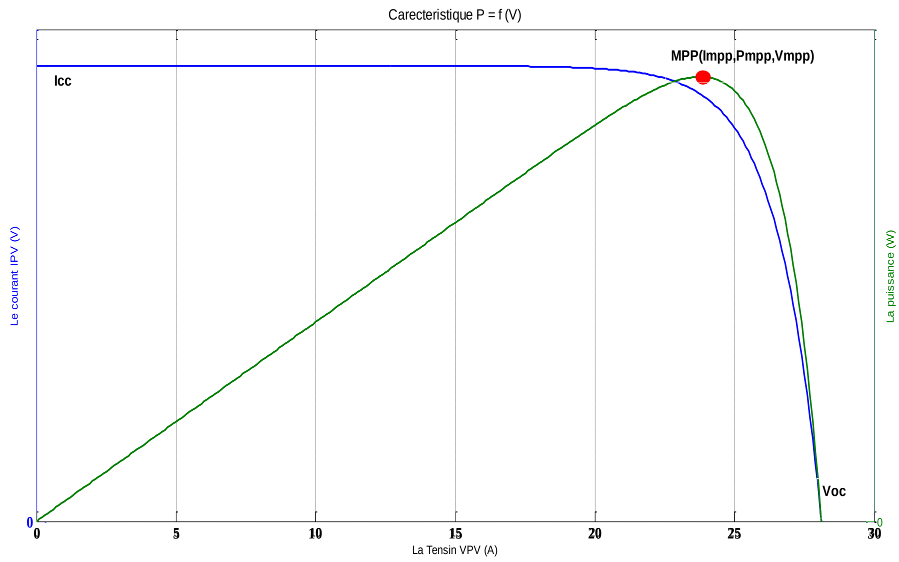


Figure I. 16: I(v)-P(v) characteristic of PV.

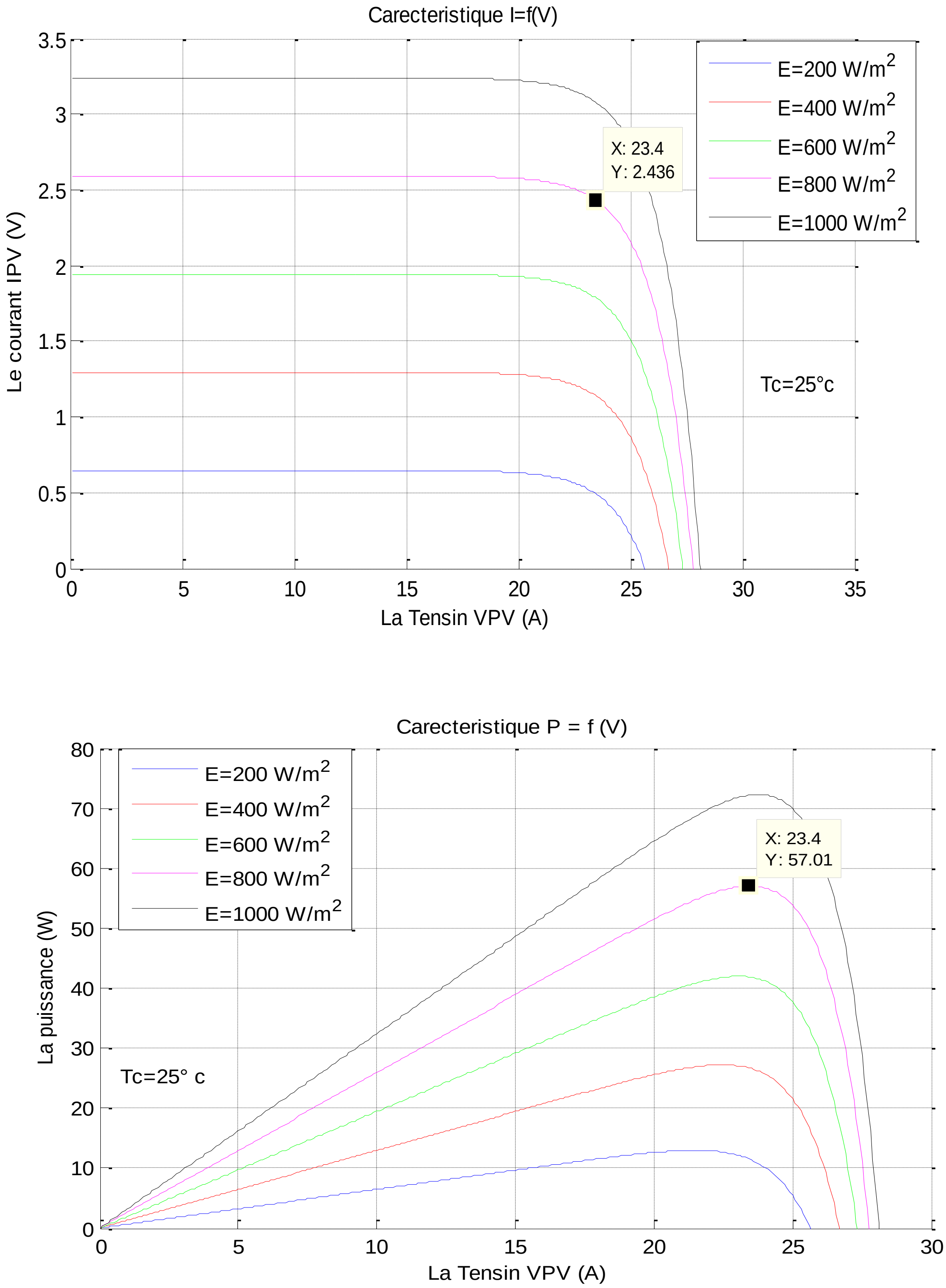


Figure I. 17 : A1- Curves and P(v) . A2- Curves I(v)of a panel to various levels of sunshine at a constant temperature T = 25°C.

It can be seen in figure (A1) that the power of the photovoltaic cells is lower The illumination of the cells is reduced precisely because The current I_{sc} . Moreover, checking the I(v) curve in figure (A2) clearly shows that the value of the short circuit current is exactly proportional to the radiant intensity. The higher the current, the higher the intensity of the radiation. On the other hand, Open circuit voltage does not change in the same proportion, but remains almost unchanged Low luminance and high luminance are the same. Therefore, this means:

- ✓ The voltage at the maximum power point is approximately the same.
- ✓ The optimal power of a Pm battery is actually lighting.

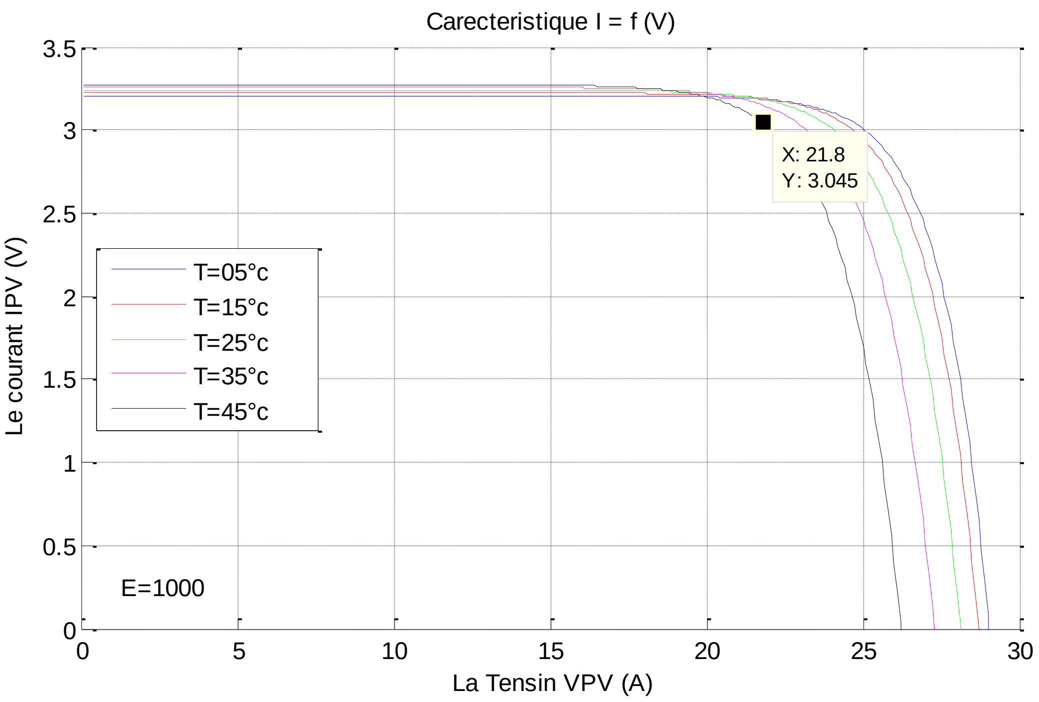
I.12 .2 Influence of temperature:

The temperature has a considerable influence on the behavior of the cell and therefore on its efficiency. This influence mainly results in a decrease in the generated voltage (and a very slight increase in the current).

Figure b1 shows curves I(v) and P(v) for different operating temperatures of the photovoltaic module varying from 0°C to 75°C and for constant irradiation, i.e.

G = 1000W/m2

We first notice in figure b2 that the effect of temperature is negligible regarding the value of the short-circuit current. On the other hand, the open circuit voltage has obviously dropped when the temperature rises [15].



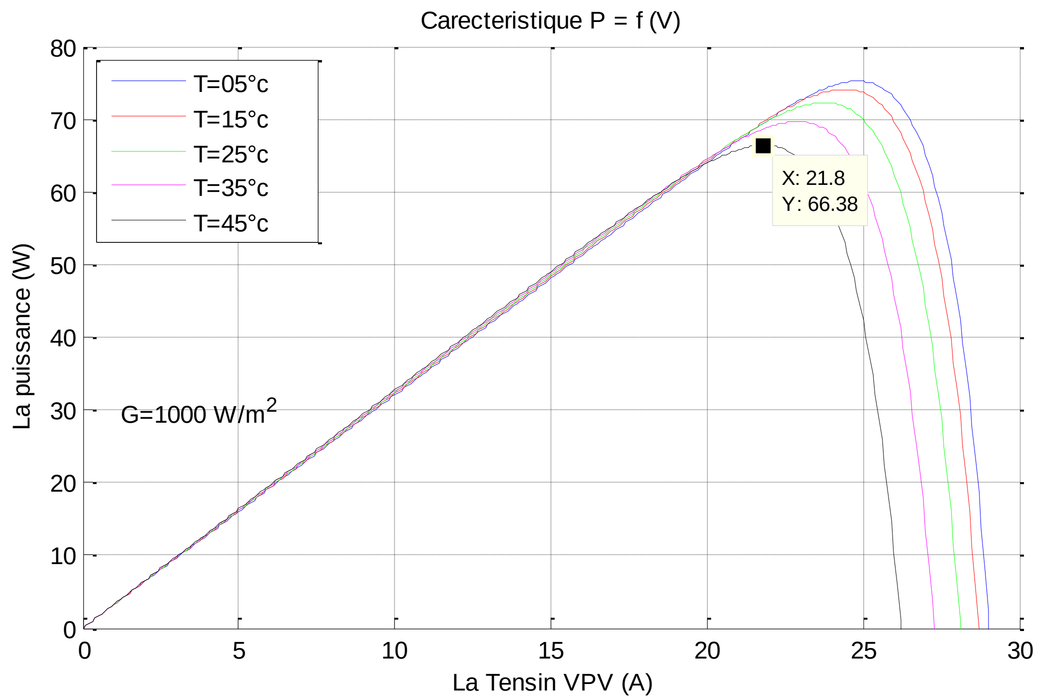


Figure I. 18 : B1- *Curves* I(v) *and* .B2- *Curves* P(v) *of a PV panel for different temperature values and for a constant illumination G = 1000W/m2.*

On another level, we know that the electricity supplied by the photovoltaic cells is directly According to the expression it is proportional to the voltage measured at its terminals. Therefore, the decrease in the voltage across the photovoltaic cell will affect When the temperature of the battery increases, it must depend on the extractable power of the battery Cells increase. This is clearly illustrated in figure b. Indeed, the force the maximum $\boldsymbol{P_{max}}$ decreases with increasing temperature. Finally, it should be noted that the panel power is reduced by approximately 0.5% each time the degree of battery temperature rises above 25°C

The nonlinear equations of the system to be solved are defined as follows: From equation (11), we obtain:

$$\left(V_{pv}, I_{pv}\right): \leftrightarrow I_{pv} - I_{ph} + I_s\left[-1 + \exp\frac{V_{pv}+R_s.I_{pv}}{A.V_t}\right] \quad \textbf{(1.16)}$$

From this equation, we can derive the first equality as follows:

$$(0, I_{sc}): \leftrightarrow I_{sc} - I_{ph} + I_s\left[-1 + \exp\left(\frac{R_s.I_{sc}}{A.V_t}\right)\right] + \frac{R_s.I_{sc}}{Rp} \quad \textbf{(1.17)}$$

Similarly, the second equality is obtained as follows:

$$(V_{oc}, 0): \rightarrow I_{ph} - I_s\left[-1 + \exp\left(\frac{V_{oc}}{A,V_t}\right)\right] + \frac{V_{pv}+R_s.I_{pv}}{R_p} = 0 \quad \textbf{(1.18)}$$

Knowing that the power supplied by a PV cell is obtained by the relationship:

$$P_{pv} = V_{pv}.I_{pv}: \rightarrow P_{pv}$$

$$P_{pv} = V_{pv}.\left(I_{pv} - I_s\left[-1\ exp\left(\frac{V_{pv}+R_s.I_{pv}}{A.V_t}\right)\right]\frac{V_{pv}+R_s.I_{pv}}{R_p}\right) \quad \textbf{(1.19)}$$

Hence, the third equality is obtained as follows:

$$P_{max} = V_m.\left(I_{ph} - I_s\left[-1 + exp\frac{V_m+R_s.I_m}{A.V_t}\right] - \frac{V_{pv}+R_s.I_{pv}}{R_p}\right) \quad \textbf{(1.20)}$$

Finally, the last equality is obtained by

$$\left(\frac{dP_{pv}}{dV_{pv}}\right)V_{pv} = V_m = 0 \quad \textbf{(1.21)}$$

which leads to the equation below:

$$\frac{d}{dV_{pv}}\left\{V_{pv}.\left(I_{ph} - I_s\left[-1 + exp\frac{V_{pv}+R_s.I_{pv}}{AV_t}\right] - \frac{V_{pv}+R_s.I_{pv}}{R_p}\right)\right\} = 0 \quad \textbf{(1.22)}$$

The simplified form of equality **(1.22)** East given by:

$$I_{ph} - I_s = \left[-1 + \left(\frac{V_m}{A.V_t}\right)\right].exp\left[\frac{V_m+R_s.I_m}{A.V_t}\right] - \frac{V_m+R_s.I_m}{Rp} = 0 \quad \textbf{(1.23)}$$

Conclusion:

In this chapter we have presented the basic electrical characteristics of a photovoltaic cell (photovoltaic module) and the equivalent circuits have been described. Mathematical models of varying complexity were discussed (modeling), as well as criteria for choosing a properly detailed model.

In the next chapter we will take a look a formulate problem of identification simple diode and double diode and the solution.

CHAPTER II

Photovoltaic system identification

II.1. Introduction

Photovoltaic (PV) structures play an important function in the sustainable generation of electricity by means of changing sunlight immediately into electric energy. As the demand for clean and renewable energy sources increases, the efficient operation and maintenance of PV structure come to be paramount. To acquire this, it is crucial to have a deep understanding of the system's behavior, characteristics, and overall performance. This is in which photovoltaic system identification comes into play.

Photovoltaic system identification refers to the process of figuring out the mathematical models and parameters that should describe the behavior of a PV system. These models offer insights into how a PV system responds to various inputs together with solar irradiance temperature, and load conditions. System identification techniques enable engineers and researchers to study, examine, and optimize the performance of PV systems

II.2. Formulate problem of identification

a. For ideal diode :

This model involves the followings four unknown parameters as m, I_{ph}, and I_s, this model is also called **1M3P** (Single Mechanism, Three Parameters).

b. For single diode SDM :

The output current I based on the combination of the above described equations, whereas it is the obvious there are serval unknown parameters as (I_o, I_{ph}, R_s, R_{sh}, and α), which are required to be derived and extracted in SDM .

c. For double diode DDM :

Like SDM, The output of double diode model which is required to extract seven anonymous and uncertain parameters such as I_{o1}, I_{o2}, I_{ph}, R_s, R_{sh}, α_1 and α_2.

II.3. Identification methods

The identification error f_ϵ measures the difference between the real i_{real} and $i_{estimated}$ current of the PV cell. It is given by the following equation.[17]

$$f_\epsilon = \sqrt{\sum_1^N (i_{real} - i_{estimated})^2} \quad \textbf{(2.1)}$$

This error represents the cost function to be minimized. The optimization algorithm will update the parameters in order to minimize the cost function.

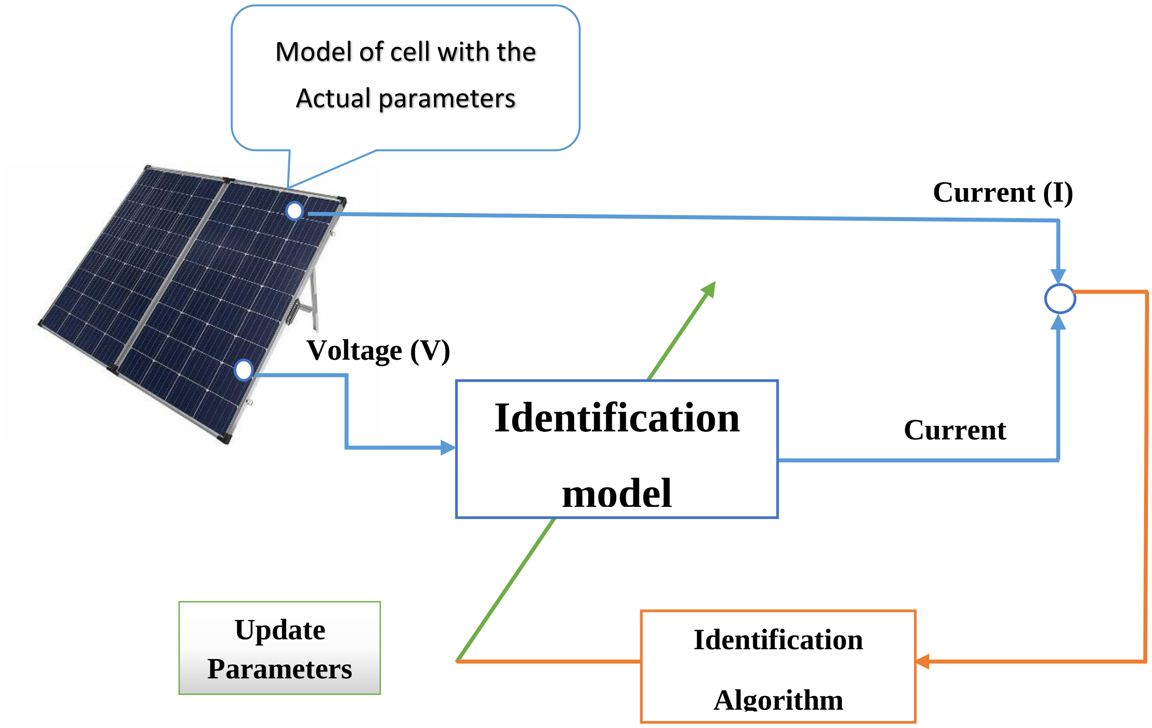


Figure II.1: Identification Method Principe [17]

II.3.1 Newton Raphson Method

II.3.1.1. Definition

Newton's method (also known as Newton-Raphson's method), named after Isaac Newton and Joseph Raphson, is a technique for evaluating iterative approximations that is superior to sampling (or zeroing) real-valued functions.

$$\boldsymbol{x}: \boldsymbol{f}(\boldsymbol{x}) = \mathbf{0} \qquad \textbf{(2.2)}$$

Find the minimum or maximum value of such a function by finding zeros in the first derivative of the function using any zero-finding method (bisection method, false position method, Newton-Raphson method, etc.) can also do. See Newton's method. As an optimization algorithm.[18]

II.3.1.2. Explanation

The Newton-Raphson method is a process that involves making preliminary guesses and following a logically sound path to arrive at an objective.

The goal is approximated by a deviation line, which can be calculated using calculus tools. By determining the x-intercept of this line with simple algebra, a better approximation of the root of the function can be obtained.

This process can then be repeated. The quasi-Newton method is an improvement over this process, as it uses collinear scaling and local quadratic approximation to avoid the need for a full Hessian matrix. In this work, we explore new collinear scaling factors that may appear singular and present an improved collinear scaling algorithm using local quadratic approximation for enhanced stability.

We also prove the global convergence of the algorithm. The numerical results of training a neural network using this improved algorithm demonstrate its superior efficiency compared to the traditional algorithm.[19]

II.3.1.3. Derivation

Newton's method (also called **Newton-Raphson method**) in numerical analysis, named after Isaac Newton and Joseph Raphson, is a method for finding progressively better approximations to the zero (or zeros) of real-valued functions. Equation **(2.2) .**
The Newton-Raphson method in one variable is implemented as follows:
Given a function f defined for a real number x and its derivative f', find the first guess x_0 for the root of the function f Start from suppose your function satisfies the following conditions:

Given all the assumptions made in deriving the formula, x_1 is a better approximation**.**

$$\boldsymbol{x_1 = x_0 - \frac{f(x_0)}{f'(x_0)}} \qquad \textbf{(2.3)}$$

Geometrically, $(x_1, 0)$ is the intersection with the x-axis of the tangent to the graph of f at

$(x_0, f(x_0))$.

The process is repeated as

$$x_{n+1} = x_n - \frac{f(x_n)}{\acute{f}(x_n)} \quad \textbf{(2.4)}$$

Until a sufficiently accurate value is reached.

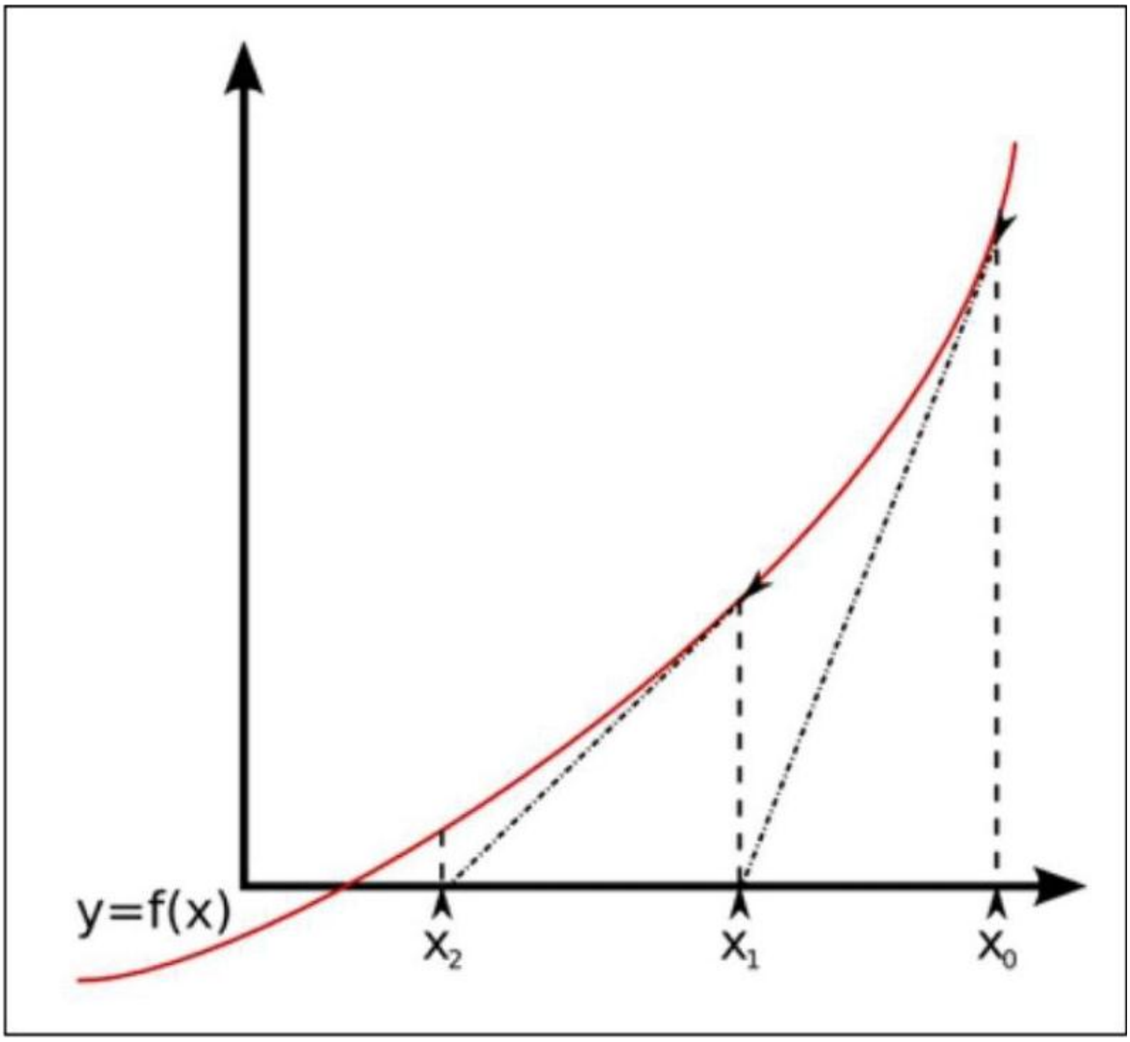


Figure II.2: Illustration of the Newton Raphson Method

II.3.4. Examples

Square root of a number

Consider the problem of finding the square root of a number. Newton's method is one of manymethods for computing square roots.

For example, finding the square root of 612 is the same as solving

$$\boldsymbol{x^2 = 612}$$

The function to use in Newton's method is then,

$$\boldsymbol{f(x) = x^2 - 612}$$

With derivative.

$$\boldsymbol{\acute{f}(x) = 2x}$$

With an initial guess of 10, the sequence given by Newton's method is

$$x_1 = x_0 - \frac{f(x_0)}{\acute{f}(x_0)} = 10 - \frac{10^2 - 612}{2 \times 10} = 35.6$$

$$x_2 = x_1 - \frac{f(x_1)}{\acute{f}(x_1)} = 35.6 - \frac{35.6^2 - 612}{2 \times 35.6} = 26.395505617978 \ldots$$

$$x_3 = \quad \vdots \quad = \quad \vdots \quad = 24.790625492455 \ldots$$

$$x_4 = \quad \vdots \quad = \quad \vdots \quad = 24.738688294075 \ldots$$

$$x_5 = \quad \vdots \quad = \quad \vdots \quad = 24.738633753767 \ldots$$

Correct numbers are **gray** **.**In just a few iterations, you can get a solution that is accurate to a few decimal places.

II.3.2. Particle swarm optimization

II.3.2.1. Overview of PSO

Particle swarm optimization (PSO) is a population-based probabilistic swarm intelligence optimization method that can leverage simple agent social interactions to find global optima

It is a direct search method that does not use partial derivatives of the system equation. In PSO, ensembles of particles fly through an unknown space, and their velocities are updated by motion inertia, self-awareness, and social interaction. For each particle, the following equations update the velocity and position of each particle at each iteration of the optimization process.[20]

$$V_i = \omega.v_i(k) + c_1.rand().\left(pbest - x_i(k)\right) + c_2.rand().\left(gbest_i - x_i(k)\right) \quad \textbf{(2.5)}$$

$$X_i(k+1) = v_i(k) + x_i(k)) \quad \textbf{(2.6)}$$

where x_i is the position of the i particle in variable space , v_i is the velocity of the i

ω is particle inertia, c_1 is cognitive acceleration constant, c_2 is social acceleration constant , $pbest$ is particle is best known position $gbest_i$ is the best known position found by all particles and $rand()$ is a random number between 0 and 1 .

II.3.2.2. Fitness Function

The PSO algorithm requires the definition of a fitness metric to score each particle. The goal is to fit the model parameters to multiple sample points. The fitness metric is therefore the error between the model's predictions and the actual measurements. [21]

$$I_0^* = \frac{I_{scd}}{e^{\frac{q\,v_{ocd}}{nkT_d}} - 1} \quad \textit{(2.7)}$$

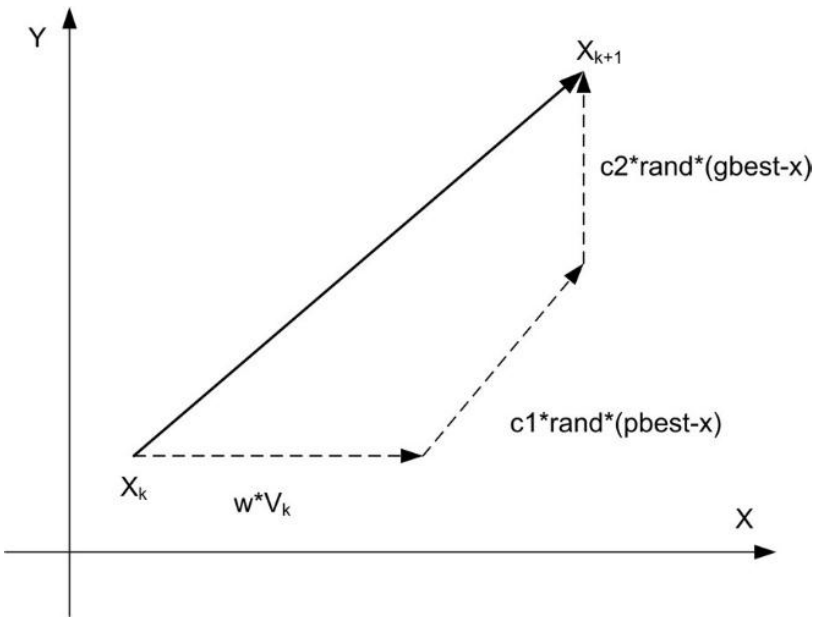


Figure II.3: PSO Position Update.

n	*Rs/Ω*	*Rsh/Ω*
0 – 2	0 – 20	10 – 200

Table II.1 : SEARCH SPACE DEFINITION

From the last equationn:

$$I^* = I_{scd} - I_0^*\left(e^{\frac{q(V_d+I_dR_S^*)}{n*KT_d}} - 1\right) - \frac{V_d+I_dR_S^*}{R_{sh}^*} \quad \textbf{(2.8)}$$

From **(2.7)** and (**2.8)**, a fitness function for one sampled point is

$$f_i = |I^* - I_d| \quad \textbf{(2.9)}$$

In **(2.7)**, **(2.8)** and **(2.9)**, $I_0{}^*$ is the predicted reverse saturation current, I_* is the predicted load current, $\mathbf{I_d}$ is the sampled load current, $\mathbf{V_d}$ is the sampled load voltage, and $\mathbf{I_{scd}}$ is Sampled short-circuit current. $\mathbf{V_{ocd}}$ is the sampled open circuit voltage, $\mathbf{T_d}$ while $\boldsymbol{I}^*$,$\boldsymbol{R_s^*}$, and $\boldsymbol{R_{sh}^*}$ is the sampled ambient temperature, and is the PV parameter to be determined.

Then the parameter set fit function for a set of N sample points is

$$f = \sqrt{\sum_{i=0}^{N} f_i^2} \quad \textbf{(2.10)}$$

II.3.2.3. Particle and Search Space Definition

In this study, the proposed optimization algorithm searches for the optimal set of PV parameters to minimize the errors associated with the sampled data. Each particle contains a vector of parameters to be optimized (diode ideality factor n), series resistance R_s , shunt resistance R_{sh}). The parameter search spaces listed in Table are defined based on common sense and experience.[22]

II.3.2.4.PSO Implementation

For PSO, the linearly decreasing mass inertia can cover both initial exploration and final exploitation. Weight inertia is defined as:

$$\omega = 0.8 - 0.4\,\frac{\text{interation}}{\text{max}_{\text{interation}}} \quad \textbf{(2.11)}$$

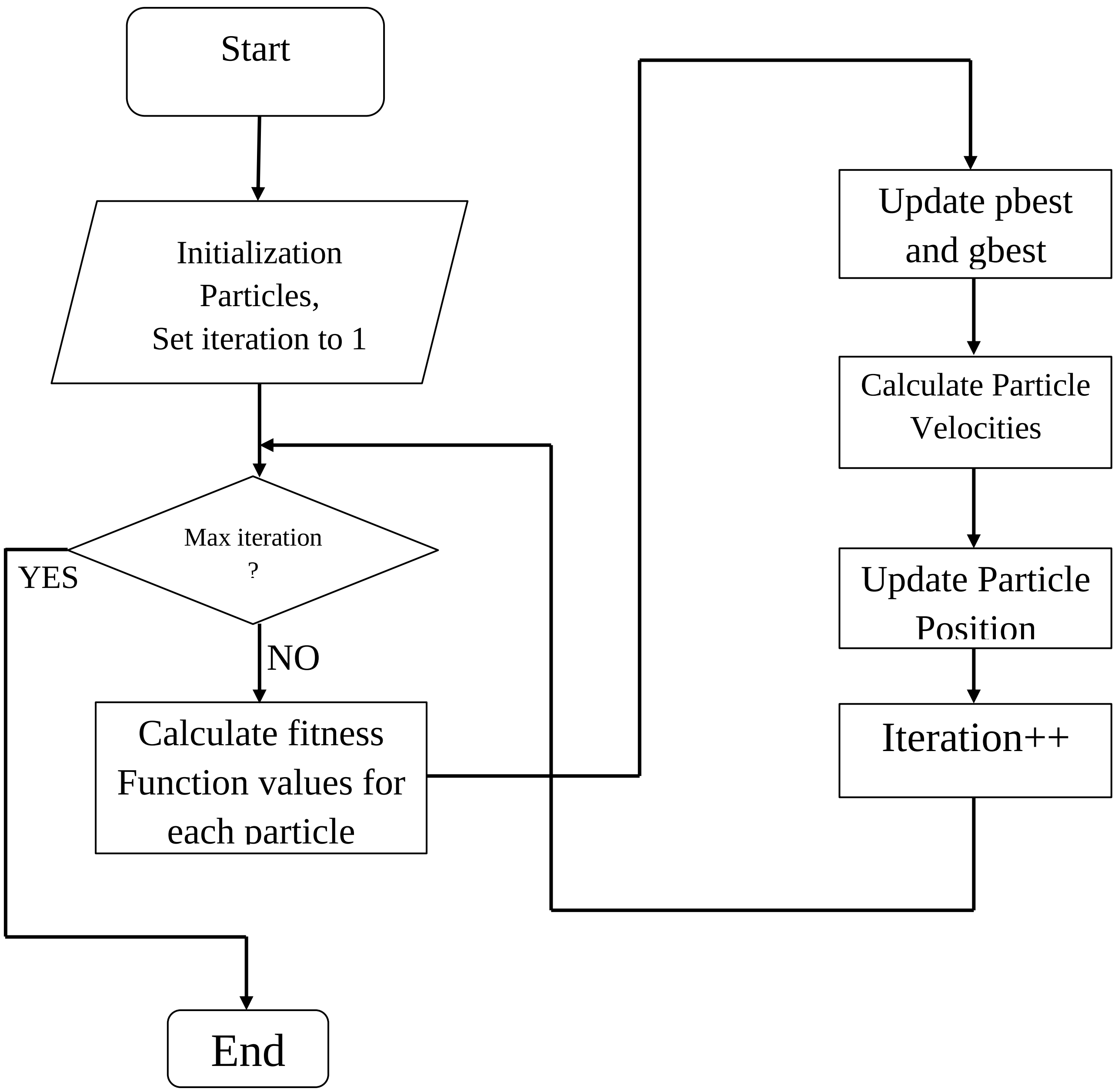


Figure II.4: PSO Flowchart [20].

According to [1], the individual and social acceleration constants are each set to 2.0. The maximum speed is fixed at half the total search space in each dimension. The number of particles is set to 50 and the maximum number of iterations is set to 100.

A PSO program for determining the PV parameters was developed in Matlab. timid. A flowchart of the PSO program is shown in Figure 4.

Conclusion

In this chapter, we propose a method to extract PV parameters using Newton Raphson and PSO methods. The proposed method is used to determine the parameters of photovoltaic cells from field test data. It is verified that the proposed method can achieve higher parameter accuracy under varying solar irradiance and ambient temperature.

In the next chapter, we will choose the simple diode in the study because this type is widely used and its results are close to reality.

CHAPTER III

Experiments Results and Simulation

III.1 Introduction:

In this chapter, the behavior of our system will analyses through simulations.in order to better understand some of the system's modeling, we will show a priori the simulation result of the identification photovoltaic system using **MATLAB/SIMULINK®**.

For a first configuration, we present the simulation results for a different solar irradiation and temperature T. for three operating points: at the beginning, a tension load V and optimal current intensity I_{max} is connected at the beginning, where its value coincides perfectly with the optimum point.

The electrical performance of silicon photovoltaic cells is described as its characteristic current -voltage (I-V), depending on the device used and the properties of the material. Comparing practical results with the manufacturer's performance; to identify and analyses various factors affecting the team's performance. On the other hand, this work suggests the application of particle swarm (PSO) to accurately identify these five unknown photovoltaic parameters in order to solve.

III.2 Algeria's solar potential:

Algeria is the largest country in the Mediterranean, according to a study by the German Aerospace Agency.

Algeria offers greater interesting possibilities; in the long term, to invest in solar thermal power plants. Indeed Algeria is one of the Mediterranean countries which have an enormous solar potential.

according to the sunshine data (Fig III.1), Algeria is counted among the best sunny countries in the world [23].

The duration of sunshine on almost all of the national territory exceeds 2000 hours annually and can reach 3900 hours in the highlands and the Sahara.

the energy received daily on a horizontal surface of 1m2 is of the order of 5 kWh on the major part of the national territory, that is to say nearly 1700 kWh/m2/year in the North and 2263 kWh/m2/year in the South of the country.

The potential of the solar resources of our paid is therefore optimal for the execution of solar projects [24].

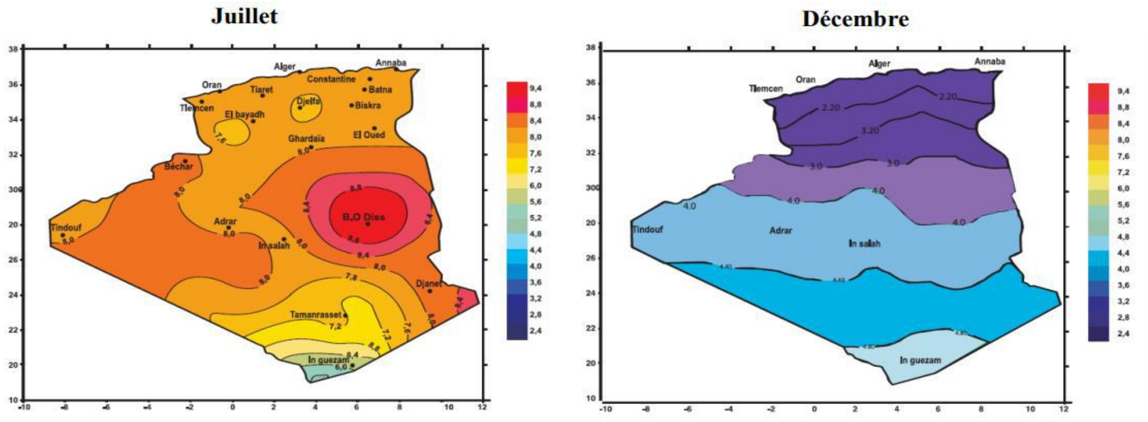


Figure III. 1: The potential of Algeria horizontal plane in solar energy [24].

III.3 Solar illumination

III.3.1 Illumination or irradiation :

IL luminance is defined as the power received by a surface. It is expressed in (W/m2). The SI (International System of Units) recommends the use of the symbol G [25].

The earth receives an average value of illumination of 1.36 TWh/m2 each year. It should be noted that in addition to the impact of the atmosphere, solar irradiation depends on it:

- The orientation and inclination of the surface.
- The latitude of the place and its degree of pollution.
- The period of the year and the time considered.
- The nature of cloud layers.

III.4 Spectral distribution of solar irradiance:

The sun sends us energy in the form of electromagnetic radiation, the wavelength of which varies from 0.22µm to 10µm.(Fig III.2) represents the variation in the spectral distribution of this radiation. On this graph we see that for the radiation is negligible while for the visible part of the radiation, for values between 0.3 and 0.7µm the absorption by the atmosphere is low [26].

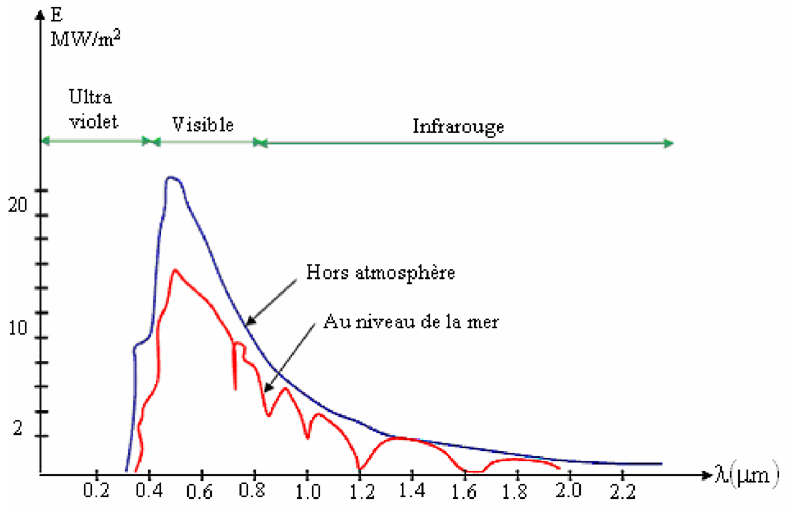


Figure III. 2: Spectral distribution of solar radiation [26].

III.5 Types of solar illumination

III.5.1 Global illumination:

- Global radiation on a horizontal surface (I_{Gh})
- Global radiation on an inclined surface (I_{Gi})[27].

III.5.2 direct illumination:

The direct illumination is the illumination which made a path in the atmosphere without geometrical deviation, and thus corresponds to the portion of the incident radiation in the direction of illumination of the Sun [28].

III.5.3 Diffuse and reflected illumination:

Diffuse illumination is illumination resulting from the diffraction of direct radiation by clouds and atmospheric particles [29].

Reflected radiation is only considered for inclined surfaces.

Albedo: The ratio of scattered or reflected incident radiation to incident radiation.

The term is generally used for the ground and clouds and is the average of the reflectance for the radiation considered and for all angles of incidence. By definition, the albedo of a blackbody is zero [30].

III.6 Irradiation:

Solar irradiance is the fraction of energy incident on a unit area. This energy is calculated by integrating the radiation incident on the unit surface area during a given day or time period. The units are Wh/m² and depend primarily on a number of factors, including cloud cover, hours of sunlight.

The moment in the day considered, the azimuth and tilt of the earth's surface, the latitude of the location, the degree of pollution, and the angular height of the sun above the horizon. All these parameters combine to produce spatial and temporal variations in solar radiation. In a region 40° north-south of the earth, the total annual energy received by the horizontal plane is 1400-2500 KWh/m [31].

III.6.1 Hourly irradiation on a horizontal plane:

The hourly global irradiation on a horizontal surface.

III.6.2 Daily irradiation on a horizontal plane:

The daily global irradiation on a horizontal surface $\boldsymbol{G0(nj)}$ is obtained by integrating the previous relationship from sunrise to sunset:

For a plane inclined at an angle β, the daily global irradiation is:

$$G_0\,(h.nj) = (nj)\,[\sin(\varphi-\beta)\sin(\delta) + \cos(\varphi-\beta)\cos(\delta)].\frac{24}{\pi} I_{sc}\, w_s w_s]. \qquad (3.1)$$

III.7 Solar irradiance measuring devices:

Solar irradiance (G) corresponds to the intensity of solar radiation falling on a given plane at a given time. It is usually expressed in watts per square meter (W/m²). Solar irradiance varies from zero at sunrise to a maximum value, typically four types of radiation at solar noon [32].

Figure III. 3: The Pyrheliometer [33].

Figure III. 4: the Pyranometer [33].

Figure III. 5: Albedo meter [33].

III.8 Geographical location of the State

Ghardaïa is located in the north of the Algerian Sahara, 600 kilometers south of the capital. It is located in a desert zone characterized by its semi-arid and dry climate; this gives it an important energy wealth, such that its insolation fraction frequently reaches values that exceed 75%, whereas the total daily irradiation received on a horizontal plane is around 6000wh/m2 on an annual average. With a desert climate, Ghardaïa Contains a scientific structure, which was established in 2002 by the Ministry of Higher Education and Scientific Research, it is the Unit of Applied Research in Renewable Energies (URAER), followed by the Centre de Development des Energies Renouvelables (CDER) in Bouzaréah, Algiers. As regards the meteorological and radiometric parameters of Ghardaïa

III.9 Overview of the Renewable Energy Applied Research Unit (URAER):

Energy Renewable Applications and Research Unit (URAER) (Figure III.6), established in 1999, is affiliated with the Center for the Development of Renewable Energies (CDER) and is located in the city of Ghardaia, 1 km from the airport. By investing significant resources in training and research in the renewable energy sector and developing specialized laboratory facilities, URAER has become a trusted and experienced partner in the renewable energy sector. Several departments are currently responsable for research .

- Bioenergy & Environment Division.
- Wind Energy Division.
- Hydro Gene- Renewable Energie Division.
- Photovoltaic solar energy Division.
- Solar Thermal and Geothermal Energy Division.

Figure III. 6: Photo of the Renewable Energy Applied Research Unit (URAER) Ghardaïa.

III.9.1 Photovoltaic solar energy Division:

The Photovoltaic (PV) Solar Energy Division is a research organization of the Renewable Energy Development Center, established in 1982. The division is essentially responsible for the development of series/parallel interconnected PV module systems, control and regulation electronics (load regulators), DC/AC conversion systems (inverters), and electrochemical storage systems (batteries), with the main objectives of the team being

1. To design, manufacture, develop and conduct experimental activities on equipment for the utilization and conversion of solar energy into electricity

2. Control the conversion and storage of solar energy

3.T development, follow-up and training of researchers, graduate and doctoral students

4. Development, innovation and adaptation of solar tracking systems in southern Algeria.

5. Development of dimensional measurements and PV system monitoring software [34].

III.10 data used

Solar energy can be divided into two categories: thermal and photovoltaic systems. In nature, only 20% of the sunlight incident on a photovoltaic module can increase the temperature of the operating cells, resulting in a gradual increase in ambient temperature that reduces the energy conversion obtained on the order of 0.4-0.5% and degrades performance.

To avoid this mistake, the overheating problem of conventional solar cells is solved using a proposed cooling system that lowers the cell temperature to near the nominal temperature range. The proposed solar cell system uses water in a closed circuit that cools the cells at high temperatures. The advantage of this system is its thermal efficiency [35].

Although the numerical method can determine the parameters of the solar cell with higher accuracy than the analytical method, several drawbacks still exist. First, the convergence of numerical methods is very sensitive to the choice of initial solution guesses. Second, the solution method is more complex due to the use of gradient operations, and singularities can occur during the solution process. To overcome the shortcomings of numerical methods, a meta-heuristic optimization method is applied to PV cell parameter estimation. Advantages of meta-heuristic optimization methods include improved convergence, less susceptibility to initial guesses, no singularity conditions, and consideration of all I-V data points rather than critical points on the I-V curve [36].

III.10.1 Method used

This study begins by introducing the mechanism of the PSO algorithm.

Next, model parameters are determined from experimental data recorded at different operating points . In the robustness analysis of the obtained PV model, other experimental data recorded at higher temperatures and at different total solar radiation levels are taken into account. Finally, the paper is concluded with conclusions.

In this study, the PV panels are tilted at an angle equal to the latitude of the region and each is equipped with a sensor: the first sensor is a K-type thermocouple, measuring absolute temperature using a Campbell CS215; the second sensor is a Kipp and Zonen CMP21 irradiometer, measuring total installed to measure solar irradiance. All recorded experimental data were performed on an Agilent experimental system.

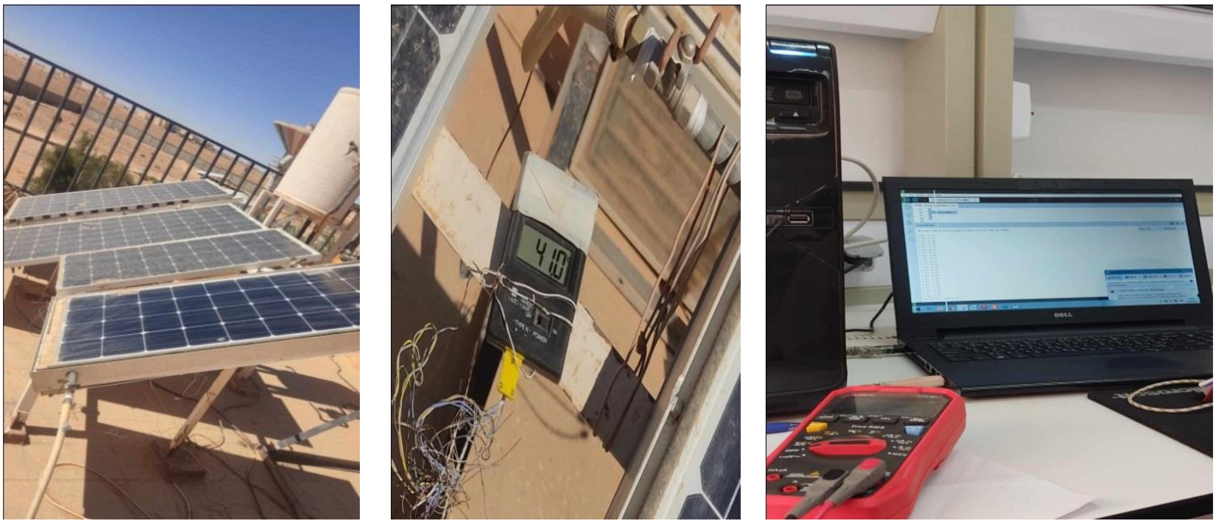


Figure III. 7: SOLO LINE LX - 100M panel photovoltaic installed in URAER used with instruments acquisition.

III.11 Properties photovoltaic panels:

Stand-alone photovoltaic systems can be installed wherever supply of electricity from a power grid is unavailable, uneconomic or not desirable. In situations such as these, Luxor offers specially developed, high-quality, efficient off-grid modules, which are also ideal for 12 V. The Solo Line modules are suitable for all kinds of power generation in the leisure sector or for professional applications such as holiday, garden or residential homes, mobile systems in caravans or boats,

solar pumps for drinking water supply and irrigation, and in traffic systems such as parking ticket machines, traffic control systems or even street lamps, measurement systems or telecommunication systems.

The compact and sturdy stand-alone PV module is the practical solution and ideal for applications with no connection to the power grid. Selecting Luxor off-grid modules provides solutions even for the most demanding requirements. Gras

Figure III.7 shows the chosen PV system to identify their parameters, where his datasheet is mentioned in bold in **Table III.1**.

Figure III. 8 SOLO LINE LX - 100M panel photovoltaic installed in URAER.

Table III. 1:summaries all datasheet types of SOLO LINE LX manufactory

Table III.1: datasheet of SOLO LINE 36/10–180W photovoltaic types

Electrical data	LX-10P	LX-50P	**LX-100M**	LX-160P	LX-180M
Rated power Pmpp [Wp]	10	50	**100**	160	180
Power tolerance	0 / +5 %	0 / +5 %	**0 / +5 %**	0 / +5%	0 / +5%
Rated current Impp [A]	0.58	2.88	**5.39**	8.56	9.31
Rated voltage Vmpp [V]	17.39	17.44	**18.70**	18.73	19.39
Short-circuit current Isc [A]	0.64	3.24	**5.87**	9.06	9.75
Open-circuit voltage [V]	21.60	21.60	**21.60**	22.98	23.05
Max. system voltage [V]	150	400	**1000**	1000	1000

Temperature coefficient [% /°C]	LX-10P	LX-50P	**LX-100M**	LX-160P	LX-180M
Temperature coefficient [P]	-0.49 %	-0.45 %	**-0.49 %**	-0.45 %	-0.49 %
Temperature coefficient [I]	0.05 %	0.05 %	**0.05 %**	0.05 %	0.05 %
Temperature coefficient [U]	-0.35 %	-0.32 %	**-0.35 %**	-0.32 %	-0.35 %

Specifications

	LX-10P	**LX-50P**	**LX-100M**	**LX-160P**	**LX-180M**
Cell size	78 x 22.5 mm	52 x 156 mm	**125 x 125 mm**	156 x 156 mm	156 x 156 mm
Number of cells | cell type	4 x 9 | poly	4 x 9 | poly	**4 x 9 | mono**	4 x 9 | poly	4 x 9 | mono
Weight	1.5 kg	5.5 kg	**7.8 kg**	11.5 kg	11.5 kg
Cable length	-	850 mm	**850 mm**	850 mm	850 mm
Cable diameter	-	4 mm^2	**4 mm^2**	4 mm^2	4 mm^2
Diode	-	-	**2 x 12 A**	2 x 12 A	2 x 12 A
Junction Box	IP 65	IP 65	**IP 65**	IP 65	IP 65

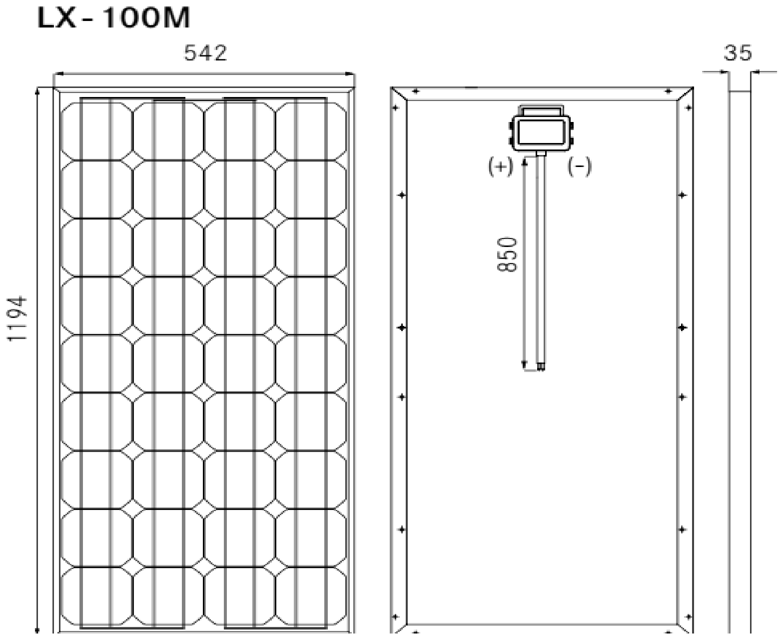


Figure III. 9:LX-100M photovoltaic dimension

III.12 Identification results of LX-100M PV cell model

Four parameters (I_{ph}, n, R_s and R_p) needed to be determined for the of LX-100M PV cell system, in simulation, we use different irradiance and temperature values as shown in .

The calculated and experimental data current of LX-100M PV module under various climatic conditions are show in **Figure III.10** to Figure III.13.

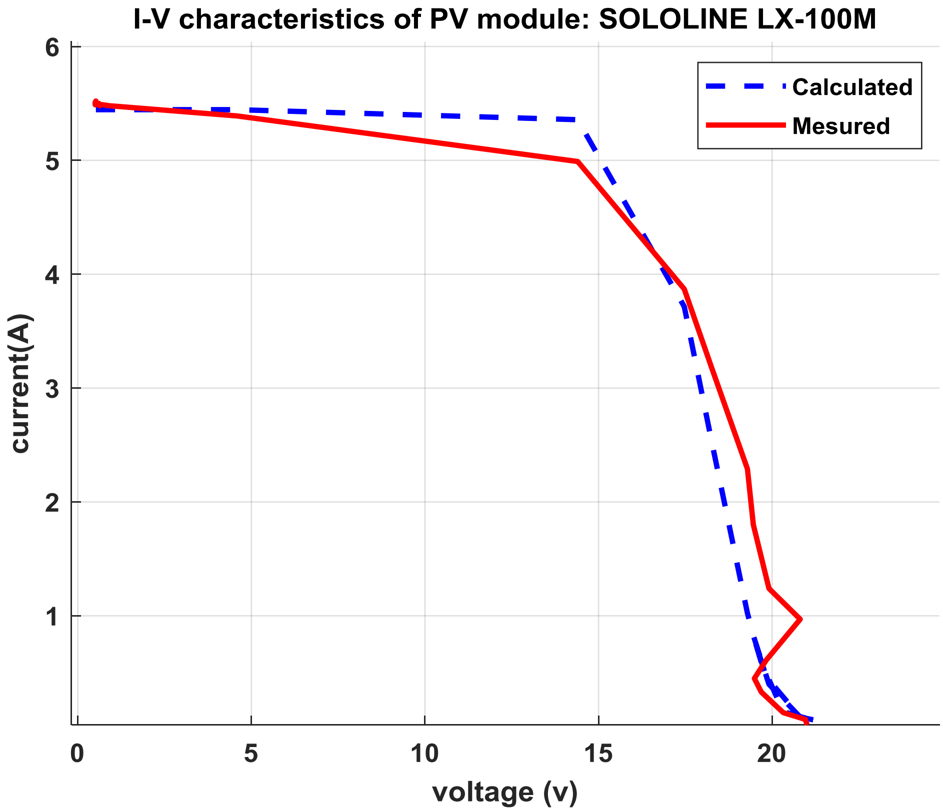


Figure III. 10: The calculated and experimental data current.

The Four parameters (I_{ph}, n, R_s and R_p) values are presented by:

$$\begin{cases} I_{ph} = 5.84A \\ n = 1.2 \\ R_s = 0.0453\ \Omega \\ R_p = 287.56\Omega \end{cases}$$

Experiential Information:

$$\begin{cases} radiation(v * 1000) = 721{,}7064 \\ T(°) = 37 \\ V(mv) = 0{,}721 \end{cases}$$

The curve fitting is illustrated in **Figure III.10**.

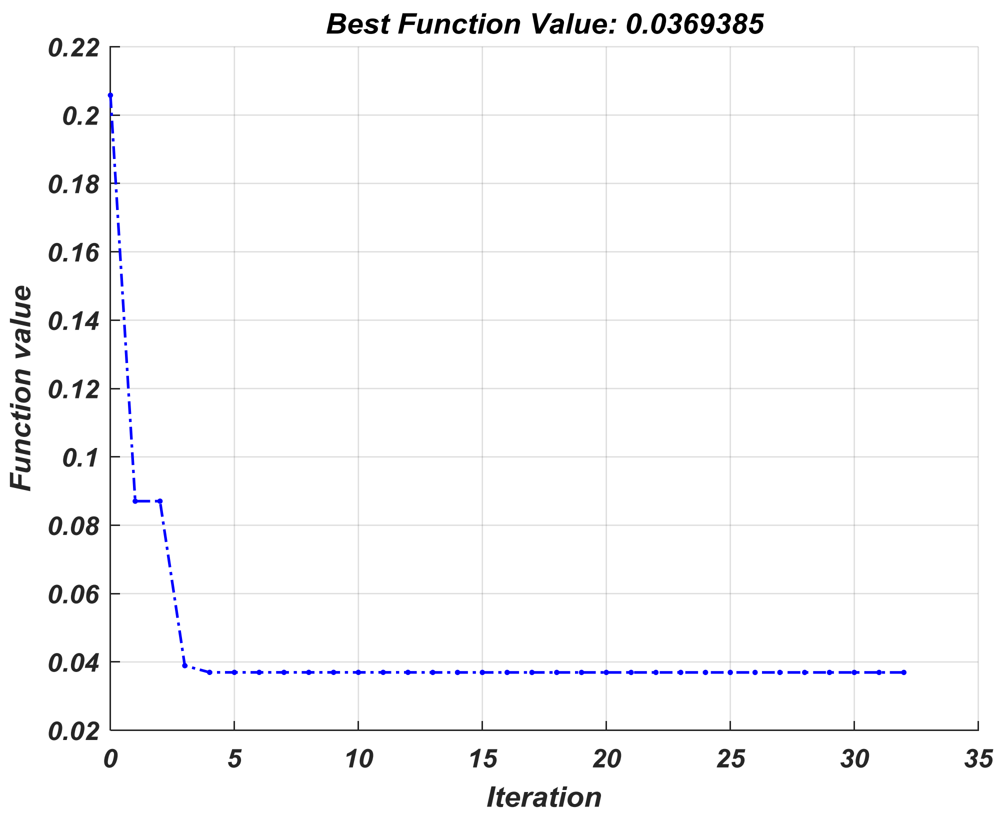


Figure III. 11: The PSO convergence curves

From Table 3.2 and Figure III.10 and Figure III.11, it can be observed by comparing with datasheet in Table 3.1 that PSO algorithm achieved a good MSE value of 0.0369385 for parameter identification.

III.13 Conclusion

In this chapter we have proposed an optimization algorithm ensuring the identification of the LX-100M PV model using only its experimental data acquired within URAER. This algorithm used to search, optimally, the parameters of the PV model such that the vector of the previous estimated current is identical to that of the real current by using the PSO algorithm.

General Conclusion

The work presented in this project focuses mainly the characterization photovoltaic system Its purpose is to ensure optimal functionality, identify potential problems, improve performance, ensure quality and safety, and assess the financial viability of the system. This is essential to maximize the benefits of solar energy and ensure the long-term sustainability of photovoltaic installations.

The PSO algorithm introduced various particle swarm optimization algorithms that have been remarkably successful since their birth, thanks to their simplicity and the ease with which the user can implement various processes without having to modify the basic structure of the algorithm.

We noticed that the PSO algorithm presents a major problem, which is the problem of rapid convergence that allows to find a local optimum, in this sense, we presented several improvements of this technique to improve the performance and avoid cases of this problem.

The results obtained in this study encourage us to propose the application of the PSO algorithm in the optimization of artificial neural network training in the future; optimization with the PSO algorithm can be tested in more difficult and complex systems in the future, and the hybridization of this method with genetic hybridization with other methods such as genetic algorithms and tabu studies will improve their performance and the results achieved.

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