PEOPLE'S DEMOCRATIC REPUBLIC OF ALGERIA
Ministry of Higher Education and Scientific Research

Amar Thelidji University - Laghouat

FACULTY OF TECHNOLOGIY

ELECTRONICS DEPARTEMENT

MASTER THESIS

Presented by:

Benlahbib Choumaissa
Benmessaoud Kawtar

DOMAIN : Science and Technology

FACULTY : Electronics

OPTION: Instrumentation

Theme

Influence of multiple faults on the behavior of a photovoltaic system

Defense Jury:

Full name	**Grade**	**Quality**
M. Ilyes ROUGAB	MAA	President
M. Aissa AMEUR	Pr	Examine
M. Mechri KIOUS	Pr	Supervise
M. Lotfi SAOUALE	PHD student	Co-supervise

Promotion: 2021/2022

Dedications:

Not all letters can find the right words … Not all words can express gratitude, love, respect, gratitude. Also, it is quite simply that: we dedicate this thesis to our dear parents Mom, you brought us into the world, and since then you haven 't stopped loving us, encouraging us, taking care of us, bringing the best within our reach; you spared no effort to make us happy. So, no dedication is strong enough, no word speaks volumes enough to express how we feel. But through this work, the crowning of your combined efforts, we would like to express to you our unparalleled esteem and respect, our infinite gratitude and above all our immense filial love. May God grant you long life, health and happiness. To our dearest sisters, To our dear brothers Throughout the development of this thesis.

Thanks:

we want to thank the God who protected and guided us until the end of this work. we are very grateful to our teacher: Mr. Kious mechri and his student Mr. Lotfi Saouale who helped us by directing and encouraging us in the realization of this work. we express our sincere gratitude to them for the great kindness they always showed towards us. Please find in this work an expression of our gratitude and deep respect.

ملخص:

في الوقت الحاضر، تعد الطاقات المتجددة قضية رئيسية في مجتمعنا، وخاصة الطاقة الشمسية. يمكن تحويل الطاقة الشمسية إلى طاقة كهربائية باستخدام الألواح الكهروضوئية.

في الواقع، لا يوجد نظام ضوئي لا يعاني من عيوب جسدية وكذلك عيوب مناخية.

لهذا السبب، يواصل الباحثون العمل على أنظمة الطاقة الشمسية من أجل ضمان الاستخراج الأمثل لهذه الطاقة. من خلال تحديد جميع الأخطاء المحتملة ومنع حدوثها أو التعرف عليها بسرعة لتصحيحها.

نحن مهتمون في هذه الدراسة بتعريف العيوب الجسدية ودمجها مع مجموعة متنوعة من العوامل البيئية. من أجل جمع عدد كبير من المعلومات لإنشاء قاعدة بيانات لنظام الطاقة الشمسية الكهروضوئية.

abstract:

Nowadays, renewable energies are a major issue in our society, especially solar energy. Solar energy can be converted into electrical energy using photovoltaic panels.

In reality, no photovoltaic system does not suffer physical defects as well as climatic defects.

For this reason, Researchers keep working on the solar systems in order to ensure optimal extraction of this energy. By identifying all possible errors and preventing them from occurring or identifying them quickly in order to correct them.

In this study, we are interested in the definition of physical defects and their combination with a variation of environmental factors. In order to collect a large number of information to create a database for the solar PV system.

Résumé :

De nos jours, les énergies renouvelables sont un enjeu majeur de notre société, notamment l'énergie solaire. L'énergie solaire peut être convertie en énergie électrique grâce à des panneaux photovoltaïques.

En réalité, aucun système photovoltaïque ne souffre de défauts physiques au même titre que de défauts climatiques.

Pour cette raison, les chercheurs continuent de travailler sur les systèmes solaires afin d'assurer une extraction optimale de cette énergie. En identifiant toutes les erreurs possibles et en les empêchant de se produire ou en les identifiant rapidement afin de les corriger.

Dans cette étude nous nous intéressons à la définition des défauts physiques et à leur combinaison avec une variation des facteurs environnementaux. Afin de collecter un grand nombre d'informations pour créer une base de données pour le système solaire PV.

Key-words: Renewable energy- photovoltaic solar- fault- PV converter boost, MPPT,

MATLAB /Simulink

I: Electricity generated by the photovoltaic cell

I_{ph}: Current photo created by the photovoltaic cell

I_d: the diode current

I_{sh}: current flowing through the shunt resistor,

R_{sh}: shunt resistance (415.405 Ω)

R_s: is a series resistance (Ω)

T: operating temperature (k)

N_s: number of cells connected on series (54 cell)

I_s: is the saturation current in amperes (A)

q: electron charge (1.6×10^{-19} C)

k: Boltzmann constant (1.38×10^{-23} J/K)

n: is the ideal factor which depends on the PV technology and is listed in Table I.

V_{oc}: the open-circuit voltage

I_{sc}: is the short-circuit current of the cell at 25°C and 1000W/m^2,

K_i: the temperature coefficient of the short-circuit current of the cell,

T_n: is the reference temperature of the cell, in Kelvin (K) (= 25°C + 273),

G: is the sunshine in watt/square meter (W/m^2),

G_{ref}: is the reference insolation of the cell (= 1000W/m^2),

I_{rs}: the reverse saturation current of the cell at a reference temperature and solar radiation

E_{go}: is the gap energy of the semiconductor used in the cell in electrovolt (1.1eV).

V = Output voltage from PV array

V_{out} (I_{out}): Output voltage (current) from boost converter

I_{in} (V_{in}): Input current (voltage) from boost converter

V_{mp}: Voltage in maximum point

I_{mp}: Current in maximum point

P_{mp}: Power in maximum point

MPPT: Maximum Power Point Tracker

MPP: maximum power point

STC: Standard Test Conditions.

(I-V) current-voltage

(P-V) Power-voltage

Table of Contents

General Introduction

The world's need for electrical energy is currently growing, and non-renewable fossil fuels account for a large segment of the energy produced globally. The consumption of these sources results in greenhouse gas emissions and therefore an increase in pollution. However, the exploitation of nuclear energy presents risks of serious accidents, not to mention those induced by the management of the resulting waste, the radioactive danger of which can last several thousand years. Energy from the sun now satisfies the criterion of both plenty on the earth's surface and limitless regeneration on our scale, in contrast to so-called renewable energy, which must regenerate spontaneously and endlessly.

Photovoltaic systems offer the ability to transform solar radiation into electrical energy for using this solar energy. [1]

The stimulating factors make the return on investment of a photovoltaic installation increasingly interesting. However, like all other industrial processes, a photovoltaic system can be subjected, during its operation, to various faults and anomalies leading to a drop in the performance of the system and even to the total unavailability of the system. All these unfavorable consequences will obviously reduce the productivity of the installation, and therefore reduce the profit of the installation, not to mention the cost of maintenance to restore the system to normal condition.

The objective of this thesis is to create a database for an eventual command for MPPT using fuzzy logic by studying faults and failures on solar panels, we are specifically interested in faults on the PV generator of the system that we created.

In the first chapter we represent some generalities about the photovoltaic systems then the different elements that go into the constitution of a photovoltaic system such as the cell with its electrical characteristics ,a PV module, PV field, DC/DC and DC/AC converter with the mention of The MPPT command , protection systems and the advantages and disadvantages of solar systems, and the most important part is the mention of some of the faults that can reduce the system’s efficiency or make it malfunction.

In the second chapter is devoted to the modeling of the photovoltaic generator. Thus, we briefly describe the structure and operation of photovoltaic cells and generators. In addition, the influence of the meteorological conditions (temperature and light) on the electrical characteristics of photovoltaic generators is also presented, the study of one of types of DC/DC converters which is boost chopper for the pursuit of the maximum power point. in addition, the MPPT command used based on fuzzy logic method.

The last chapter is concerned with the simulation of the photovoltaic system in the presence of the various faults as well as the display of the results obtained and making comments on them in the form of percentages to create a database for the MPPT command and control.

Finally, a general conclusion to our thesis.

Generalities on photovoltaic system

I.1. Introduction:

Customers have the option to produce electricity using photovoltaics in a safe, quiet, and dependable manner. Photovoltaic cells, which turn light energy directly into electricity, are the building blocks of photovoltaic systems. They are frequently referred to as solar cells because the sun is typically their source of light. The words "photovoltaic" and "voltaic," which both refer to the creation of electricity, are derived from each other. As a result, "generating energy directly from sunshine" is what the photovoltaic method does. PV is a common abbreviation for photovoltaics.

With an efficiency of about 15%, a typical photovoltaic cell can convert 1/6 of solar energy into electricity. Photovoltaic systems do not emit pollutants into the environment, make no noise, or have any moving parts. When compared to electricity produced through the use of fossil fuel technologies, photovoltaic cells produce several tens of times less carbon dioxide per unit when the energy used in their manufacture is taken into consideration. One of the most dependable semiconductor products is the photovoltaic cell, which has a lifespan of over thirty years. The bulk of solar cells are built of silicon, which is both abundant and non-toxic in the earth's crust.

Photovoltaic systems are now relatively accessible and have a quick and steadily declining return on investment thanks to the introduction of subsidies for energy provided by renewable sources in all developed nations.

The photovoltaic business has been expanding at a pace of 40% per year in recent years, and it generates thousands of jobs locally. [2]

Figure I- 1: example of PV field.

I.2.Global trends in photovoltaic energy:

Direct exploitation of solar radiation, a renewable energy source, is now possible because to solar energy technology. One of the most promising technologies to address urgent energy requirements, slow climate change, and promote sustainable development is this so-called photovoltaic (PV) energy. Installed PV capacity is now expanding quickly, driven by sustainable energy legislation, deep country commitment, technological advancement, and cost reduction. Compared to just 40 GW in 2010, the total PV power reached 303 GW in 2016. Fig I-2 also depicts the capacity development and the annual global addition of solar photovoltaic energy from 2000 to 2016. We see that the global increase in energy generation due to photovoltaics is exponential. [3]

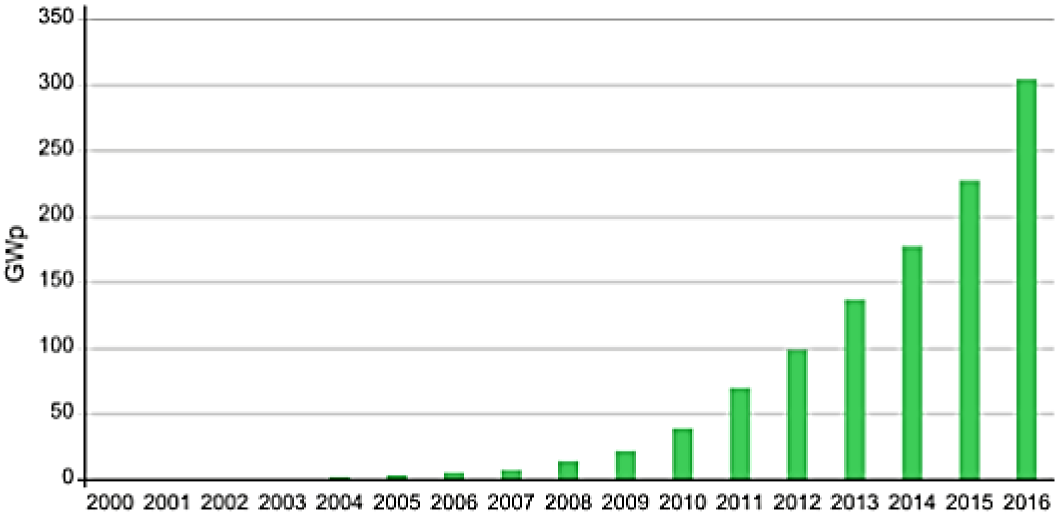


Figure I- 2:Evolution of global photovoltaic energy production

I.3.The Solar energy in Algeria:

Algeria has one of the highest solar reserves in the world as a result of its geographic location. Almost the whole national territory experiences more than 2000 hours of sunshine each year, with some areas experiencing up to 3900 hours (high plateaus and Sahara). Nearly 1700 KWh/m²/year in the north and 2263 KWh/m²/year in the south of the nation are received on a horizontal surface of 1 m^2 every day, covering the majority of the national area. If this potential is economically harnessed in the Sahara, it might play a significant role in sustainable development.

The rate of sunshine for each region of Algeria is displayed in the following table. [4]

Table I- 1:sunshine rate in various regions in Algeria:

Regions	**Coastal regions**	**HIGHLANDS**	**SAHARA**
Area	4%	10%	86%
Average sunshine duration (Hours=year)	2650	3000	3500
Average energy received (KWh/m²/year)	1700	1900	2650

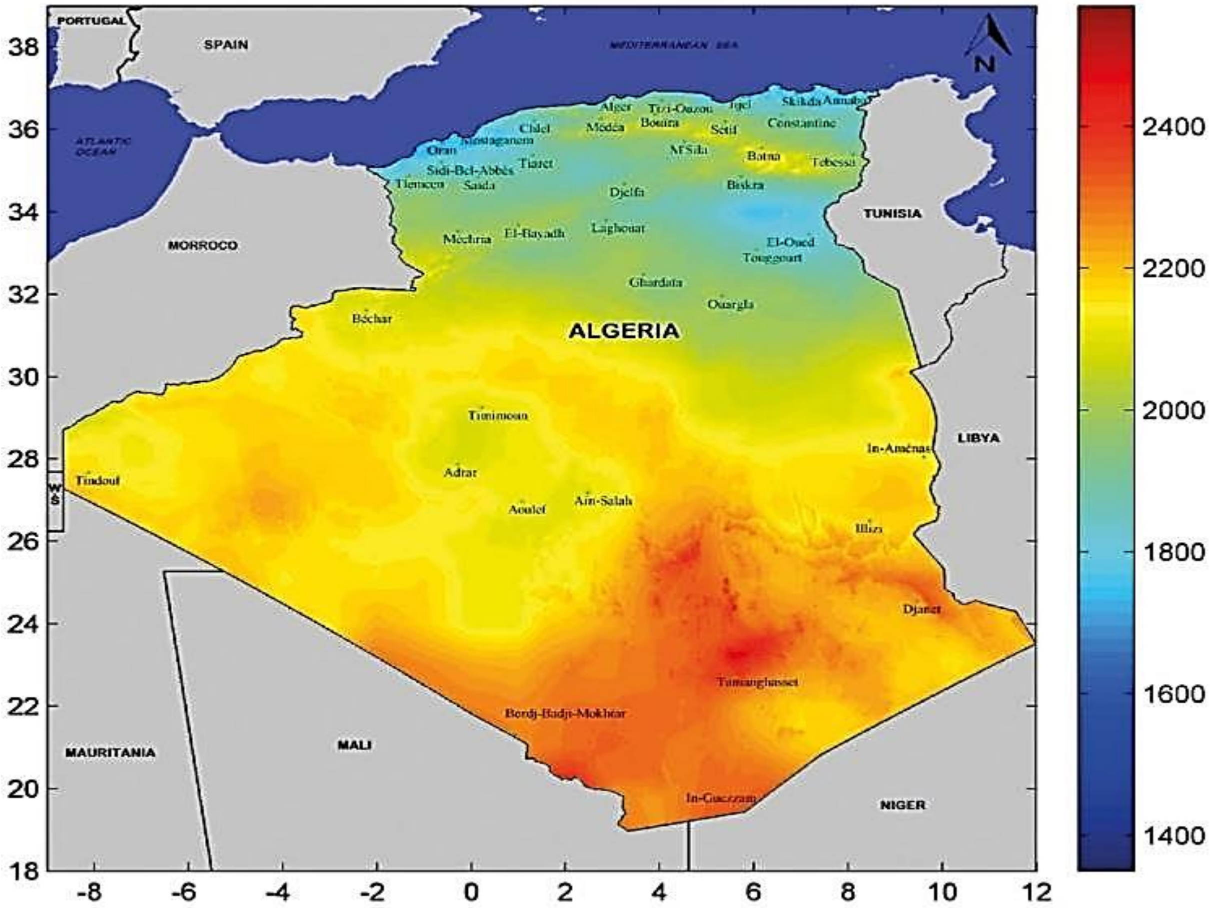


Figure I- 3:Solar radiation potential in Algerian valid source specified.

Solar energy development is being accelerated as part of Algeria's energy policy. By 2020, the government intends to start a number of solar photovoltaic projects with a combined capacity of about 800 MWp. Over the years 2021-2030, more projects with a capacity of 200 MWp should be completed. [4]

I.4.Photovoltaic generator:

I.4.1. PV effect:

A photovoltaic effect allows photovoltaic cells, a type of electronic device, to convert light into electrical energy. Although it is a physical process, we can deconstruct how sunlight is transformed into usable power by solar cells in solar panels into three simple phases.

In a solar photovoltaic (PV) cell, there are three main processes that occur:

- Light absorption generates carriers (knocked-out loose electrons).
- Power is produced as carriers flow.
- Energy is collected and sent through cables.

Two silicon semiconductors—one positively charged (p-type), the other negatively charged—make up each photovoltaic circuit (n-type). An n-type semiconductor always absorbs the photon, the smallest unit of light. It causes higher-energy electrons to leave the solar cell and enter an external circuit. After releasing their energy in the external circuit, the electrons return to the solar cell. [5]

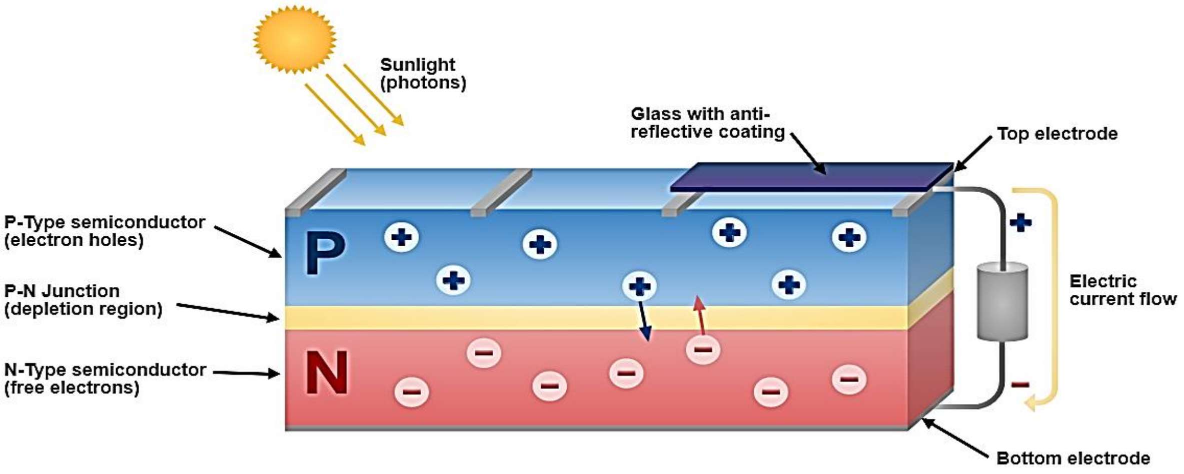


Figure I4 -:photovoltaic cell

I.4.2. Photovoltaic cell technologies:

Silicon, an excellent semiconductor, is used to make the bulk of solar cells. Materials span from amorphous (nanocrystalline), through polycrystalline, to crystalline (single crystal) silicon forms, with varying requirements and financial capacities.

I.4.2.1. Monocrystalline Solar Panels:

They are top-quality solar goods. Higher efficiency, durability, and great aesthetic value are these panels' key benefits. Single-crystal silicon is cut into wafers and formed into strips for use in solar cells. The electrons have greater space to move because the cell is made of a single crystal. Monocrystalline panels consequently have the highest efficiency (about 20 percent), but they also cost the most to purchase.

I.4.2.2. Polycrystalline solar panels:

They are one of the cheaper options for solar power enthusiasts. Moderate cost is their great advantage, but they have significantly lower efficiencies (~15%) and slightly shorter durability than monocrystalline options. Polycrystalline solar cell panels are also made from many fragments of silicon melted together to form the wafers. Due to their multi-crystalline construction of every silicon solar cell, there is less freedom for the electrons to move, which results in lower efficiency.

I.4.2.3. Thin-Film, Amorphous Panels:

Despite being the easiest and least expensive to make, they are the least effective and durable (between 7 and 10 percent). Since the film thickness ranges from a few nanometers to tens of micrometers, they are far thinner than rival technologies based on first-generation crystalline silicon solar cells (Mono-SI, p-Si, c-Si). The thin-film photovoltaic cell is hence exceedingly light and flexible. As a result, they are often used as photovoltaics that are integrated into structures, such as semi-transparent material bonded onto windows.

I.4.3. Electrical characteristic of a PV cell:

The photovoltaic cell has its own operating characteristics and is represented by the nonlinear characteristic curves I(V) and P(V). [6]

There are several electric models of the photovoltaic cell, but in this study, we use the model schematized in by Fig I-5. This circuit introduces a current source and a diode in parallel, as well as series R_s and parallel R_{sh} resistors to take into account dissipative phenomena at the cell level.

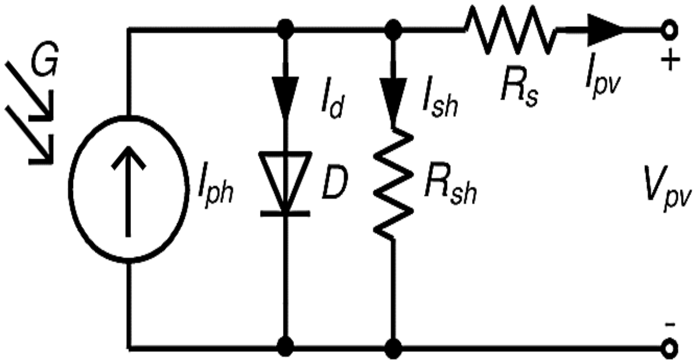


Figure I- 5:equivalent circuit of a solar panel.

I.4.3.1. Current-Voltage characteristic:

The fig I-6 represents the curve I= f(V) of a Typical photovoltaic panel under constant conditions of irradiation and temperature**.**

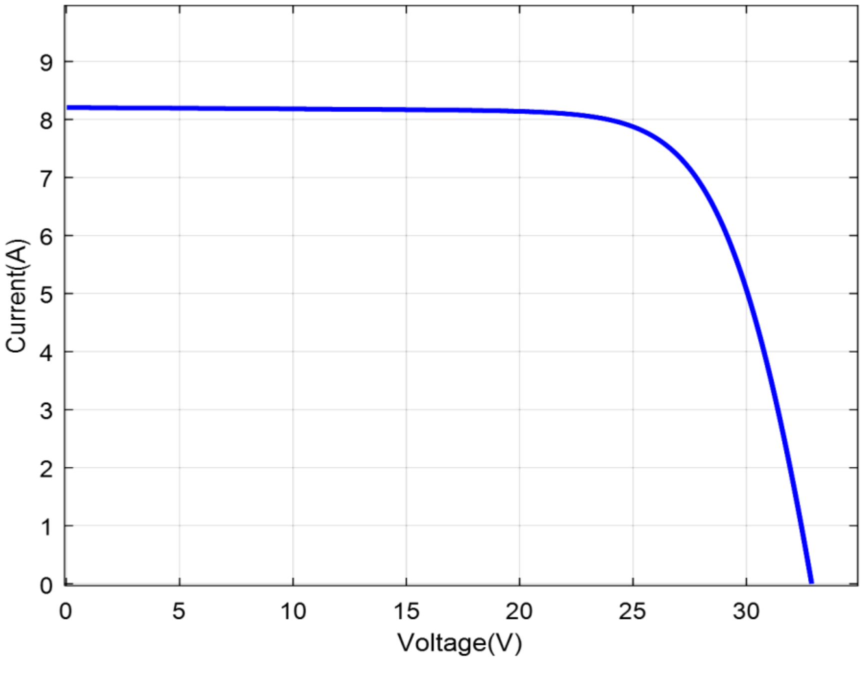


Figure I- 6:The curve I=f(V) of PV under G=1000 W/m², T=25°C.

I.4.3.2. Power-Voltage characteristic:

Cell power-voltage characteristic has the expression P = V.I. The fig I-7 represents the curve P= f(V) of a Typical photovoltaic panel under constant conditions of irradiation and temperature.

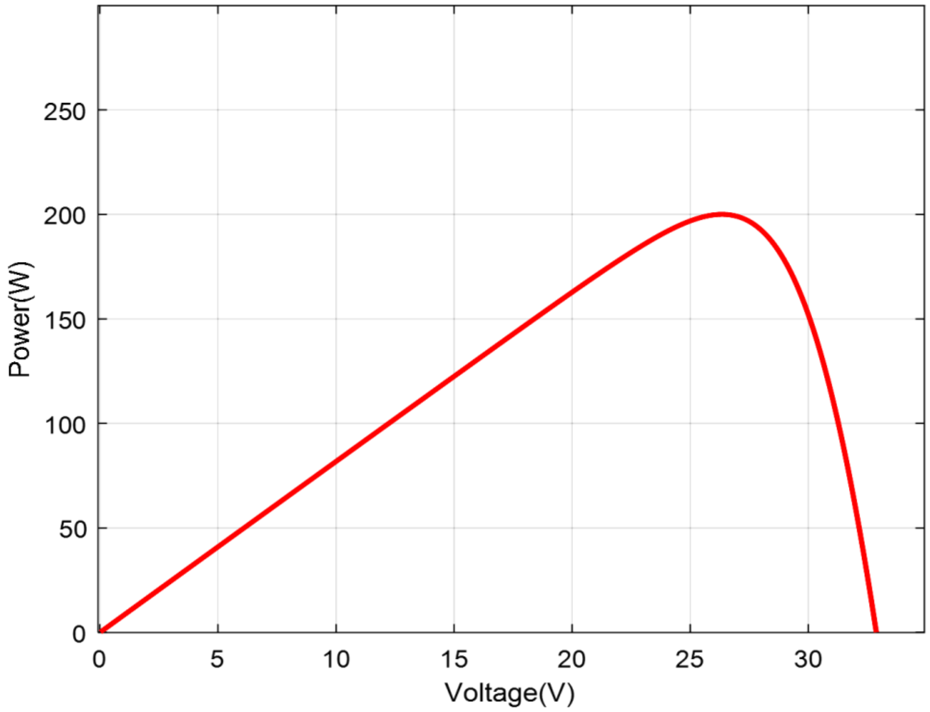


Figure I- 7:The curve P=f(V) of PV under G=1000 W/m², T=25°C.

I.4.3.3. The short-circuit current I_{sc}:

It relates to the maximum current that the cell can produce. It is created when the circuit is shorted (V_{OC} = 0). Isc and illuminance at room temperature are directly related. Additionally, it differs based on the cell surface. By interfacing an ammeter with the cell terminals, its value can be determined.

I.4.3.4. Open circuit voltage V_{oc}:

It relates to the highest voltage that the cell can produce. It is created when the circuit is open (I c=0). A photovoltaic cell's open circuit voltage varies logarithmically with irradiance and decreases as temperature rises. By directly connecting a voltmeter to the cell's terminals, you may measure it.

Power Point Maximum (PPM): For the user, the aspect of the I(V) characteristic that generates energy is interesting. As a result, it won't be at either the open-circuit voltage point (also known as open-circuit voltage) or the short-circuit point, which produces no energy because power is calculated by multiplying current by voltage. P =V I. The operational point M (VPPM, IPPM) for which the power dissipated in the resistive load is maximum called the maximum power point. [6]

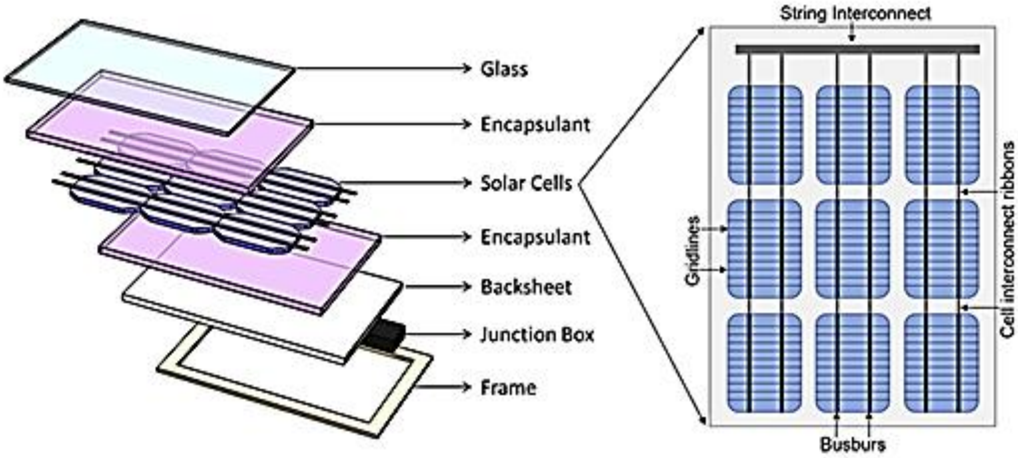
I.5: GPV Constitution :

I.5.1: PV cell :

A photovoltaic is the basic building block. The maximum amperage of the cell is proportional to its surface area, and depends on the intensity of the light.

I.5.2: PV module:

The solar cells are put together to create a figure module, which can generate more power fig I-8(a). While connecting many cells in parallel improves the current while maintaining the voltage, connecting multiple cells in series increases the voltage for the same current. Encapsulated in an EVA polymer (ethylene-vinyl-acetate) fig I-8(b), these cells are shielded from humidity on their front surfaces by tempered glass with high transmission and superior mechanical resistance, and on their back surfaces by a polyethylene. [7]



b) a)

Figure I- 8:photovoltaic module.

Currently, a module's peak power ranges from a few to a few tens of watts. The modules in Fig I-8 must be connected in series and parallel to create a PV generator with larger powers. If there are major imbalances caused by the occultation of one or more cells, the modules may also need to function as a receiver. Diodes can be connected in series and parallel to the modules to solve these issues. [7]

I.5.3: string and photovoltaic field:

The photovoltaic modules must be put together in a series/parallel configuration in order to have an installed power of several hundred kilowatts, or even megawatts[7] .

The primary components of a solar panel installation are the photovoltaic panels and the inverter. The panels must be put together in chains, or "strings," connected to an inverter, for these components to operate at their best. This approach saves the need to attach each panel to a separate inverter.
In fact, all the voltage can be sent to a single inverter thanks to the panel strings. Consequently, the voltage is optimized.

How many panels can be connected together in a chain depends on a number of factors:

In the event of a darkened area, the path the current takes between the panels and the inverter may be the cause of production losses. In fact, a shadow zone on one panel will have an impact on the entire chain of panels since the voltage of the string depends on the voltage of the weakest member. To reduce the effect of shadow areas on the entire installation, each string of panels will be made either vertically or horizontally.

Finally, a certain panel layout is mandated by the building's restrictions. The installation's configuration is impacted by these technical limitations. This justifies the necessity of the layout and the significance of stringing the panels together.

Thus, the strings are technical concessions that allow for the resolution of voltage issues as well as the minimization of potential production losses associated with photovoltaic panel installations. [8]

I.6.Connection of a photovoltaic generator (GPV):

The association of several photovoltaic cells in series/parallel gives rise to a photovoltaic generator.

I.6.1. Association of Photovoltaic Cells in Serial:

The combination of (N_s) serial cell f increases the voltage of the photovoltaic generator. The cells are then crossed by the same current and the characteristic resulting from the serial grouping is obtained by addition of the elementary voltages of each cell. The equation summarizes the electrical characteristics of the series combination of (N_s) cell.

$V_{co}N_S = N_s \text{ x } V_{co}$
$I_{cc} = I_{cc}N_s$

V_{co} N_s: the sum of the open circuit voltages of Ns cells in series

I_{cc} N_s : courant de court-circuit de Ns cellules en série.

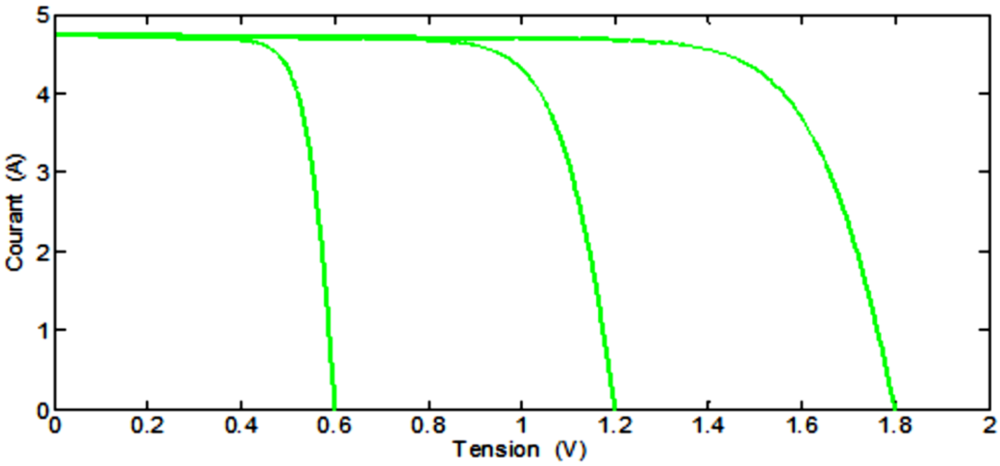


Figure I- 9:Characteristic current voltage of Ns cell in series.

I.6.2. Association of Photovoltaic Cells in Parallel:

A parallel association of (NP) cell is possible and allows to increase the output current of the generator thus created. In a group of identical cells connected in parallel, the cells are subjected to the same voltage and the resulting characteristic of the group is obtained by the addition of currents.

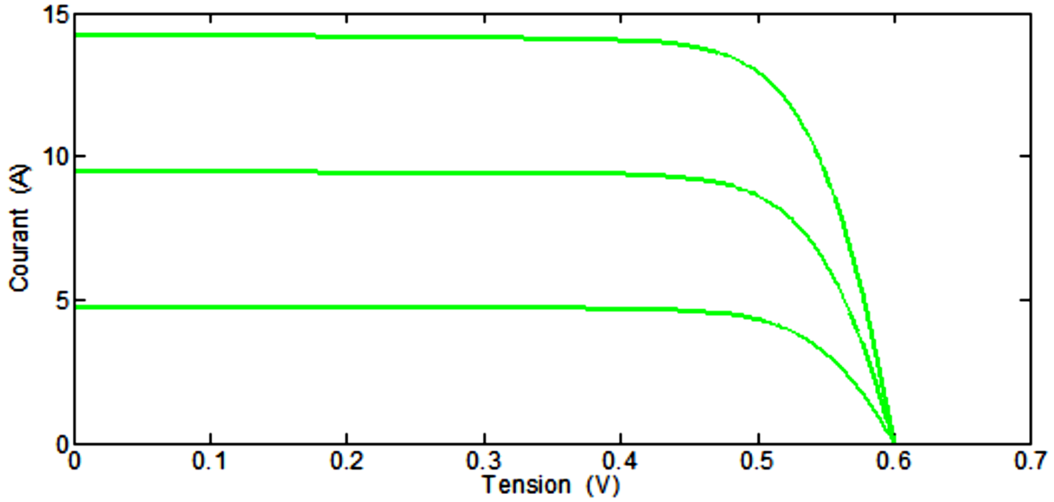


Figure I- 10:Characteristic current voltage of (Np) cell in parallel.

I.7. Photovoltaic system:

The GPV alone does not represent much, while being an essential link in the chain that a PV system represents. These modules actually need to be firmly linked to a full system that corresponds to a very specific application in order to fulfill a defined demand. In order to guarantee a supply within power standards, devices like static converters (inverter and chopper) with the MPPT regulating system disregard the type of batteries, any connections, and any safety or protective device. [9]

A photovoltaic system typically consists of three major components, which are seen in the fig I-11.

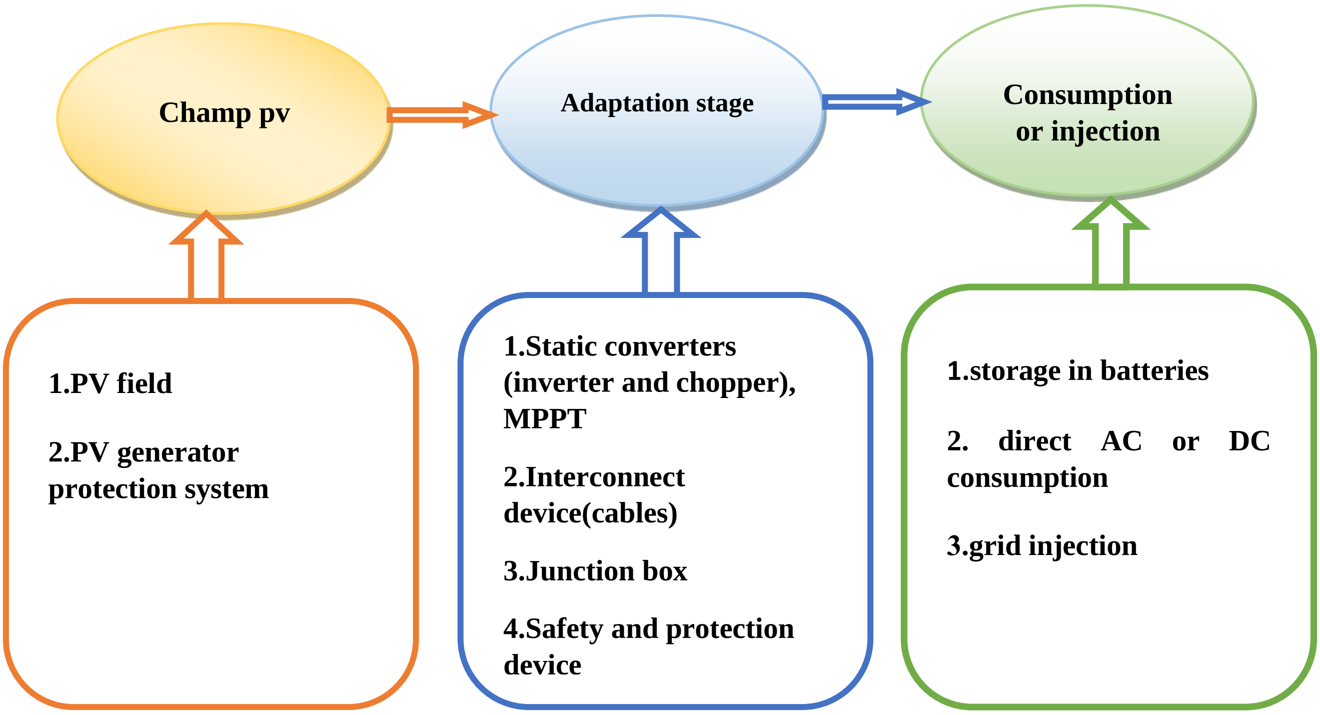


Figure I- 11:the different configurations of stand-alone photovoltaic systems.

I.7.1. Elements of a photovoltaic system:

For the generation of low or medium power electricity in remote locations, particularly for residences, photovoltaic systems appear to be the preferred option. The main components of this PV system are the PV modules, which serve as the solar ray collection field, the batteries, which serve as the energy storage field, the regulator, which guards the battery against overcharging by controlling the nominal voltage, the inverter, which transforms the direct current into the alternating current that users require, and the wiring, which links the various system components.

The following components are often found in a photovoltaic installation:

- A solar-powered device
- An immovable DC/DC converter
- DC/AC converter that is stationary

I.7.1.1. PV Generator:

As already mentioned in the first chapter, the photovoltaic cell is the smallest element in a PV generator, that said it is the basic element of the latter, it is responsible for the direct conversion of solar energy into a direct electric current, only it generates a very low power which is of the order of a few watts. A PV module consists of several PV groups which is the basis of a set of PV cells connected in series with the aim of increasing their voltage. [10]

These PV cells are brought together in parallel with a single bypass diode. As shown in fig I-12.

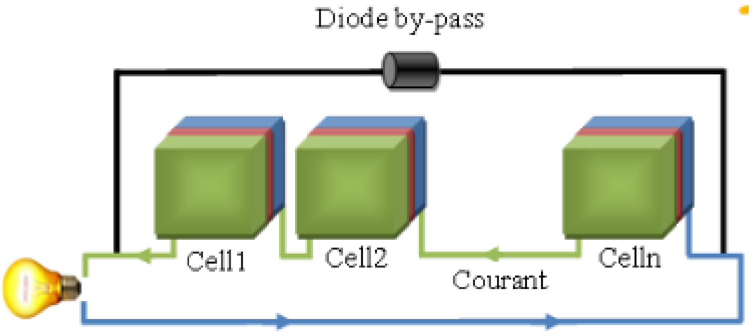


Figure I- 12:PV panel.

Then these PV groups are connected together in parallel to increase the current so the power will be increased to tens or hundreds of watts per module (panel) Several other components are added such as (junction box, hard glass, tempered glass, silicone seal, aluminum frame and other…) for mechanical safety of the panel and to have better performance. [10] As shown in fig I-13.

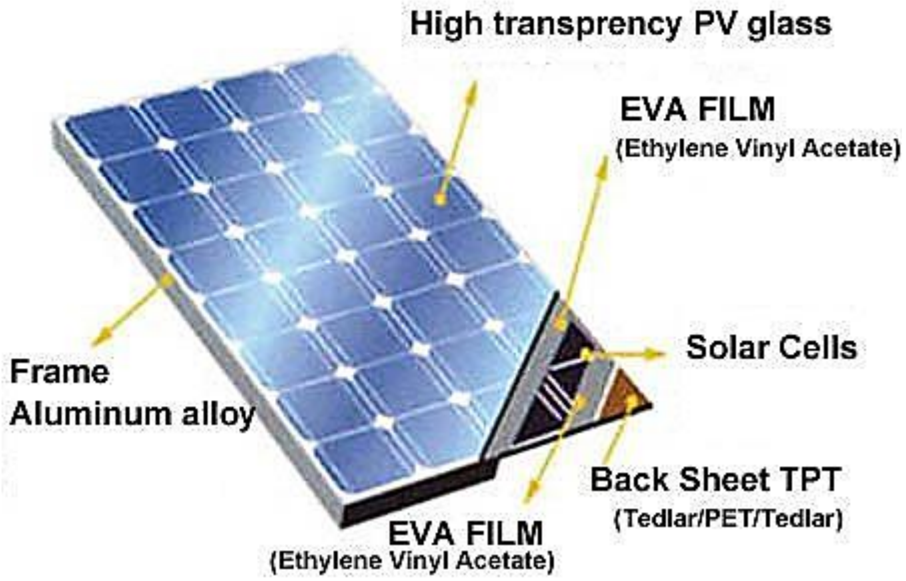


Figure I- 13:Components of a PV generator.

I.7.1.2. PV field:

A photovoltaic field is composed of several PV modules wired in series between them, creating a chain or a string which is a grouping of several PV modules in series, it ends with a so-called anti-return diode, which aims to block the reverse current circulating throughout the PV string, the voltage is thus increased at the terminals of this string. Then these chains can be put in parallel, the tension is preserved and the current increases (basic principle of electricity).

The sizing will consist in adapting, by a judicious combination, the number of PV modules in series and in parallel to the available surface (on a roof for example) but also and above all in checking the voltage and intensity compatibility of the photovoltaic field with the inverter. In particular There are several possible configurations for interconnecting the modules in a photovoltaic field: simple parallel series connection, Total Cross Tied connection, Bridge Linked connection. It has been shown that the last two configurations can improve the performance of the field but the economic viability prevents the use of such configurations. We therefore do not retain in this work the simple parallel series connection. [10]

Converters are devices used to transform the DC voltage supplied by the panels or batteries to adapt it to receivers operating in a different DC voltage or an AC voltage. The study of the converter is interesting insofar as it is used in most new types of energy production sources (wind, photovoltaic, fuel cell...).

In general, there are two kinds of converters in a PV installation, the chopper and the inverter which have the role of extracting the maximum power from the PV generator and converting it into alternative power before consuming it. [10]

I.7.1.3.1. converter DC/DC (the chopper):

Choppers are DC-DC type converters for controlling electrical power in circuits operating on DC with great flexibility and high efficiency. [11]

DC-DC converters (or choppers) are used in solar power systems to adapt the variable amplitude DC source (PV panel) to the load which generally requires a constant DC voltage.

The three basic configurations are:

1. Boost converter.

2. Buck converter.

3.Buck-boost converter.

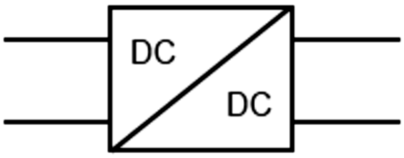


Figure I- 14:Symbol of a DC-DC converter.

1.Boost chopper:

It is a direct DC-DC converter. The input source is DC type (inductor in series with a voltage source) and the output load is DC voltage type (capacitor in parallel with resistive load). The switch K can be replaced by a transistor since the current is always positive and the switching must be controlled (on blocking and on starting). [12]

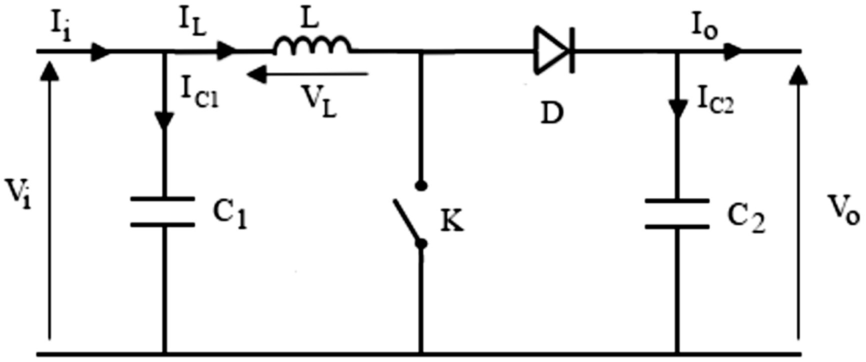


Figure I- 15:Circuit diagram of a boost chopper.

a) Operation:

When the switch is closed for the duration, αTe the current in the inductor increases linearly. The voltage across K is zero. During the time T∊ [αTe; Te] the switch opens and the energy stored in the inductor controls the flow of current in the freewheel diode D. We then have Vs=Vk By writing that the voltage at the terminals of the inductance is zero, we arrive at:

$$v_i = (1-\alpha)v_0$$

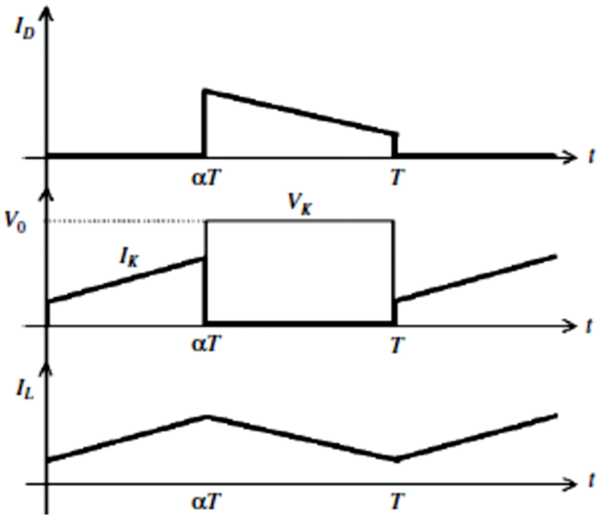


Figure I- 16::Current and voltage timing diagrams of a boost chopper.

b) Equivalent mathematical model:

In order to be able to synthesize the functions of the boost chopper in the steady state, it is necessary to present the equivalent circuit diagrams at each position of the switch K. that of the fig I-17, presents the equivalent circuit boost when K is closed i.e., between [0, αT_e]. [9]

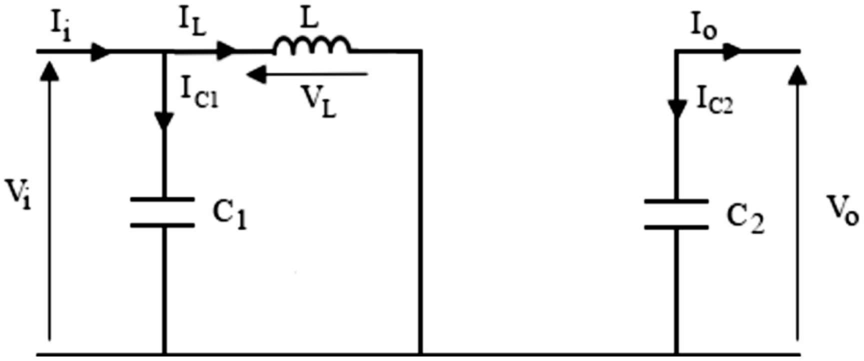


Figure I- 17:Circuit diagram of a closed boost chopper.

the application of Kirchhoff's laws on the equivalent circuits of the two phases of operation gives:

$$I_{C_1} = C_1 \frac{dV_i(t)}{dt} = I_i(t) - I_l(t)$$

$$I_{C_2} = C_2 \frac{dV_0(t)}{dt} = -I_0(t)$$

$$V_L = L \frac{dV_L(t)}{dt} = V_t(t)$$

In the open state of the switch K, the circuit equivalent to the operation of the Boost is the following:

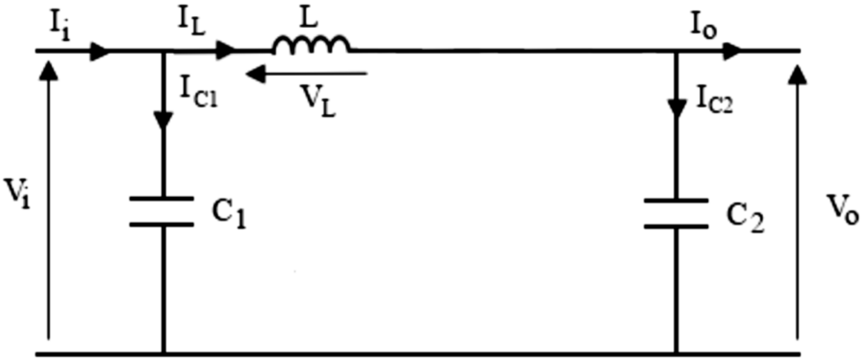


Figure I- 18::Circuit diagram of an open boost chopper.

$$I_{C_1} = C_1 \frac{dV_i(t)}{dt} = I_i(t) - I_l(t)$$

$$I_{C_2} = C_2 \frac{dV_0(t)}{dt} = I_l(t) - I_0(t)$$

$$V_L = L \frac{dV_L(t)}{dt} = V_i(t) - V_0(t)$$

I.7.1.3.2. The DC/AC converter (inverter):

The main function of the inverter is to transform the direct current produced by the solar panels into a three-phase alternating current to operate the pump motor unit. The inverter obviously operates with a PWM signal generation circuit controlled by a regulation and protection circuit. The DC/AC converter ensures optimum transfer of power from the solar generator to the pump motor unit and protects the pump against running dry when there is no water in the well. The efficiency of the inverter is generally high to make the most of the energy produced by the generator. It is around 95% at the nominal operating point. [13]

The inverter is one of the most important components in a PV station, there are several different types topologies of inverters used depending on the nature and requirement of the installation.

I.7.1.4. Wiring and junction box:

The purpose of the wiring is to electrically group the solar modules. Generally, the modules are first wired in series to create branches which each include their diode in series. The paralleling of branches is carried out, practically, using junction boxes fixed on the frames. This junction box can contain protective elements such as fuses, switches and disconnectors. It is essential to pay particular attention to the tightening of the terminals and the wiring of an installation because too great a voltage drop in the connections and in the cables can considerably reduce the charging current of the battery. This voltage drop is far from negligible when high currents are supplied at low voltages. This constraint requires the use of weather-resistant cables whose section will depend on the distance between the solar panel and the battery. [13]

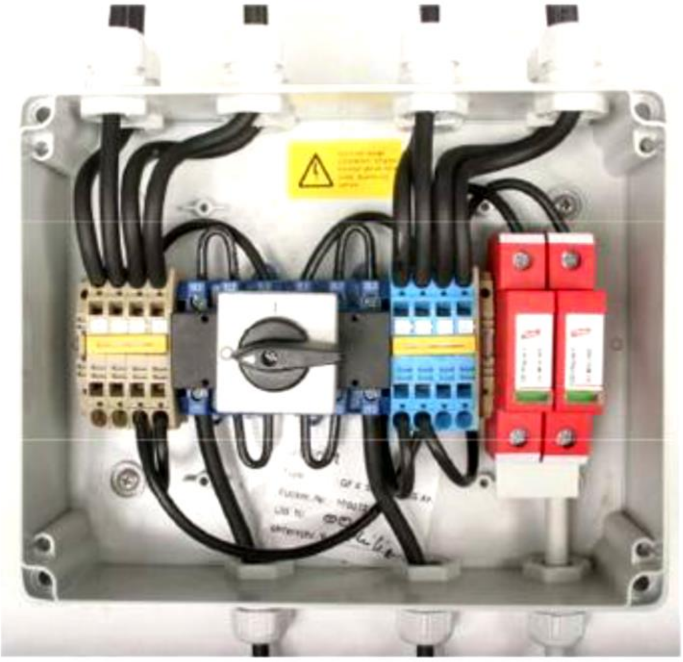


Figure I- 19:Example of junction box and wiring.

I.7.1.5. Protection of photovoltaic modules:

To guarantee the lifespan of a photovoltaic installation intended to produce electrical energy for years, electrical protections must be added to the PV modules in order to avoid destructive breakdowns linked to the association of cells in series and panels. in parallel. [14]

There are several kinds of protection for a photovoltaic installation, among them the protection of the PV generator:

I.7.1.5.1. Protection of a PV generator against electric shocks:

This type of protection includes protection against direct contact: "PV equipment in the direct current part must always be considered as live and have protection by insulation of live parts or by enclosure", and protection against indirect contact: "The protection methods must incorporate the provisions implemented on the DC and AC side as well as the presence or absence of galvanic separation by transformer between the DC and AC parts"

I.7.1.5.2. Protection of a photovoltaic generator against overvoltage’s:

Surges are present in several ways in a PV installation. They can be:

- transmitted by the distribution network and be of atmospheric origin (lightning) and/or due to maneuvers.
- generated by lightning strikes near buildings and PV installations, or on building lightning rods.
- generated by electric field variations due to lightning.

Typically, a lightning protection system for a PV generator consists of the following components:

1. Exterior Lightning Protection System (SPF);
2. Grounding installation and potential equalization;
3. Magnetic shielding and wiring;
4. Coordinated Surge Protection Device (SPD) protection;

I.7.1.5.3. Protection of a photovoltaic generator against overcurrent's:

The PV generator like any other generator of electrical energy must be protected against over currents, and other types of problems. We are only interested here in two components used for the protection of the PV generator.

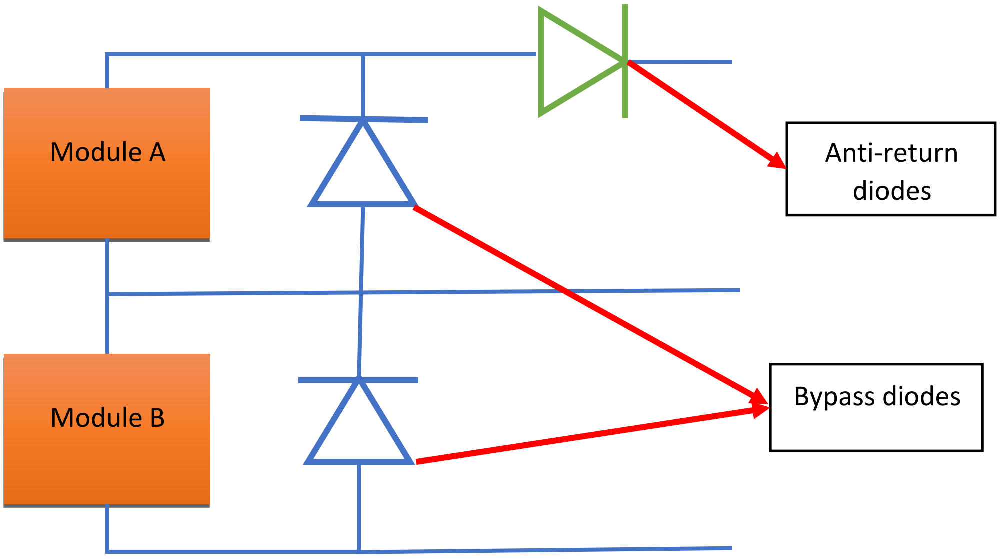


Figure I- 20:Schématisation d'un GPV élémentaire avec diodes by-pass et diode anti-retour.

I.7.1.5.3.1. Bypass diodes:

Bypass Diodes are wired in parallel with individual solar cells or panels, to provide a current path around them in the event that a cell or panel becomes faulty or open-circuited.

This use of bypass diodes allows a series (called a string) of connected cells or panels to continue supplying power at a reduced voltage rather than no power at all.

Bypass diodes are connected in reverse bias between a solar cells (or panel) positive and negative output terminals and has no effect on its output. Ideally there would be one bypass diode for each solar cell, but this can be rather expensive so generally one diode is used per small group of series cells. [15]

I.7.1.5.3.2. Anti-return diodes:

The anti-return diode preventing a negative current in the PVs. This phenomenon can appear when several modules are connected in parallel, or when a load in direct connection can switch from receiver mode to generator mode, for example a battery during the night. [16]

I.7.1.6. Load:

It represents all the functions provided by various devices connected to the photovoltaic system. Given the constraints on the energy efficiency of photovoltaic systems, it is important to define the criteria on which the choice of loads to be used will be based: continuous or alternating load.

I.7.1.7. MPPT command (Maximum Power Point Tracking):

Due to nonlinear behavior of PV system the generated power varies according to the change of ambient temperature and solar irradiance. The highest produced power from PV system at different weather conditions is called a maximum power point (MPP). This happens at maximum voltage and maximum current. To achieve this, an electronic system called maximum power point tracking (MPPT) has been invented and developed. This implies that there is always one optimum terminal voltage for the PV array to operate at each condition as illustrated in Fig I-21, to obtain the maximum power output to enhance the array's efficiency.

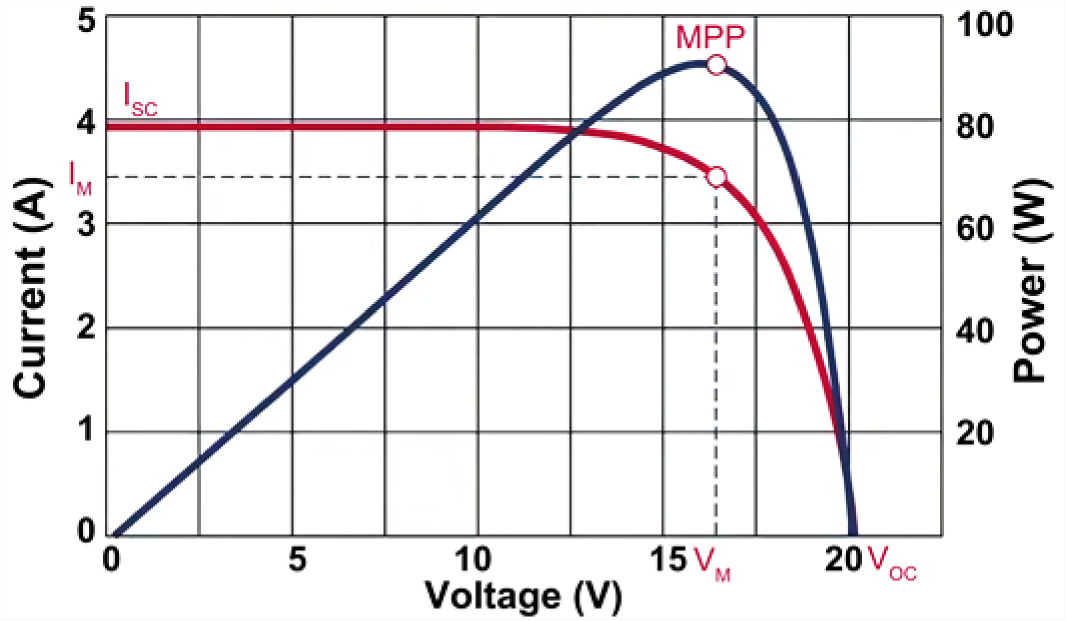


Figure I- 21:PV curve showing Maximum Power Point.

In other words, an MPPT is a complete electronic system that varies the electrical operating point of the modules so that the modules can deliver maximum available power. Any increase in power that is reaped from the modules that increases battery charge current. The basic method of charge controller is called PWM (Pulse Width Modulation). Its operation based on simply connecting the modules directly to the battery. But this technique forces the PV modules to operate at battery voltage, actually it is not the ideal operating voltage at which the modules are able to produce their maximum available power (PPWM<PMPPT). Where PPWM is the extracted power by using PWM controller and PMPPT is the obtained power using MPPT controller.

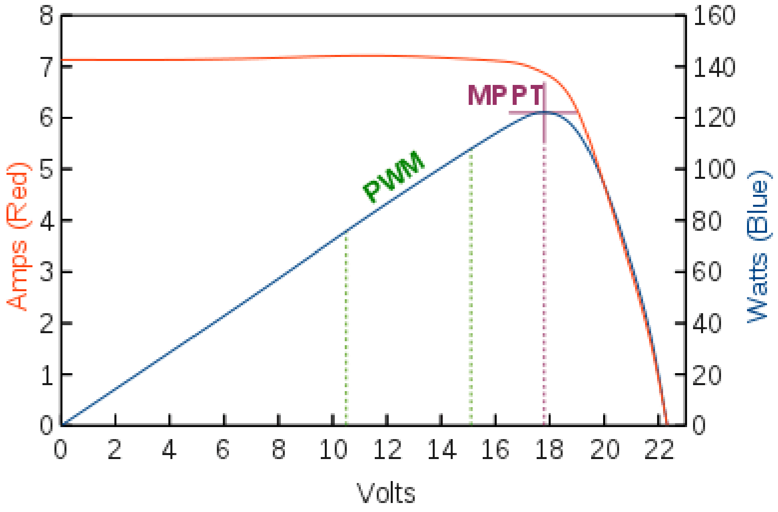


Figure I- 22:The MPPT vs PWM performance.

For instance, as shown in Fig I-20, the classical PWM controller frugally connects the module to the battery and hence forces the module to operate at 12V (Vpwm). By forcing a PV panel of 75W module to operate at 12V (Vpwm) the PWM reduces artificially power production to nearly 53W. This means the PWM decreases the efficiency of PV modules to about 29%. On the other hand, using MPPT system in a solar charge controller can calculate the voltage at which the module is able to produce maximum power (Vmp). Thus, the MPPT can extract the full 75W (+30% power), regardless of present battery voltage as illustrated in Fig I-22 above. [17]

I.7.2. Different types of photovoltaic systems:

There are two large families of photovoltaic installations, the most commonly encountered are:

- Autonomous photovoltaic installations to supply certain applications on site, either with a single photovoltaic energy source, or with an additional energy source, we therefore speak of the hybrid system,
- Photovoltaic installations connected to the network whose electricity produced is injected into the electricity distribution network. [14]

I.7.2.1. Autonomous photovoltaic systems:

A stand-alone photovoltaic system meets the electricity needs of those who are isolated and not connected to the electrical distribution network. This type of system requires the use of an electricity energy storage system to ensure the autonomy of the system.

Fig I-23 details the different configurations of stand-alone photovoltaic systems:

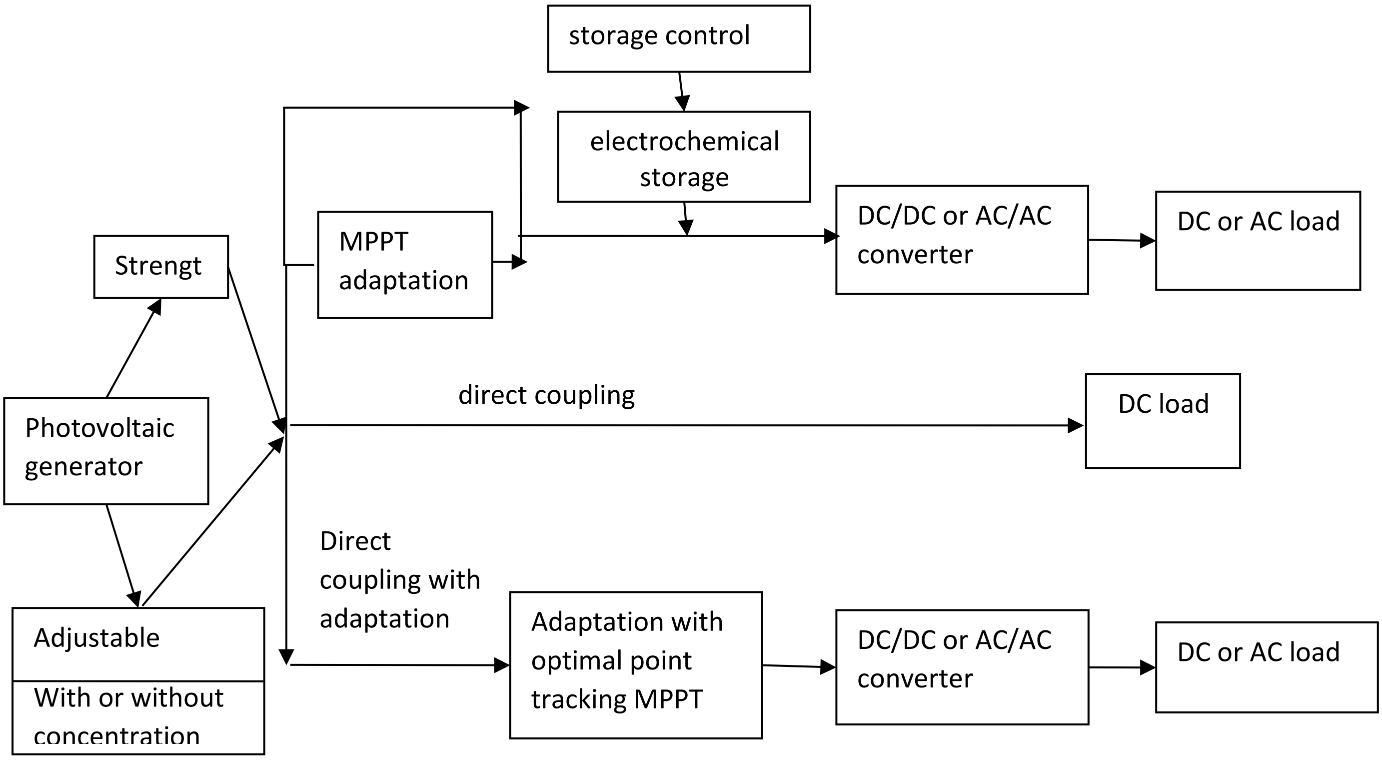


Figure I- 23:The different configurations of stand-alone photovoltaic systems.

From fig I-23, we can distinguish 3 stand-alone photovoltaic system configurations as follows:

I.7.2.2. Hybrid photovoltaic systems:

One of the limits of an autonomous photovoltaic system only, as we have just detailed it, is that it offers a limited and variable power according to the season, which means that we are unable to consume more than we produce. otherwise, the battery will be destroyed by deep discharge. Therefore, consumers have changing needs from time to time, and not necessarily in phase with the seasons.

The new technological solution provided by the hybrid system is to have another autonomous source of electricity which completes the photovoltaic contribution. This other source can be a generator or a wind turbine in particular. We will choose the wind turbine if the site is perfectly windy, rather during the seasons when sunshine is low. But when the reserve in diesel is possible, the generator is more practical (apart from the noise and the effluents), because one uses it as much as one wants and it also makes it possible to recharge the battery when it is weak. [18]

I.7.2.3. Grid-Connected Photovoltaic Systems:

Grid-connected photovoltaic systems allow the decentralization of production on the electricity grid. These installations which are fully coupled to the electrical network into which they inject the electricity they produce via a DC-AC power converter. The huge advantage of these installations is that the network plays the role of unlimited storage, and therefore all the energy is recovered. [14]

There are two types of installations for the injection of solar energy production into the electricity network:

> **Injection of the entire production:** The energy produced by the photovoltaic generator is directly injected into the electrical network. The grid injection periods coincide with the photovoltaic production periods.
>
> **Injection of production surplus**: The energy produced by the photovoltaic generator is consumed directly by the loads, the production energy surplus compared to the instantaneous consumption is injected into the local distribution network.

I.8.Faults in a photovoltaic system:

Faults in photovoltaic (PV) systems, which can result in energy loss, system shutdown or even serious safety breaches. Generally, a PV system can be affected by different types of faults that can result in significant loss of power in a PV system. According to the fault duration, two types of faults can be distinguished: temporary and permanent faults. Temporary faults, such as shading, disappear after a certain period of time or after being manually cleared in cases of dust, leaves or bird dropping. The PV system then returns to its normal operating conditions. On the other hand, permanent faults, including short circuits and open circuits are persistent or ongoing. [19]

I.8.1. Electrical Faults in PV Arrays:

The table I-2 below gives a classification and definition of some faults in PV array on the DC and AC side, based on location and structures. [20]

Table I- 2:Classification and definition of faults in PV system:

PART	FAULT	DESCRIPTION
DC	Partial shading	Presence of trees, overhead power lines, or nearby buildings
	Uniform irradiance distribution	Various irradiance intensity during the day
	Soiling	The bird droppings and dirt on the surface of a PV module
	Snow covering and hot spot	The worst temperatures depending on the geographical location and different weather conditions
	Ground fault	An unintentional path to ground with zero fault impedance occurs between two modules at PV string
	Line-to-line faults	An accidental short-circuits between two points in a string with different potentials
	Bypass diode faults	Short-circuit in case of incorrect connection
	Degradation faults	Yellowing and browning, delamination, bubbles in the solar module, cracks in cells, defects in antireflective coating and delamination over cells and interconnections lead to degradation and increasing of the internal series resistance
	Open-circuit fault	Physical breakdown of panel-panel cables or joints, objects falling on PV panels, and loose termination of cables, plugging and unplugging connectors at junction boxes
	MPPT faults	Problem in MPPT charge controllers
AC	Inverter faults	Failure of each component of inverter such as IGBTs, capacitors, and drive circuitry can result in inverter failure
	Sudden natural disasters	Total blackout due to Lightning, storm, and so forth

I.8.2. Environmental disturbance factors:

Some environment factors that effects directly or indirectly on the PV system are illustrated in the table I-3 down below. [21]

Table I- 3:environmental disturbance factor:

Environmental disturbance factors	**Its effect**
Temperature	Photochemical degradation or delamination of the encapsulant is influenced by the operating temperature of the module.
Humidity	It is a determining stress factor in the mechanisms of corrosion and deamination.
Radiation	Irradiation which can damage the polymers encapsulating cells. they are also a harmful role insofar as, if they are not converted by the cell, they are absorbed by the other elements of the module, which has the effect of increasing its temperature.
The wind	The small vibrations and tearing of the system induced by wind are important in the long term (braking weak modules).
Dust	An accumulation of dust will reduce the power produced by the module. sand is also harmful, especially when it combines with the wind to form abrasive sandstorms that can damage the front faces of the modules.

I.9.Advantages and disadvantages of photovoltaic energy:

Photovoltaic systems offer many advantages while having some disadvantages.

I.9.1Benefits:

- The high reliability.
- Its unlimited potential.
- 5% of the surface of deserts would be enough to feed the entire planet.
- the modular character of the photovoltaic panels allows a simple and adaptable installation to various energy needs.
- Photovoltaic technology has ecological qualities because the finished product is non-polluting, silent and does not disturb the environment.
- The use of solar energy avoids the use of fossil or nuclear energy to produce the same amount of electricity and thus reduces greenhouse gas emissions or the production of nuclear waste. [22]

I.9.2. Disadvantages:

- The manufacture of the photovoltaic module is high-tech and requires high-cost investments.
- The actual conversion efficiency of a module is low (the theoretical limit for a crystalline silicon cell is 28%).

- Many devices sold in the market run at 220 to 230 V alternative. However, the energy from the PV generator is unidirectional and low voltage (<30V), so it must be transformed through an inverter.
- When the storage of electrical energy in chemical form (battery) is necessary, the cost of the photovoltaic generator is increased. The reliability and performance of the system, however, remain the same as long as the battery and associated regulation components are carefully selected.
- Power is reduced when weather conditions are unfavorable (clouds). [22]

I.10. Conclusion:

In this chapter, we cover the fundamentals of how photovoltaic cells convert solar energy into electrical energy, the main characteristics and construction methods of a photovoltaic generator, the various photovoltaic system configurations and their applications, as well as some of the various faults that can affect photovoltaic systems as a whole. The modeling of a solar generator with a dc/dc converter and fuzzy logic controller-based MPPT will be covered in the following chapter. The impact of specific parameters on its properties is the next step.

Modelization of a photovoltaic system

II.1. Introduction:

This study aims to develop a mathematical model of a photovoltaic system (PV) and incorporate it into a renewable energy production chain. The open-circuit voltage, short-circuit current, and voltage and current corresponding to the maximum power point are the nominal values published by the manufacturer on which this model is based. With the model thusly generated, it is possible to better account for the impact of the climatic factors, including temperature, radiation. After providing a general overview of the PV system, the chapter clarifies the specifics of the modeling of solar panels. In addition, the study of how voltage-current and voltage-power properties change with temperature and light exposure.

II.2. The structure of the photovoltaic energy conversion chain:

Our solar conversion chain consists of a PV generator, a DC/DC converter (Boost chopper), and a fuzzy logic controller for tracking the maximum power point. Providing a load is this system. The following figure1 depicts the structure of our photovoltaic conversion chain.

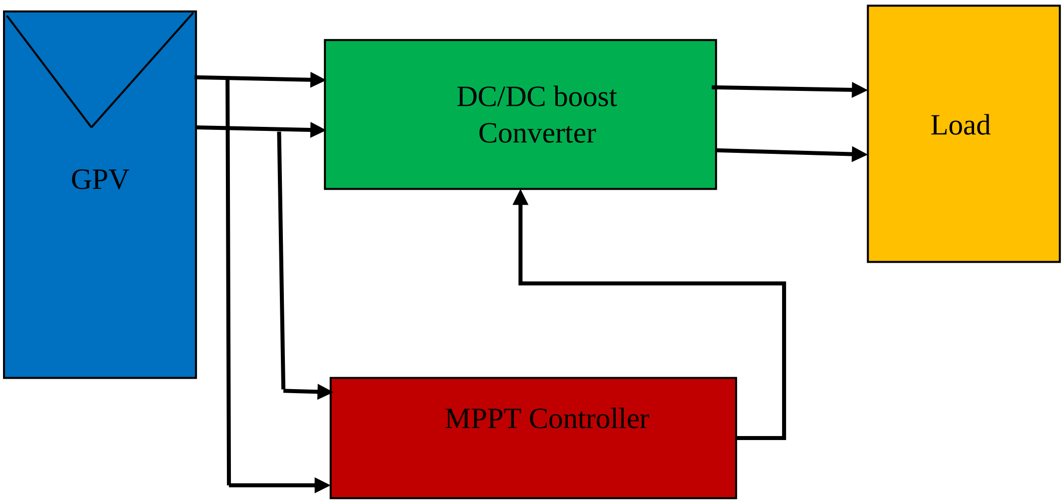


Figure II- 1:The structure of the photovoltaic energy conversion chain.

II.3. Modeling of a PV system under MATLAB/Simulink:

The following illustrates a PV system's synoptic diagram for supplying a resistive load (RS):

- The PV generator is composed of polycrystalline silicon.
- A booster-type energy converter is used for situations that call for greater voltages.
- The MPPT command, which bases itself on automatically varying duty cycle D to the proper value in order to continuously set the ideal voltage at the PV generator's output.

II.3.1. Modeling and simulation of the PV cell:

A p-n semiconductor junction is essentially what makes up a solar cell. Direct current is produced when exposed to light. This document uses the single-diode model shown in the illustration for simplicity. With its fundamental structure, this model provides a solid balance between ease of use and accuracy. The photocurrent (**I_{ph}**), diode, shunt resistance (**R_{sh}**), which expresses leakage current, and series resistance (**R_s**), which results from contacts between semiconductors and metal components, make up the analogous circuit of the general model.

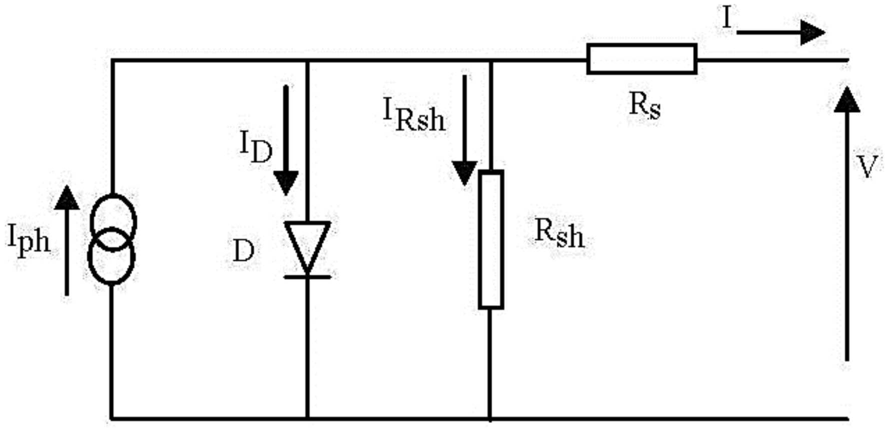


Figure II- 2:Equivalent model of a PV cell.

1.Photovoltaic generator:

Kirchhoff's law will be used to determine the current in Fig II-2 using the following equation:

$$I = I_{ph} - I_d - I_{sh} \qquad \textit{Eq II- 1}$$

With:

- I: Electricity generated by the photovoltaic cell
- I_{ph}: Current photo created by the photovoltaic cell
- I_d: the diode current which is proportional to the saturation current, it is given by the following equation

$$I_d = I_s \left[exp\left(\frac{q(V_{oc}+R_S.I_{rs})}{n\,K\,N_s\,T}\right) - 1\right] \qquad \textit{Eq II- 2}$$

- I_{sh}: current flowing through the shunt resistor, is given by the following equation:

$$I_{sh} = \left[\frac{V_{oc}+IR_S}{I_{sh}}\right] \qquad \textit{Eq II-3}$$

With:

- R_{sh}: shunt resistance (415.405 Ω)
- R_S: is a series resistance (Ω)
- T: operating temperature (k)
- N_S: number of cells connected on series (54 cell)
- I_S: is the saturation current in amperes (A)

- q: electron charge (1.6×10^{-19} C)
- k: Boltzmann constant (1.38×10^{-23} J/K)
- n: is the ideal factor which depends on the PV technology and is listed in Table II-1.
- V_{oc}: the open-circuit voltage.

Table II- 1:factor n dependence on PV technology:

TECHNOLOY	N
SI-mono	1.2
SI-poly	1.3
a-SI:H	1.8

The characteristic voltage-current equation of a solar cell is stated as follows. We substitute *Eq II*-2 and II-3 in Eq II-1.

$$I = I_{ph} - I_S\left[exp\left(\frac{q(V_{Oc}+R_S.I_{rs})}{n\,K\,N_s\,T}\right)-1\right]-\left[\frac{V_{Oc}+IR_S}{R_{sh}}\right] \qquad \textit{Eq II-4}$$

The following equation, which describes how the photo current is mostly influenced by insolation and cell operating temperature:

$$I_{ph} = [I_{sc} + K_i(T - T_n)]\,\frac{G}{G_{ref}} \qquad \textit{Eq II-5}$$

- I_{sc}: is the short-circuit current of the cell at 25°C and 1000W/m^2,
- K_i: the temperature coefficient of the short-circuit current of the cell,
- T_n: is the reference temperature of the cell, in Kelvin (K) (= 25°C + 273),
- G: is the sunshine in watt/square meter (W/m^2),
- G_{ref}: is the reference insolation of the cell (= 1000W/m^2),

On the other side, the cell saturation current is stated as changing with the cell temperature as

$$I_s = I_{rs}\left(\frac{T}{T_n}\right)^3\ exp\left[\frac{qE_{go}\left(\frac{1}{T_n}-\frac{1}{T}\right)}{n\,K}\right] \qquad \textit{Eq II-6}$$

With:

- I_{rs}: the reverse saturation current of the cell at a reference temperature and solar radiation
- E_{go}: is the gap energy of the semiconductor used in the cell in electrovolt (1.1eV).
  The reverse saturation current is given by the following equation:

$$I_{rs} = \frac{I_{sc}}{exp\left(\frac{q\,V_{oc}}{n\,N_s\,KT}\right)-1} \qquad \textit{Eq II-7}$$

The electrical parameters of the PV module, which is being utilized as the simulation reference module, are displayed in Table II-2:

Table II- 2:reference table:

K_i	0.0032	R_{sh}	415.405Ω
Q	1.6e-19 C	T_n	298 k
K	1.38e-23 J/K	V_{oc}	32.9 V
N	1.3	I_{sc}	8.21 A
E_{go}	1.1 e. V	N_s	54 Cell
R_s	221Ω	t_s	1e-6 s

II.3.2. MATLAB /Simulink simulation according mathematical models:

The mathematical equations already represented in the modulation phase will be followed by the GPV simulation, and each equation will be expressed in a subsystem to make the GPV appear more logical and understandable.

Fig II-3 displays Subsystem 1. These are the inputs this model requires:

(G/1000) Insolation/Irradiation 1 kW/ m^2 = 1.

T = 25°C is the working temperature for modules.

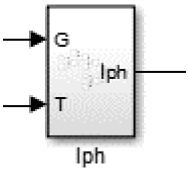


Figure II- 3:Subsystem 1.

Eq II-5 is used in this model to determine the short circuit current (ISC) at a specified operating temperature. The circuit for subsystem 1 is shown in Fig II-4.

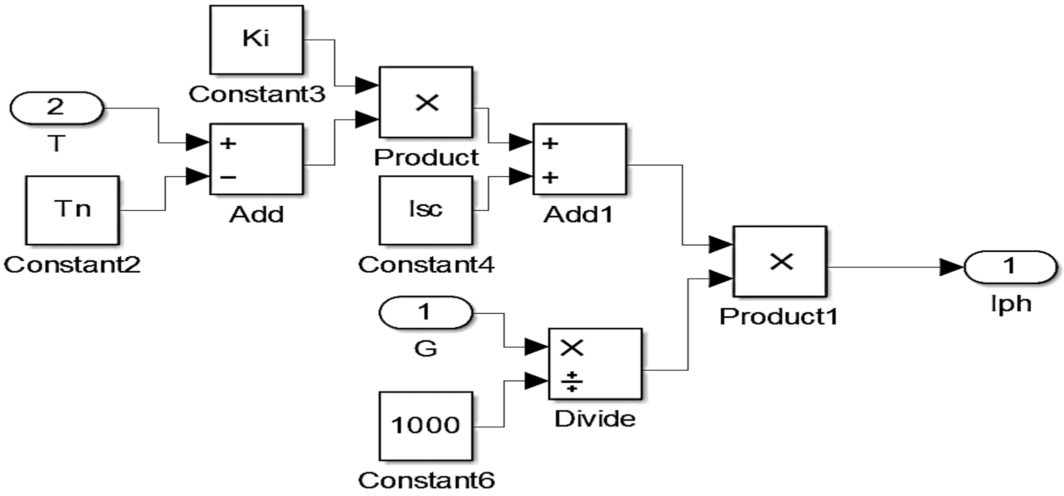


Figure II- 4:Under subsystem1.

Fig II-5 displays Subsystem 2, which is based on the Module operating temperature T.

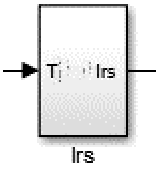


Figure II- 5: subsystem 2.

Eq II-7 is used to compute the diode's reverse saturation current in subsystem 2. The circuit for subsystem 2 is shown in Fig II-6.

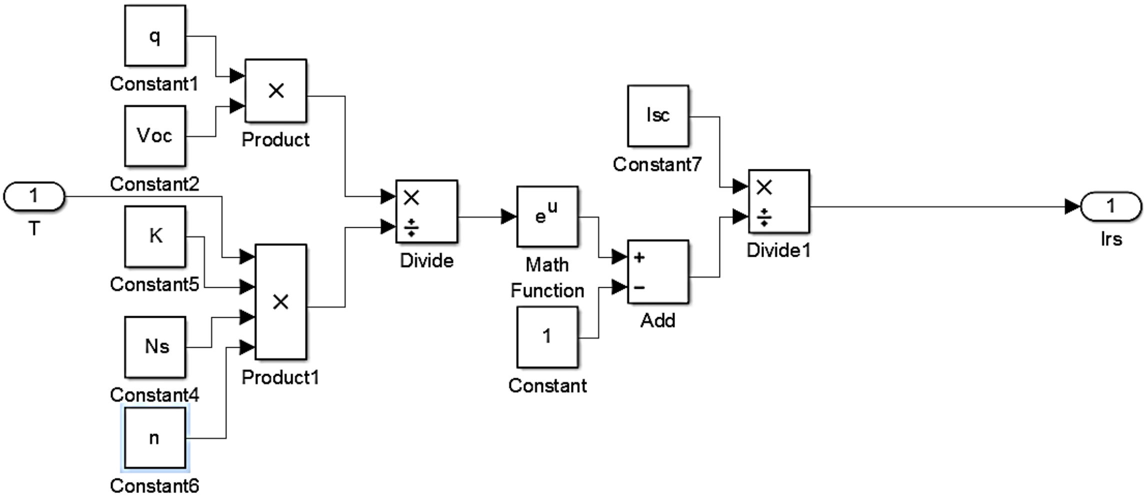


Figure II- 6:Under subsystem 2.

Subsystem 3 is shown in fig II-7

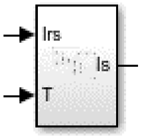


Figure II- 7: Subsystem 3.

Eq II-6 is used in this model to determine the module saturation current from the inputs of reverse saturation current (I_{rs}) and module operating temperature (T). The circuit for subsystem 3 is shown in Fig II-8.

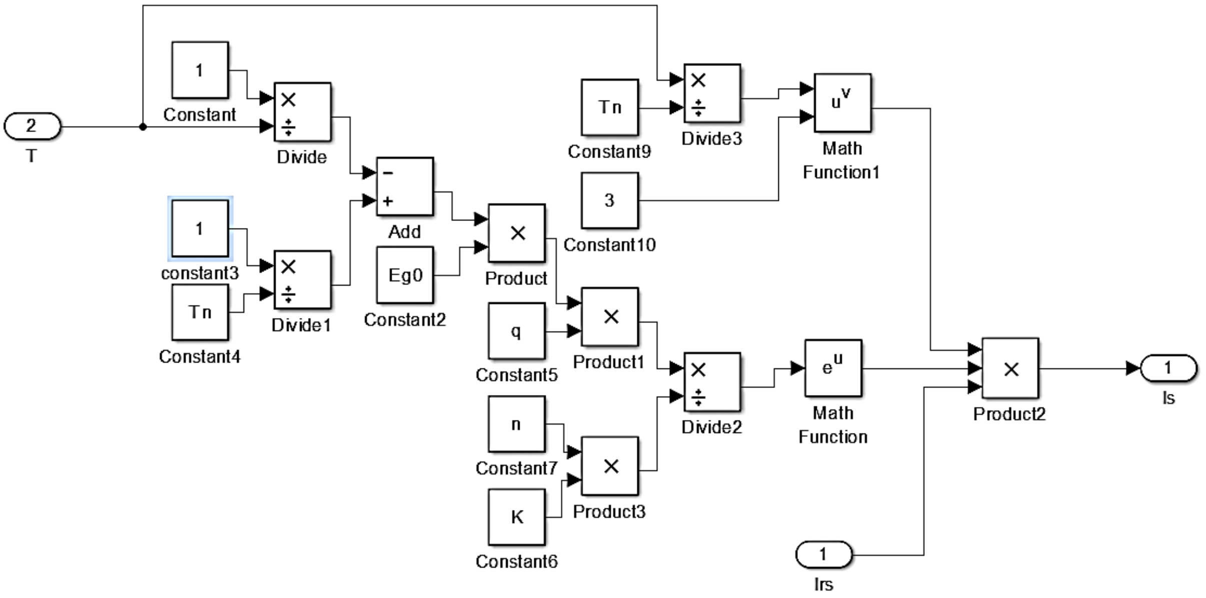


Figure II- 8:Under subsystem 3.

Subsystem 4 is shown in Fig II-9.

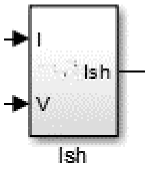


Figure II- 9: Under subsystem 4.

This model, which is showed in Fig II-10, performs out the function described by Eq II-3 to compute the current through the shunt resistance.

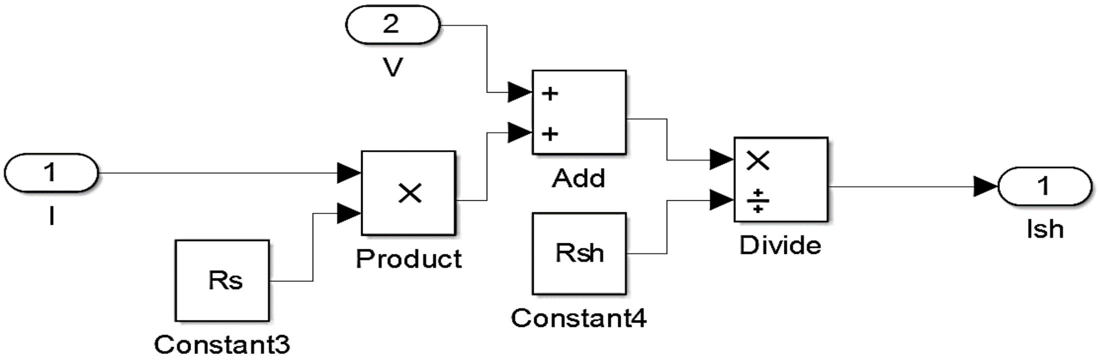


Figure II- 10:Under subsystem 4.

The function specified by Eq II-4 is given out by subsystem 5.

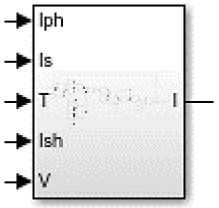


Figure II- 11:Subsystem 5.

This model uses the operating temperature, the open-circuit voltage, the photo current, the shunt current, the saturation current, and the running shunt current as inputs to determine the output current of the PV cell. Eq II-4

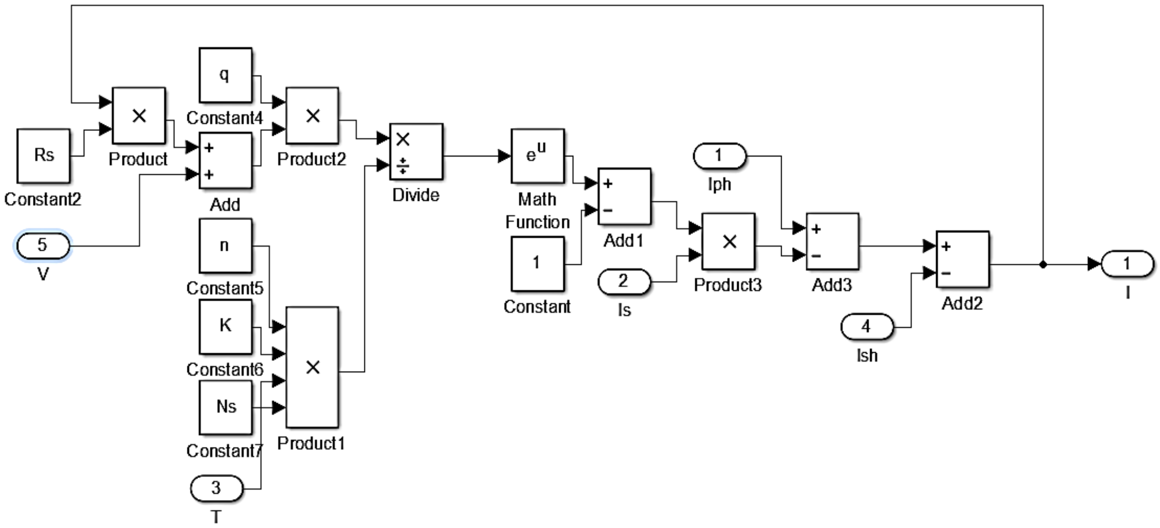


Figure II- 12:Under subsystem 5.

To represent the final result of the GPV module, all five of the previous methods are now connected as shown in Fig II-13:

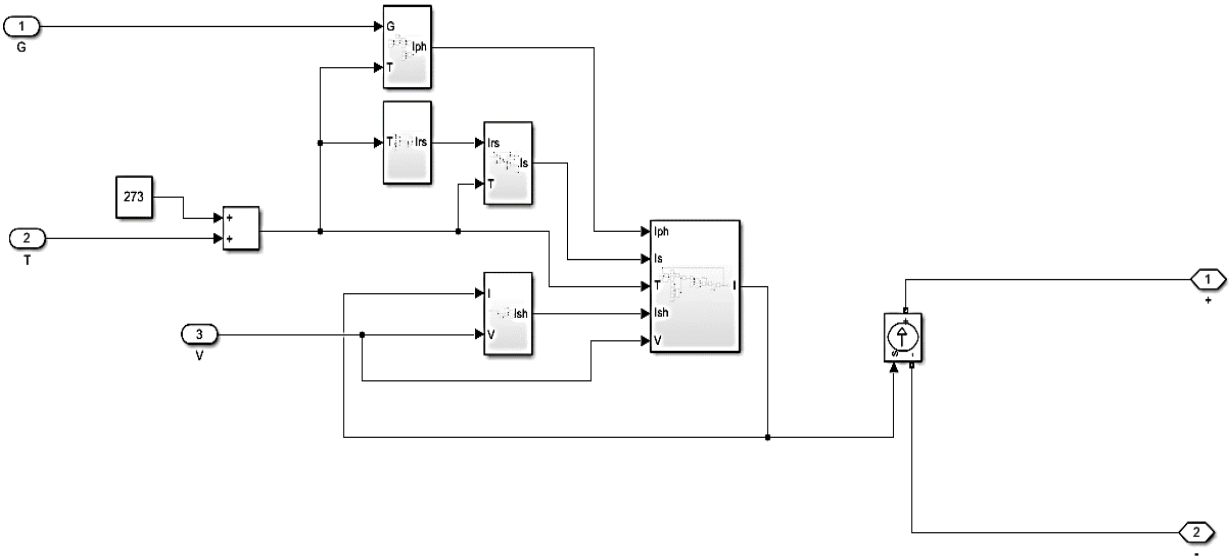


Figure II- 13:GPV Module.

II.3.3. Modeling of the boost converter:

Step-up converter and boost converter are synonyms. Typically, it is employed to convert a low input voltage to a high output voltage.

Its components include a DC input voltage source (GPV) called Vin, an inductance L, an IGBT transistor, a diode D, two capacitors C1 and C2, and a load R. Where f_s = 25 KHZ is the converter's switching frequency, V_{out} is the DC output voltage, D is the duty cycle, and I_{out} is the output current. Taking into account that the maximum peak to peak ripples for input and output voltage (V) are 2 % and for input and output current (I) are 40 %.

The proposed boost converter's circuit diagram is shown in Fig II-14.

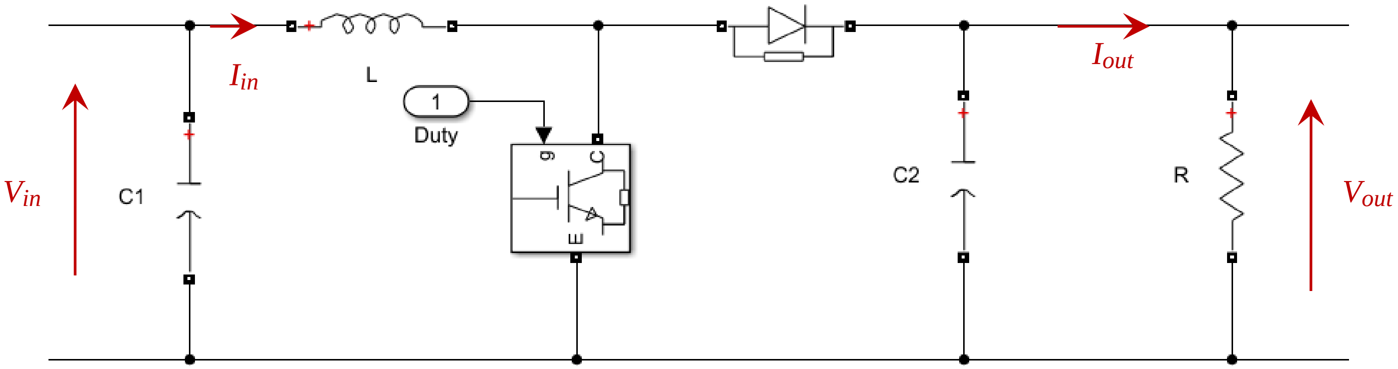


Figure II- 14:boost converter circuit..

We take from the curve the values of V_{mp}, I_{mp}, and P_{mp} that match to the radiation value we previously obtained for G=1000 W/m2 and T=25 C°:

V_{mp1}= 26V
I_{mp1}= 7.6 A
P_{mp1}= 200 W

We take from the curve the values of V_{mp}, I_{mp}, and P_{mp} that match to the radiation value we previously obtained for G=50 W/m2 and T=25 C°:

V_{mp2}= 22.1 V
I_{mp2}= 0.33 A
P_{mp2}= 7.4 W

For that, we determine:

$$R_{mp} = \frac{V_{mp}}{I_{mp}} \qquad \textit{Eq II-7}$$

$$R_0 = 2.5 \cdot R_{mp} \qquad \textit{Eq II-8}$$

$$D_{m_P} = 1 - \sqrt{\frac{R_{m_P}}{R_0}} \qquad \textit{Eq II-9}$$

$$V_{out} = \frac{V_{in}}{1-D} \qquad \textit{Eq II-10}$$

$$\Delta V_{out} = 0.04 \cdot I_{out} \qquad \textit{Eq II-11}$$

$$\Delta V_{in} = 0.002 \cdot V_{in} \qquad \textit{Eq II-12}$$

$$\Delta V_{0ut} = 0.002 \cdot V_{out} \qquad \textit{Eq II-13}$$

$$R_{in} = R_{out} \cdot \left(1 - D_{mp}^2\right) \qquad \textit{Eq II-14}$$

We can determine the capacitors C1 and C2 as well as the inductance L using the preceding equations:

$$C_1 = \frac{4 \cdot V_{mp} \cdot D_{mp}}{\Delta V_{in} \cdot R_{in} \cdot f_s} \qquad \text{Eq II-15}$$

$$C_2 = \frac{2 \cdot V_{out} \cdot D_{mp}}{\Delta V_{out} \cdot R_{out} \cdot f_s} \qquad \text{Eq II-16}$$

$$L = \frac{V_{mp} \cdot D_{mp}}{\Delta I_{out} \cdot 2 \cdot f_s} \qquad \text{Eq II-17}$$

The boost converter's Valeur settings are **C1 = 150 µF**, **C2 = 200 µF**, and **L = 0.2 mH.**

II.3.4. Fuzzy Logique MPPT Controller :

Fuzzy logic controllers have recently been used in PV systems to track the MPP. Since they don't need to know the precise model, they have the advantage of being reliable and relatively easy to create. On the other hand, they do necessitate that the designer has thorough knowledge of how the PV system works.

The suggested system in this thesis consists of one output variable, duty ratio or duty cycle (D), two input variables, error (E) and change of error (CE), and two input variables, E and CE.

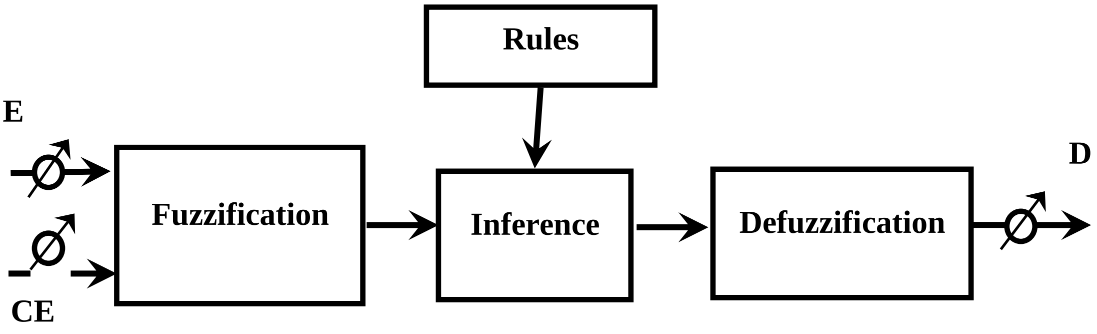
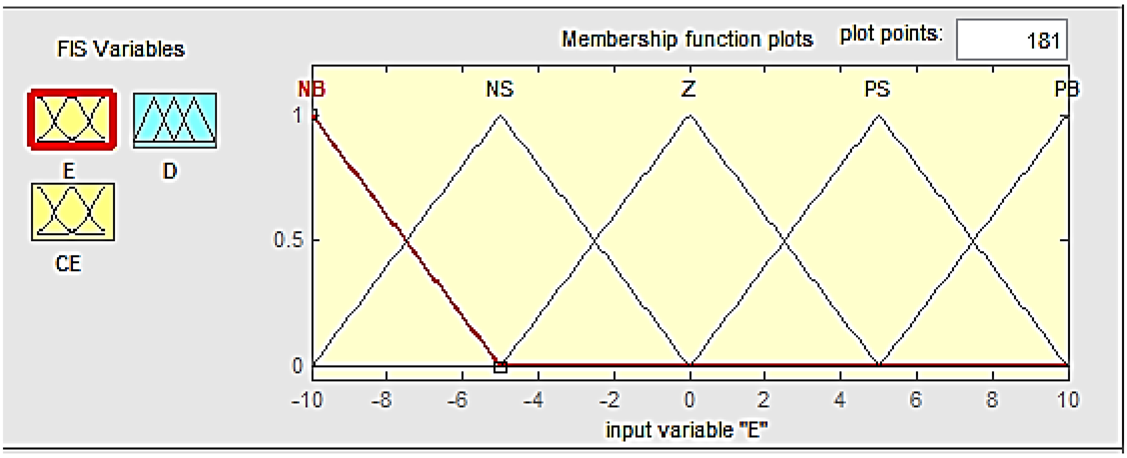


Figure II- 15:Genaral diagram of a fuzzy controller.

A) Fuzzification:

Five fuzzy subsets are used to assign membership function values to the linguistic variables: NB (negative big), NS (negative small), ZE (zero), PS (positive small), and PB (positive big). Fig II-16 and II-17 explain how fuzzy subsets are divided and how membership functions can be tailored to fit a system.



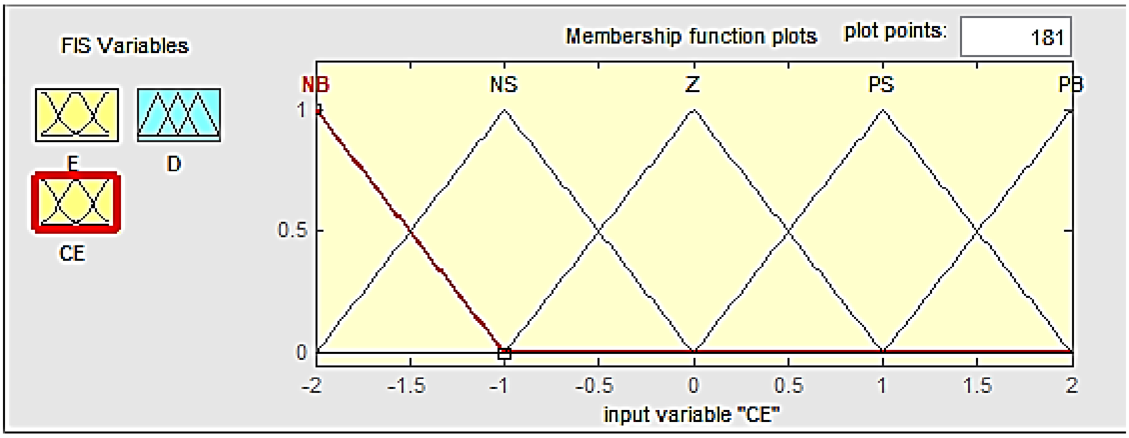


Figure II- 16:Membership function for input (E, CE).

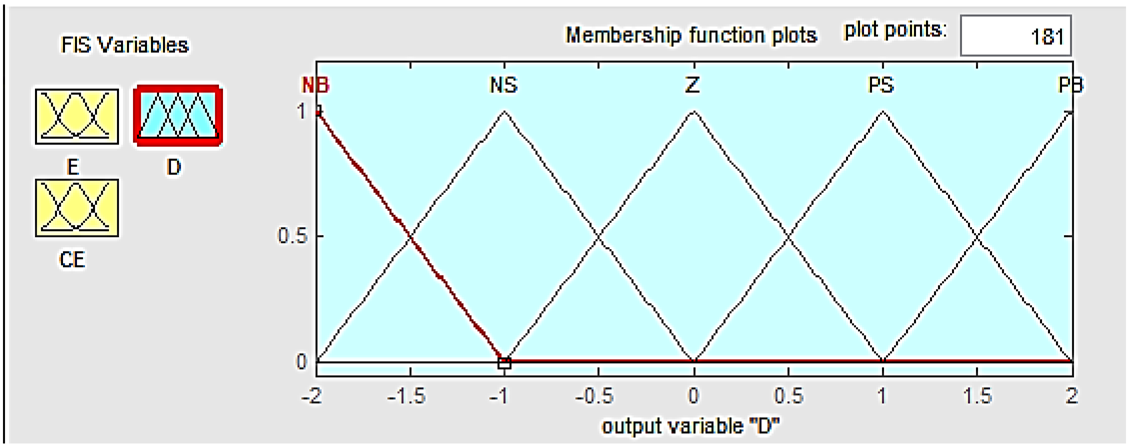


Figure II- 17:Membership function for output D.

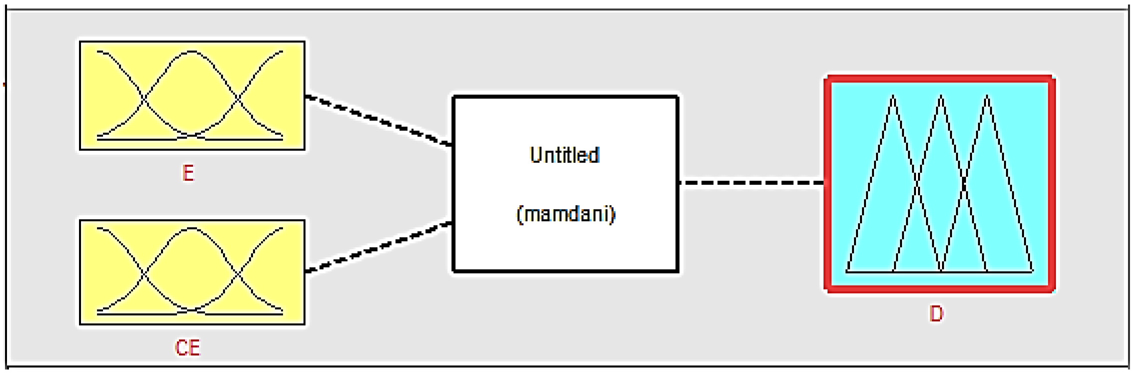


Figure II- 18:The structure of the fuzzy controller.

An input scaling factor is used to standardize the values of input error (E) and change of error (CE). The input scaling factor in this system has been created so that input values fall between -2 and 2.

There is only one dominant fuzzy subset for each given input, according to the arrangement's triangle membership function. Depending on the needed accuracy, the number of fuzzy subsets is decided; some papers use five subsets for the same problem, but the accuracy improvement is just marginal.

The fuzzy logic controller's input variables error (E) and change of error (CE) can be calculated as follows:

$$E(K) = \frac{P(K)-P(K-1)}{V(K)-V(K-1)} \qquad \textit{Eq II-18}$$

$$CE(K) = E(K) - E(K-1) \qquad \textit{Eq II-19}$$

Where:

P(k) and V(k) are the instant power and voltage respectively of the PV generator.

B) Inference Method:

the composing process that can produce a control output. The fuzzy tool box in MATLAB has proposed a number of composition approaches, including MAX-MIN and MAX-DOT. This thesis employs the MAX-MIN approach, which is frequently utilized. The MIN (minimum) and MAX (maximum) operators provide the output membership function for each rule.

The fuzzy logic controller's rule table is displayed in Table II-3 [23].

Table II- 3:Fuzzy rule table.

CE \ E	NB	NS	Z	PS	PB
NB	NB	NB	NS	NS	Z
NS	NB	NS	NS	Z	PS
Z	NS	NS	Z	PS	PS
PS	NS	Z	PS	PS	PB
PB	Z	PS	PS	PB	PB

c) Defuzzification:

The system's defuzzification uses the system's center of gravity to calculate the duty ratio, which is the output of this FLC (cycle). The center of gravity approach is incredibly quick and easy to use. The formal specification of the center of gravity defuzzification algorithm in a set of rules is generated by:

$$D = \frac{\sum_{j=1}^{n} \mu(Dj) - Dj}{\sum_{j=1}^{n} \mu(Dj)} \qquad \text{Eq II-20}$$

Duty ratio, a product of fuzzy logic control, is managed by PWM, which creates a pulse to manage the IGBT switch in the DC-DC converter.

D) Fuzzy Logic Control Simulation in MATLAB/SIMULINK:

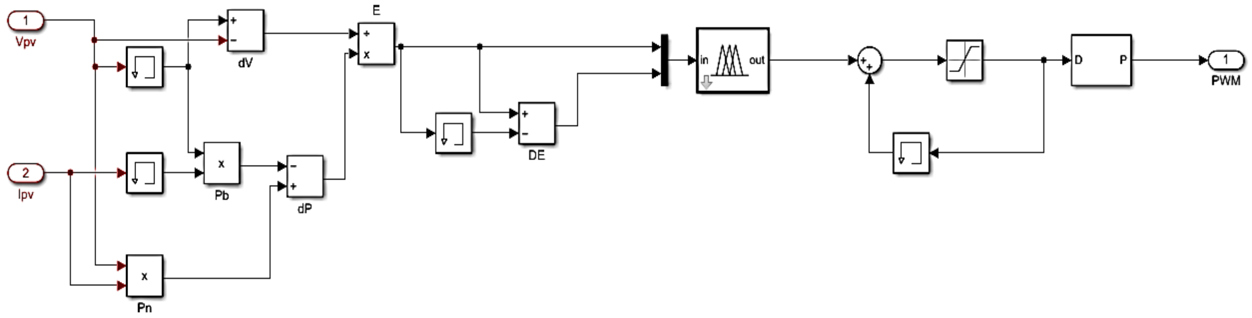


Figure II- 19 :FLC BLOCK.

Fig II-19 depicts the FLC block in MATLAB/SIMULINK in detail. The FLC for MPPT has one out variable and two input variables, as I explained at the beginning of this section. The input variables in the displayed block are first calculated using Eq II-18 and Eq II-19, and then the duty cycle pulse width modulator input that controls the DC–DC converter to produce the required output voltage and current is calculated using the FLC block, which was programmed as mentioned in earlier sections.

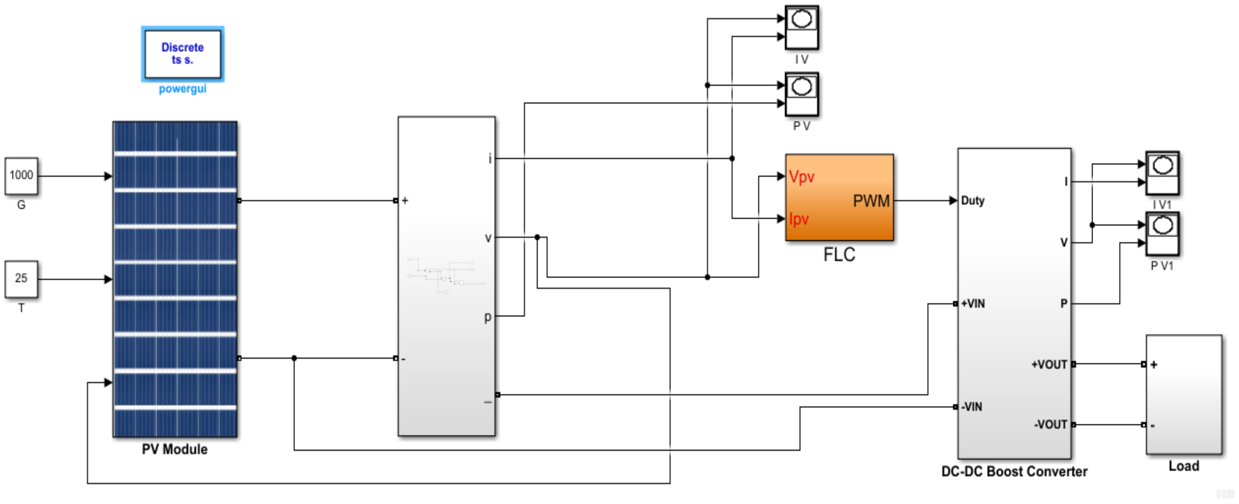


Figure II- 20:PV system.

II.4. Influences on GPV:

The characteristic of a PV cell (or PV generator) is directly dependent on illumination and temperature.

II.4.1. Influence of the temperature:

The behavior of solar cells is greatly influenced by temperature. A PV generator's properties are also influenced by temperature.

With a 25°C pitch, the ambient temperature (T) ranges from 0°C to 100°C.
Figure 21 with an irradiation (G=1000 W/m2) illustrates the impact of this on the characteristic of PV.

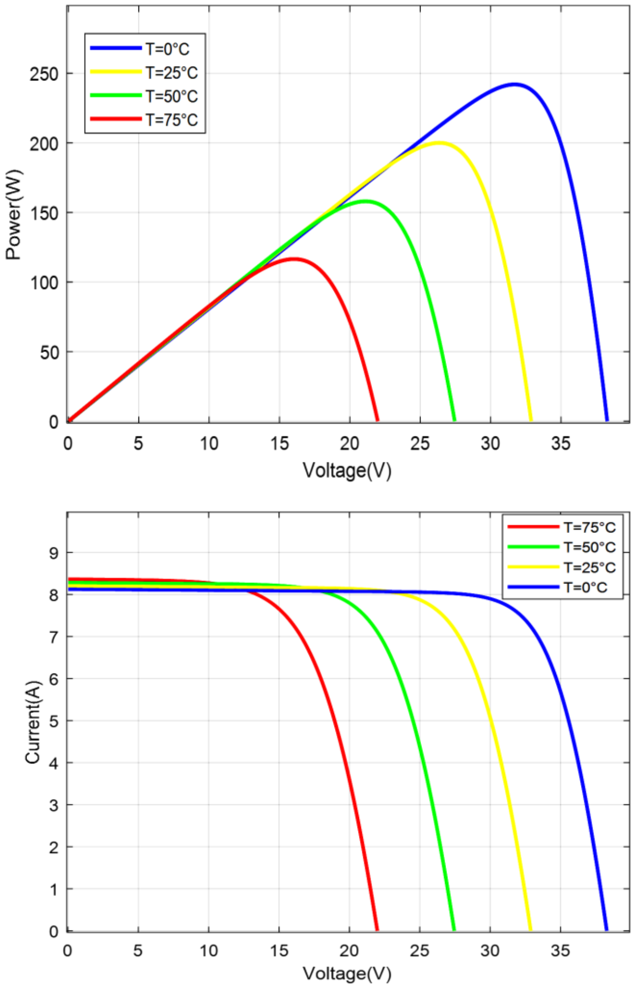


Figure II- 21:characteristic I-V, P-V of a solar panel for different temperatures with constant illumination equal to 1000 w/m2.

We note that the open circuit voltage is negatively impacted by temperature (The higher the temperature the lower V_{oc} and the I_{sc} short circuit current increases with the temperature). Additionally, as the temperature rises, the generator's maximum power will drop.

II.4.2. Influence of illumination:

The characteristics are provided by the fig II-22 by adjusting the illumination (G) in steps of 250 between 250 and 1000. The short circuit current I_{sc} varies proportionally with the irradiation at constant temperature of 25°C, where there are variations in current and power as a function of voltage. At the same time, the maximum power falls as irradiation increases while the open circuit voltage V_{oc} varies relatively little.

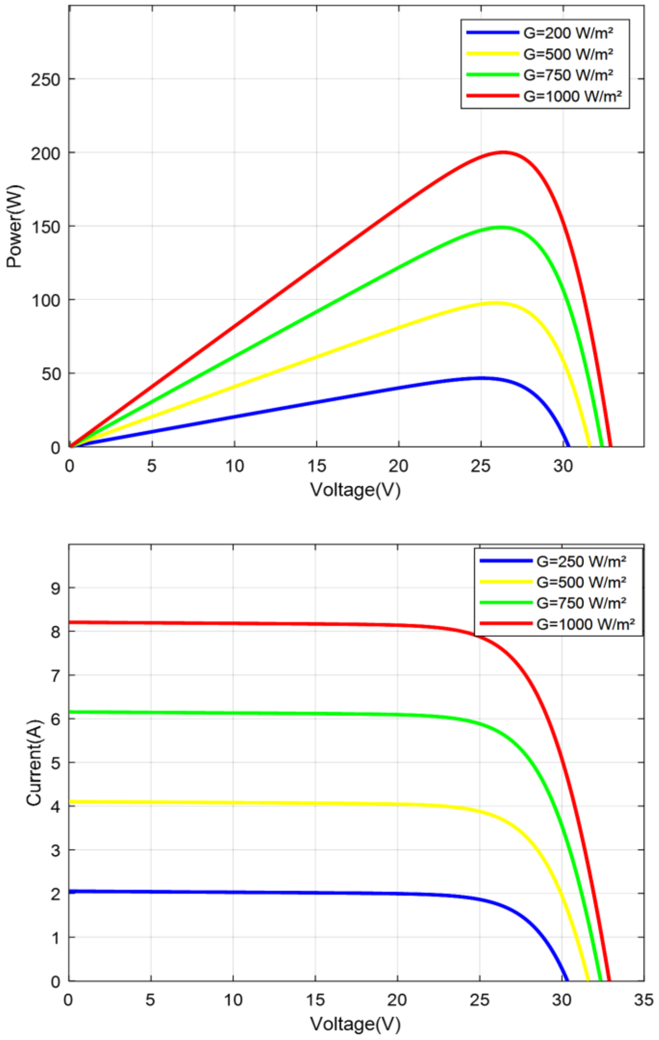


Figure II- 22:characteristic P-V, I-V of a solar panel for different solar illuminations at a constant temperature of 25°C.

II.5. Conclusion:

The mathematical model of a photovoltaic panel has been created in this chapter using the mathematical model of an illuminated cell. The simulation results demonstrate that weather factors, particularly solar and temperature, have a significant impact on a PV panel's performance. We used MATLAB Simulink to analyze the photovoltaic generators (GPV) and their various potential groupings. Additionally, we looked at a particular DC-DC converter utilized in photovoltaic systems called a boost chopper and provided an MPPT control for the photovoltaic generator using fuzzy logic. in the next chapter we compare the simulation results in the presence of faults, whether it was summer or winter.

Result and comments of faults in PV array

III.1. Introduction:

In this chapter, some PV array faults will be discussed and emulated to examine how they effect on the GPV characteristics, without connecting GPV to a converter and in the presence of a boost chopper under various environmental conditions, and also the mention of the shunt and serial resistance increase faults due to the aging of solar panels.

III.2. PV array:

To realize this study, we made at first a simple PV array by connecting two strings, each string contains two modules together, this array will represent our GPV, then the GPV is connected to an elevator converter with MPPT fuzzy logic controller and then directly to the load as shown in figure1.

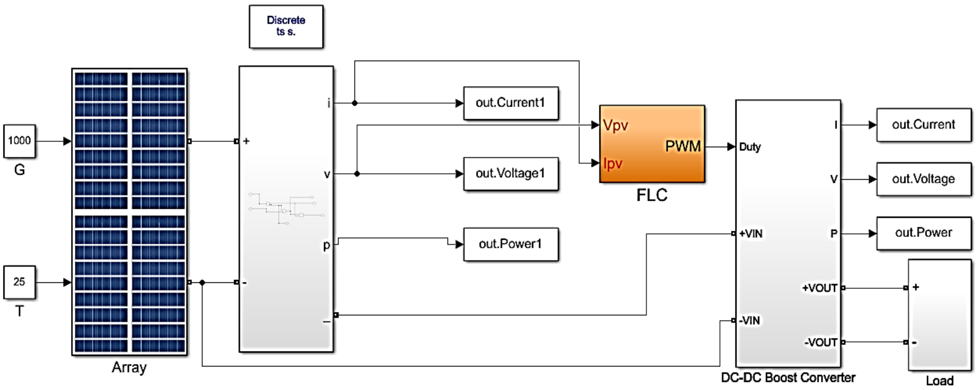


Figure III- 1: PV array

We'll use this PV array as a reference going forward and start introducing defects in its replica. As represented in fig III-2.

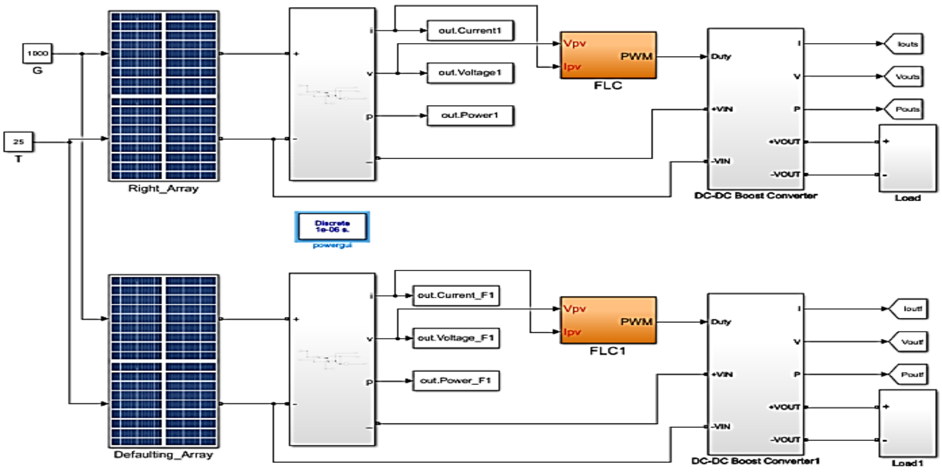


Figure III- 2:Comparing PV arrays.

III.3. Fault simulation:

The simulation results of a PV field with a fault will be presented in this section for both winter (day G=800W/m2 T=14°C and night G=20W/m2 T=0°C) and summer (day G=1200W/m2 T=45°C and night G=20W/m2 T=18°C). we varied irradiation to introduce day /night, and temperature to introduce the season variation.

III.3.1Short circuit failure (F1):

The fig III-3 shows the short-circuit fault emulated by short-circuiting a cell of a PV array module, then results were taken as percentages that represents the rate of loss of the power in the failed array by comparing its results with the reference one.

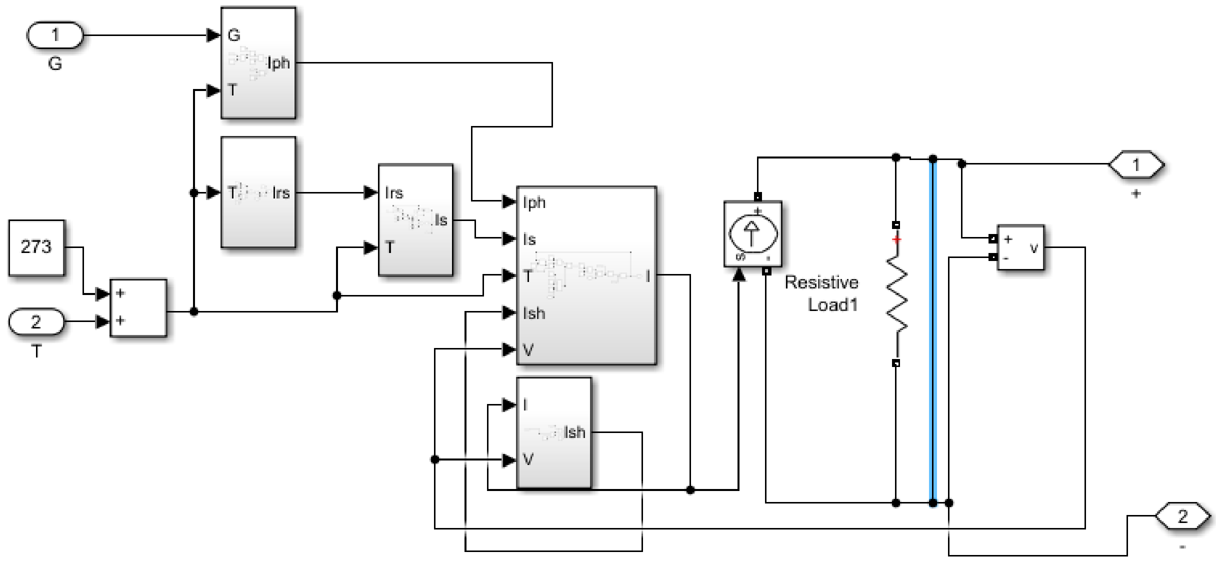
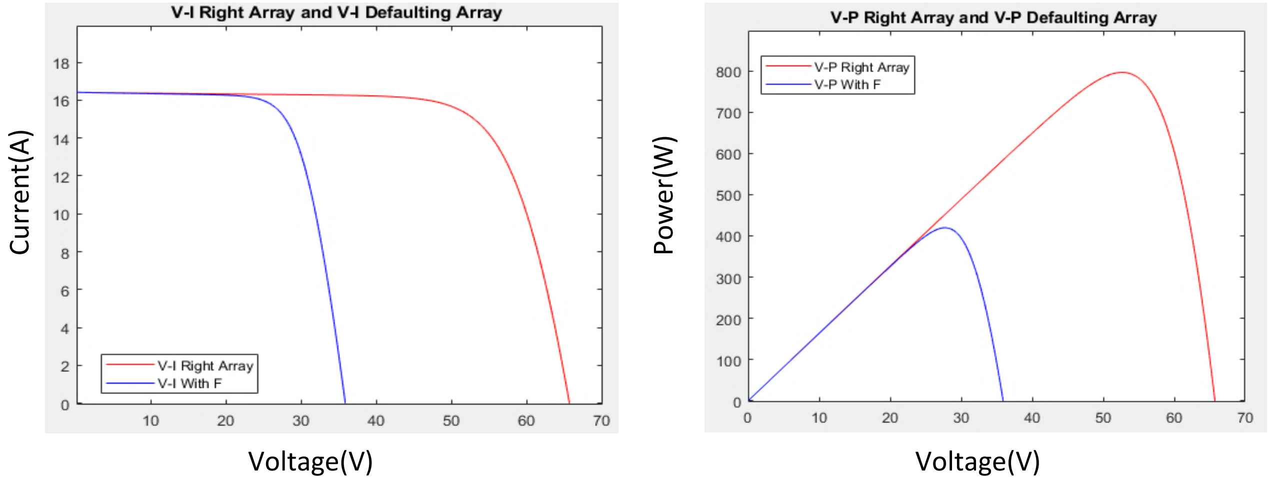


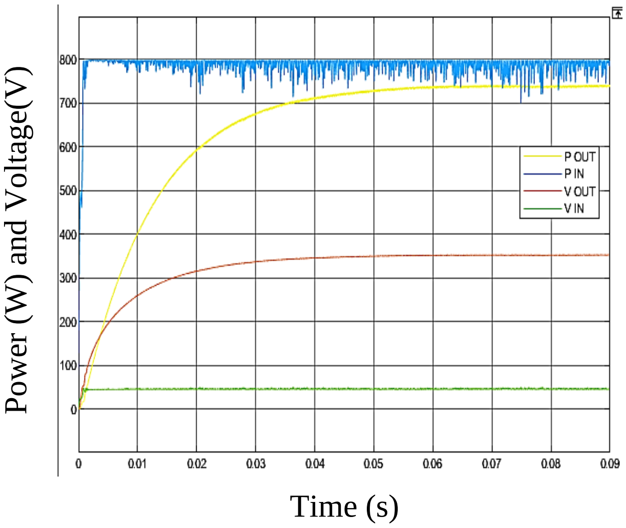
Figure III- 3:short circuited PV cells of module.



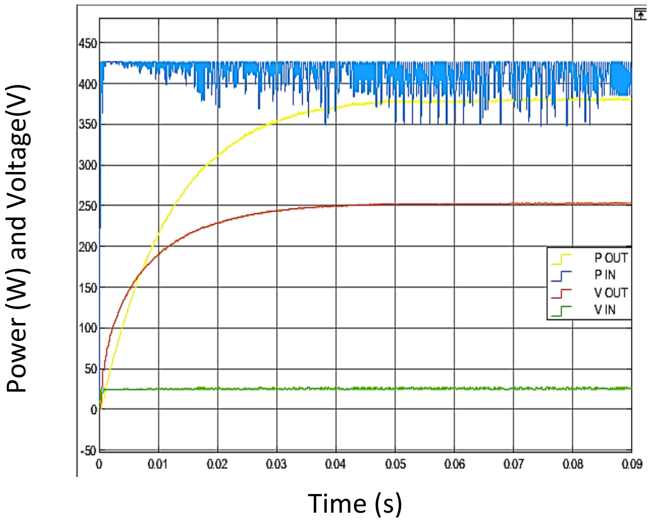
P_V caractéristiques curve

I_V characteristics curve

Figure III- 4:Curves in STC conditions with F1.

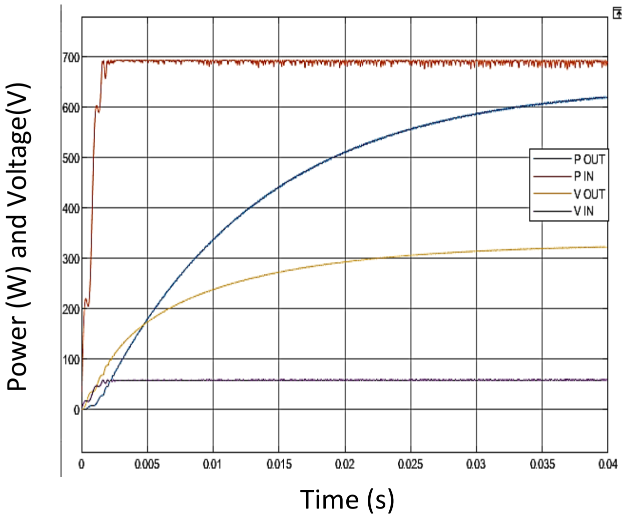


reference PV.

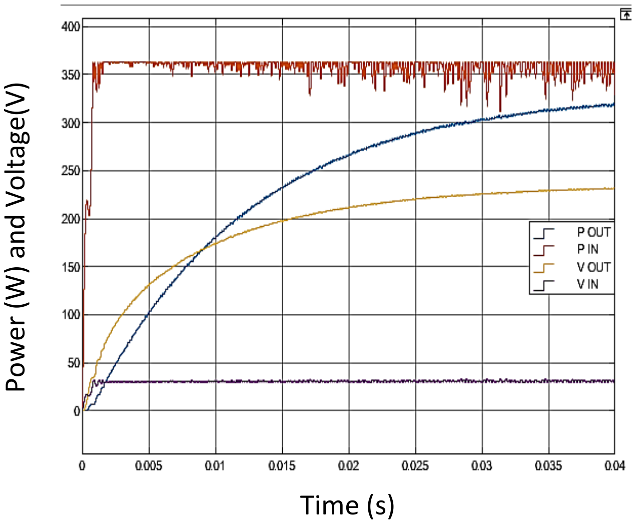


PV with short circuited cell

Figure III- 5:Power and voltage curves before vs after the boost converter in summer day F1.



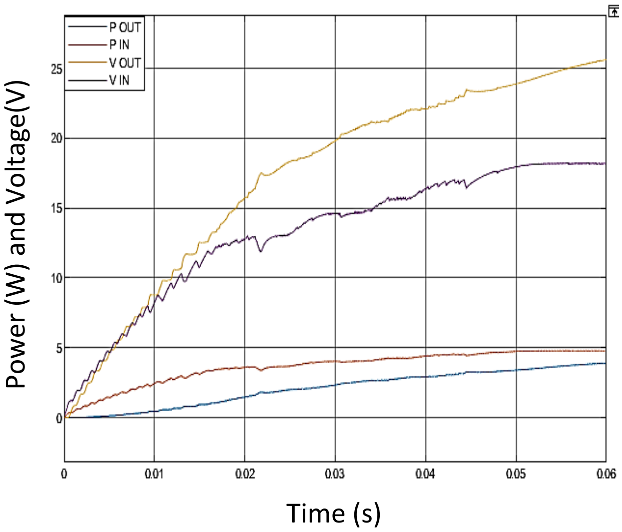
Reference PV.



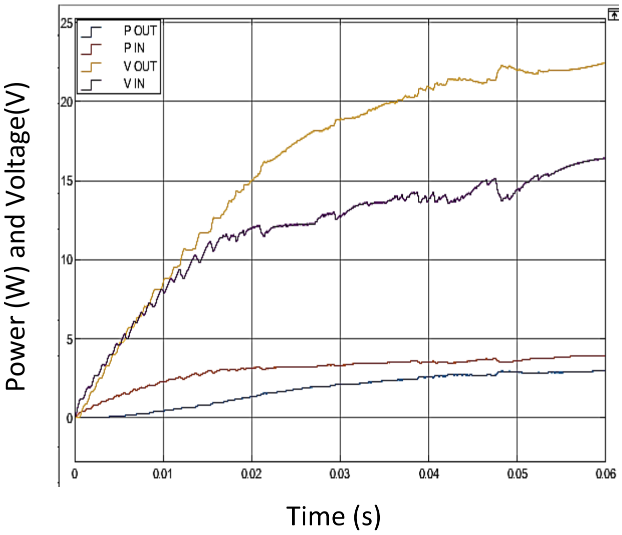
PV with short circuited cell

Figure III- 6:Power and voltage curves before vs after the boost converter in winter day F1.

.

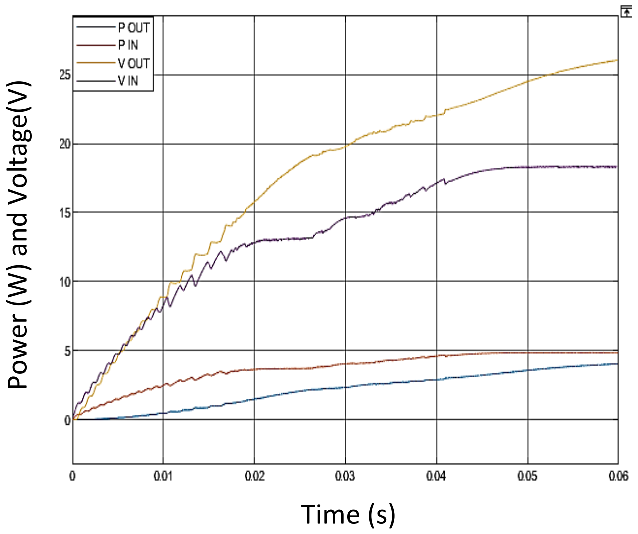


Reference PV

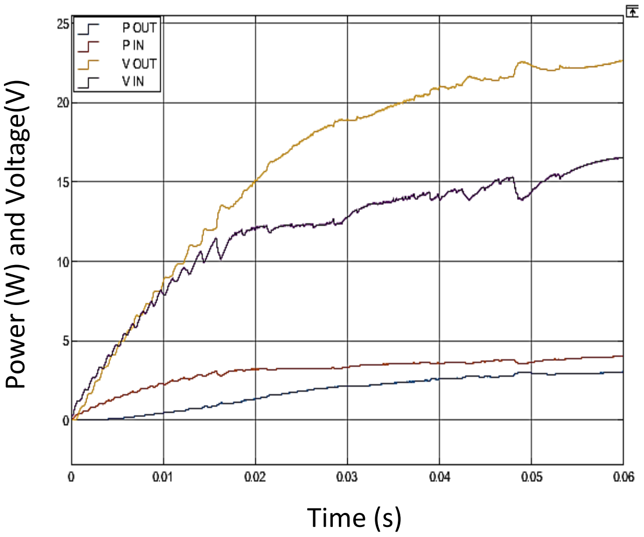


PV with short circuited cell

Figure III- 7:Power and voltage curves before vs after the boost converter in winter night F1.



Reference PV



PV with short circuited

Figure III- 8:Power and voltage curves before vs after the boost converter in summer night F1.

The table below represents our comments on the curves obtained from the short circuit fault, as it is cleared in the top of the chapter.

Table III- 1: results of short circuiting a cell on PV array before and after the boost converter:

Short circuit		**Before dc /dc Converter**	**After dc/dc Converter**	**Consequence**
STC		• Isc: is unchanged. • The power reduces with 50%. • Voltage reduces with 45.5%.	• The power decrease with 50%. • The voltage decreases with 28.5%.	• Only the right string is generating voltage depending on the radiation value.
Winter	**Day**	• Isc: don't change. • The power decrease with 48%. • The voltage decreases with 46%.	• The power decrease with 48%. • The voltage reduces with 23%.	
	Night	• Isc: don't change. • The voltage decreases with 53%. • The power decrease also 38%.	• The power decreases with 25%. • The voltage decreases with 12%.	
Summer	**Day**	• Isc: is unchanged. • The power reduces with 48%. • Voltage reduces with 45%.	• The power reduces with 48%. • Voltage reduces with 29%.	
	Night	• Isc: is unchanged. • The power reduces with 40%. • Voltage reduces with 46%.	• The power reduces with 25%. • Voltage reduces with 12%.	

The comments in table III-1 on the top were taken from fig III-(4,5,6,7,8) down below, by calculating the rate decrease of power using the triple rule:

$$percentage = \frac{Power\ generated\ from\ failed\ array \times 100}{power\ generated\ from\ correct\ arry} \qquad 1$$

III.3.2. By-pass diode fault with partial shading (F2):

Bypass diode faults Assuming that only the bypass diode is the faulty component, the open circuit fault has no impact on the I-V and P-V curves. So, this fault alone cannot be considered in this simulation, for this reason another fault will happen concomitantly with bp diode failure, this fault will be a partial shading.

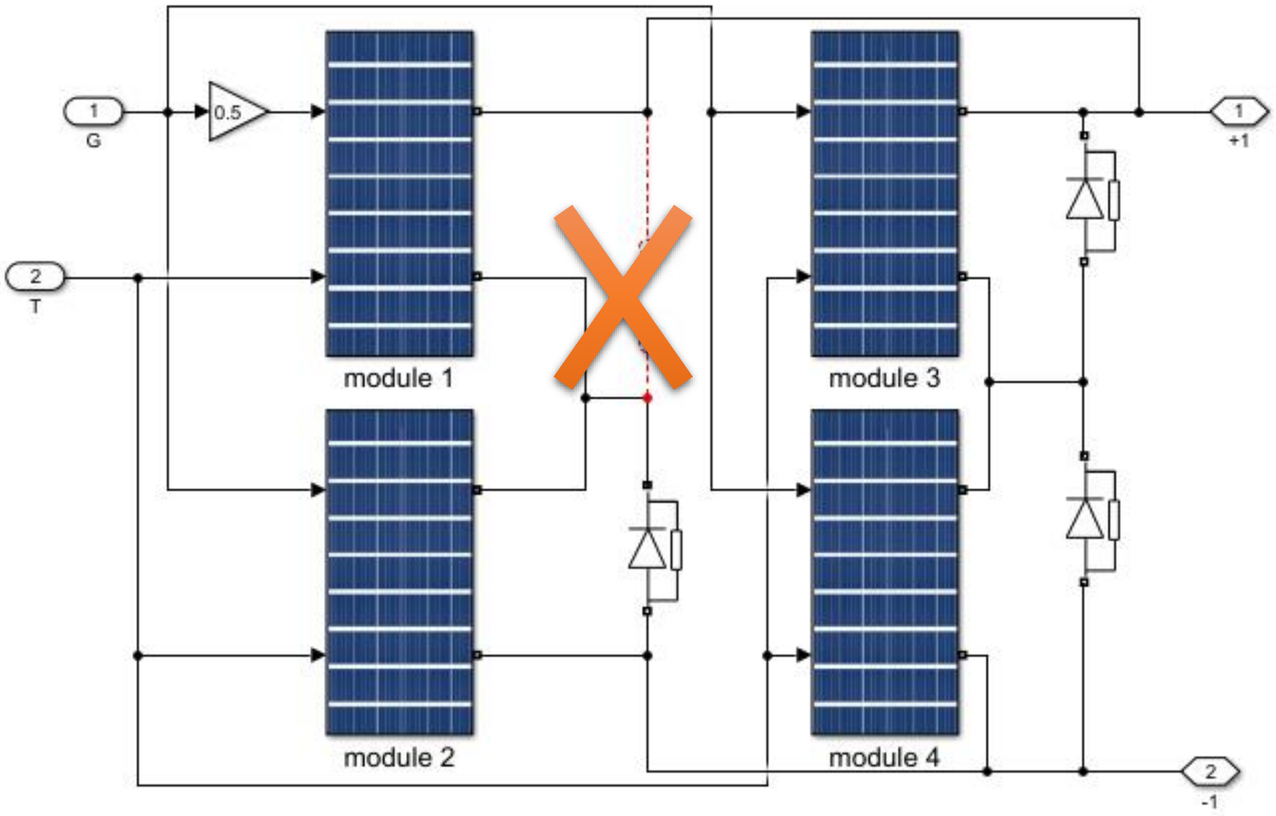
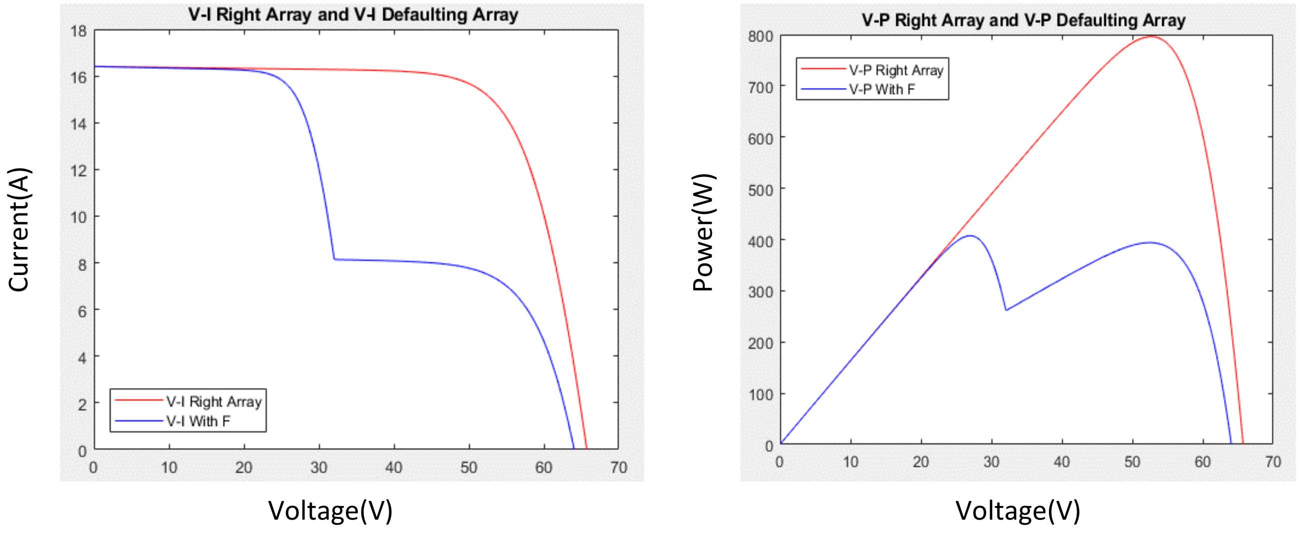


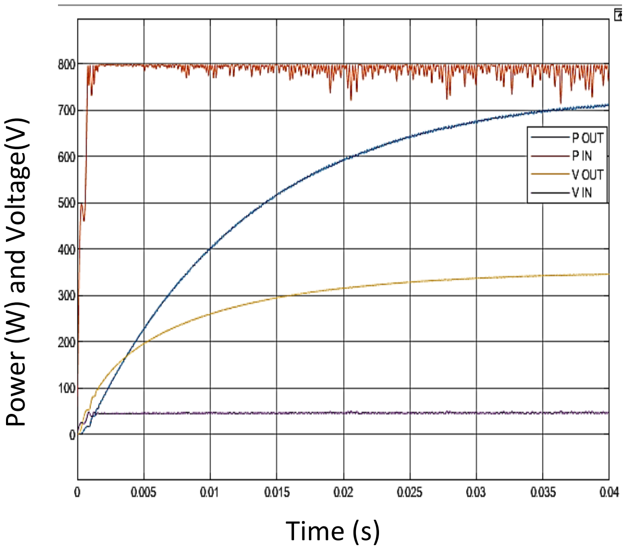
Figure III- 9: shaded module with absence of the bp diode.



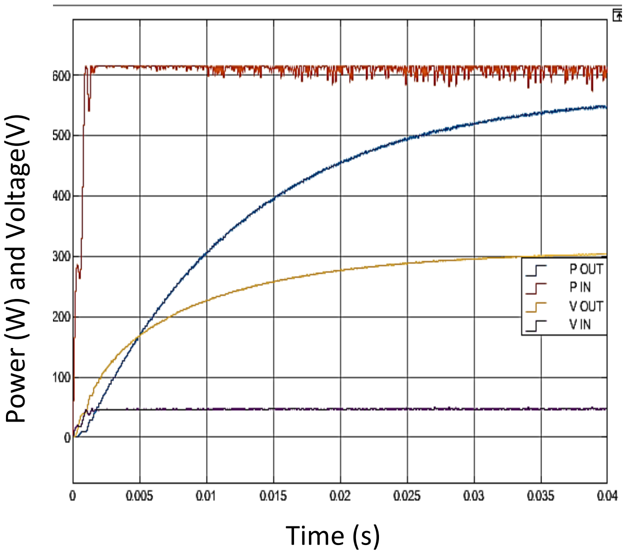
I_V characteristics curve

P_V characteristics curve

Figure III- 10:Curves in STC conditions with F2.

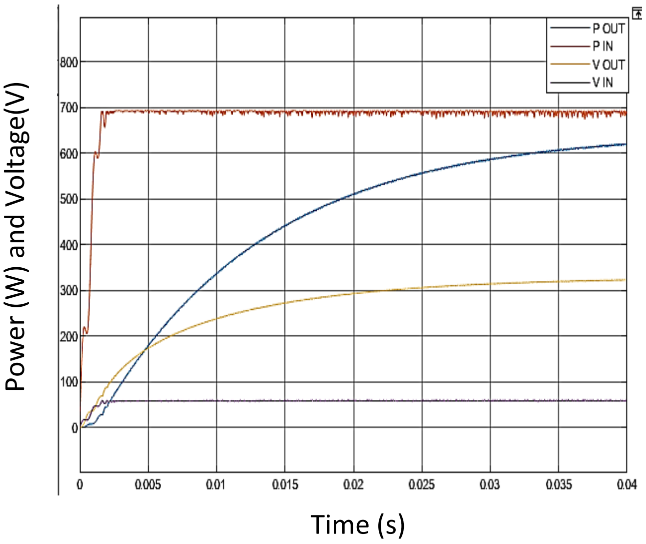


Reference PV

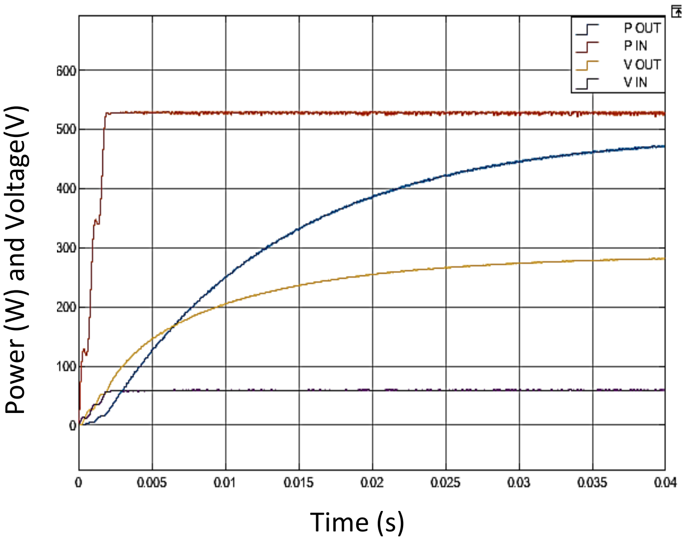


PV with shaded module
without bp protection

Figure III- 11:Power and voltage curves before vs after the boost converter in summer day F2.

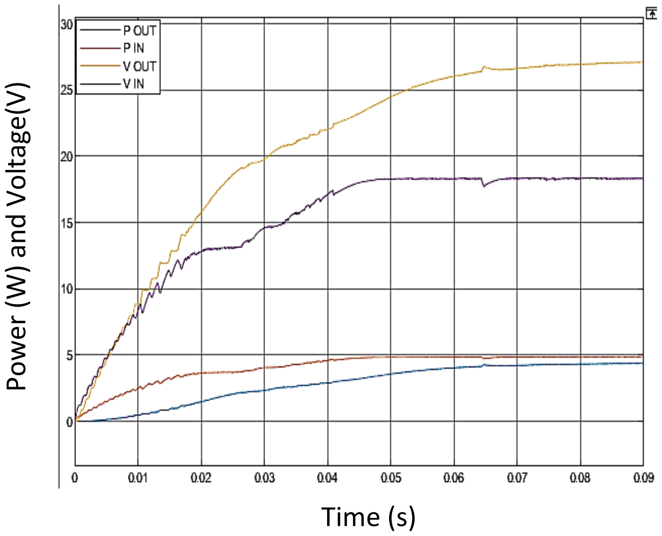


Reference PV

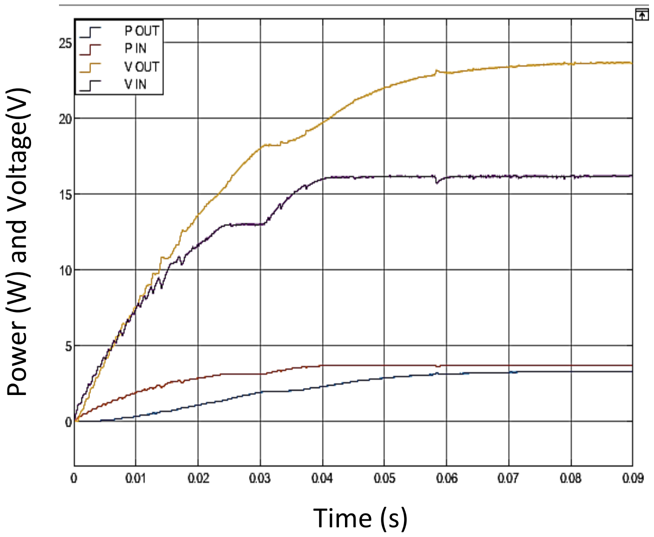


PV with shaded module
without bp protection

Figure III- 12:Power and voltage curves before vs after the boost converter in winter day F2.

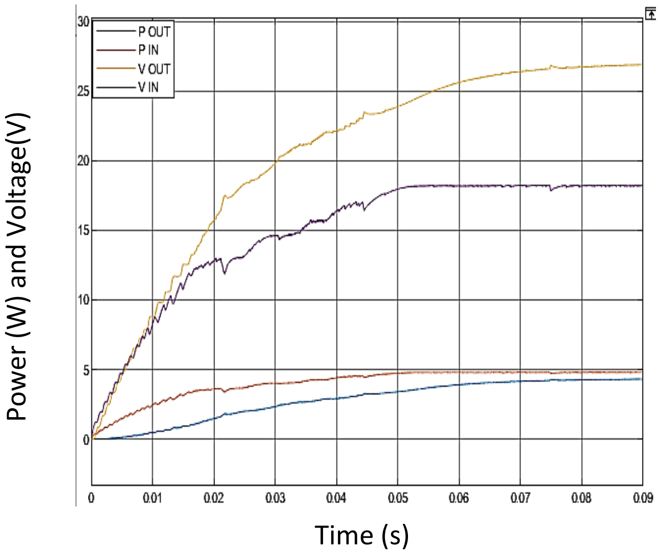


Reference PV

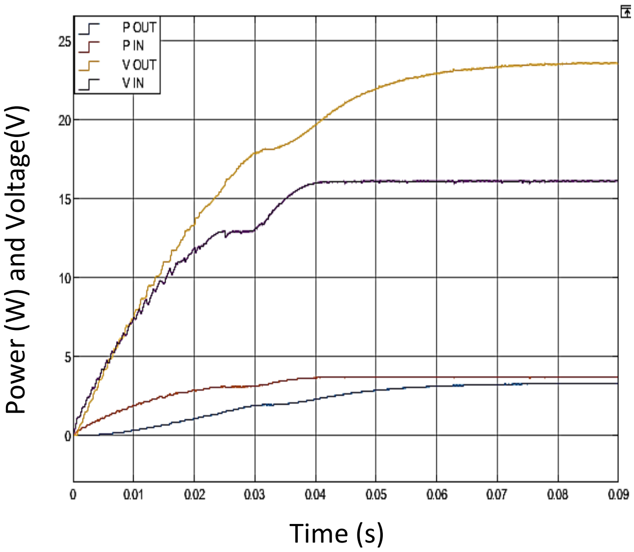


PV with shaded module
without bp protection

Figure III- 13:Power and voltage curves before vs after the boost converter in summer night F2.



Reference PV



PV with shaded module
without bp protection

Figure III- 14:Power and voltage curves before vs after the boost converter in winter night F2.

The table below represents our comments on the curves obtained from the partial shading with bp diode fault, as it is cleared in the top of the chapter figure.

Table III- 2:results of shading a PV module with the bp fault before and after the boost converter:

Shading + diode		**Before dc /dc Converter**	**After dc/dc Converter**	**Consequence**
STC		• Isc: is unchanged. • The power reduces with 50%. • Voltage reduces with 46.2%.	• The power decrease with 26.7%. • The voltage decreases with 15%.	• The right string is generating voltage depending on the irradiation value.
Winter	**Day**	• Isc: don’t change. • The power decrease with 47.2%. • The voltage decreases with 45.72%.	• The power decrease with 85.2%. • The voltage reduces with 9.86%.	
	Night	• Isc: don’t change. • The voltage decreases with 48.8%. • The power decrease also 38.5%.	• The Power decreases with 7.7%. • The voltage decreases with 25%.	
Summer	**Day**	• Isc: is unchanged. • The power reduces with 50%. • Voltage reduces with 44.83%.	• The power reduces with 22.6%. • Voltage reduces with 14.3%.	
	Night	• Isc: is unchanged. • The power reduces with 40%. • Voltage reduces with 46.8%.	• The power reduces with 33.4%. • Voltage reduces with 12.97%.	

III.3.3. Shading (F3):

The figure 15 blows show the one of the modules of our PV system is shaded partially at (40%) in different environmental conditions, we varied irradiation to introduce day /night, and temperature to introduce the season variation.

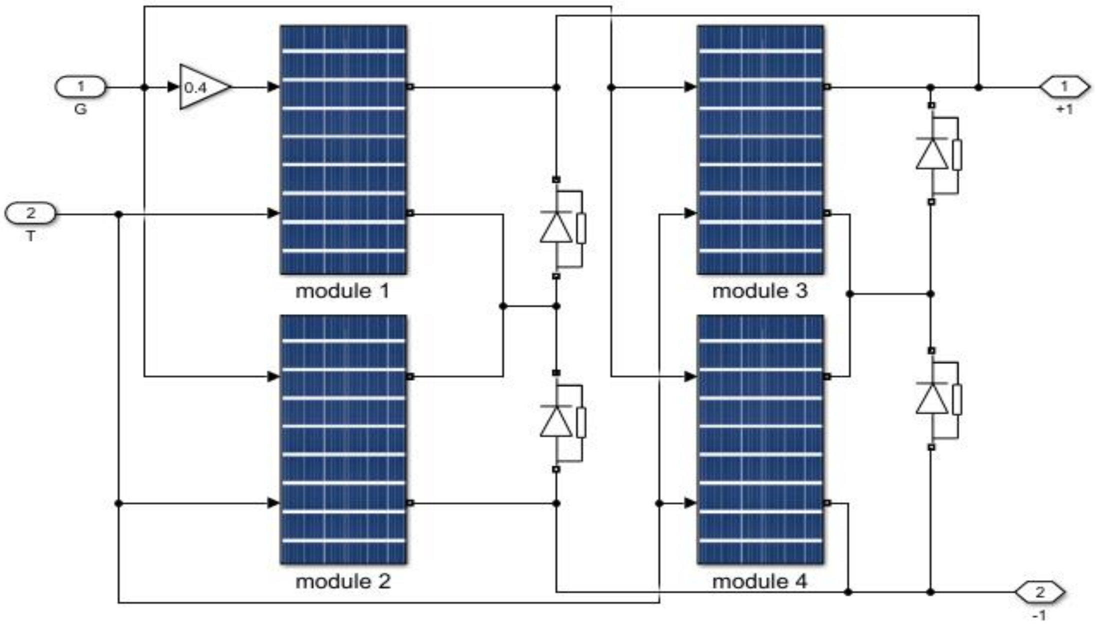
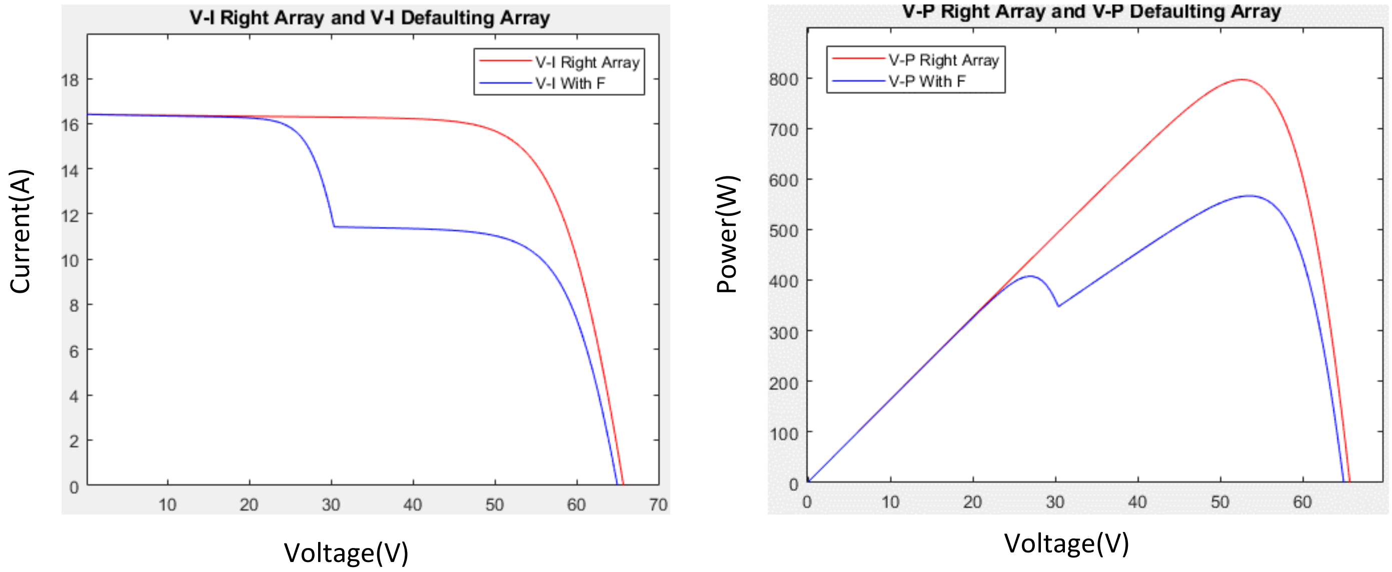


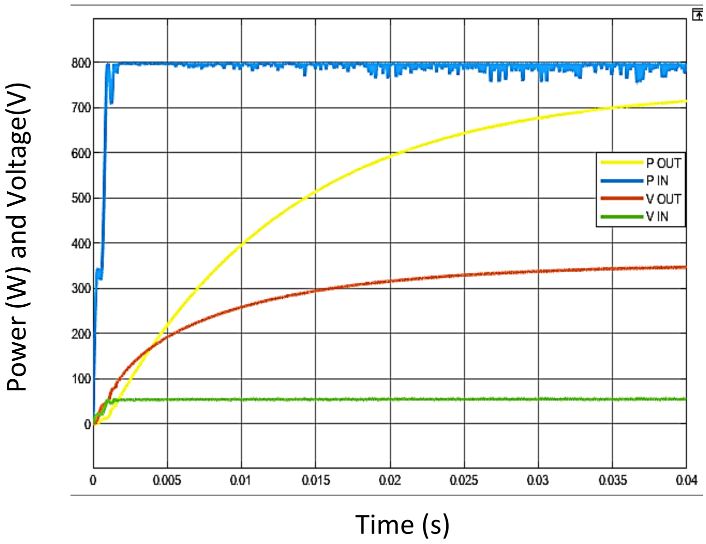
Figure III- 15: partial shading simulation in MATLAB/SIMULINK.



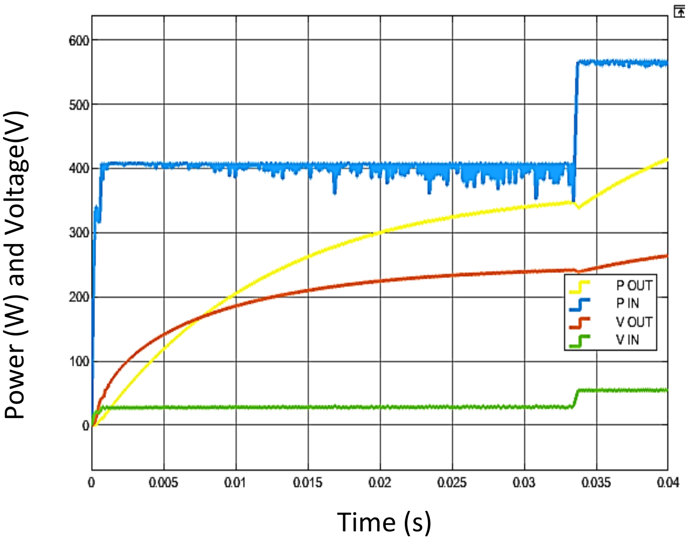
I_V Characteristic curve

P_V Characteristic curve

Figure III- 16:Curves in STC conditions with F3.

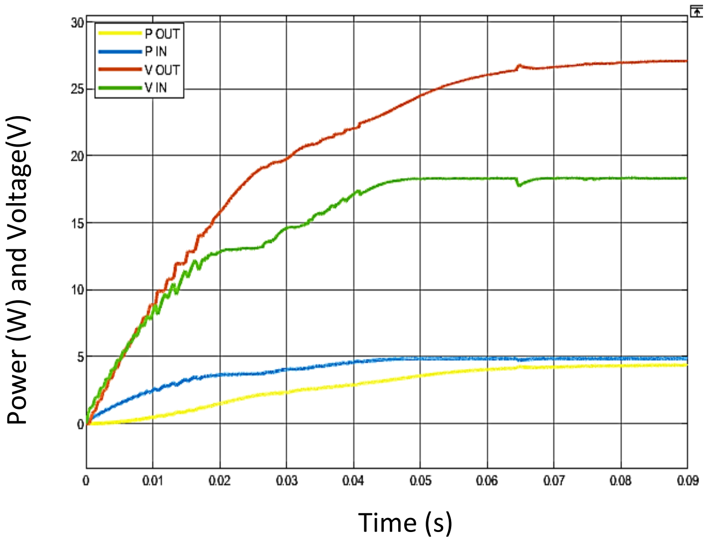


Reference PV

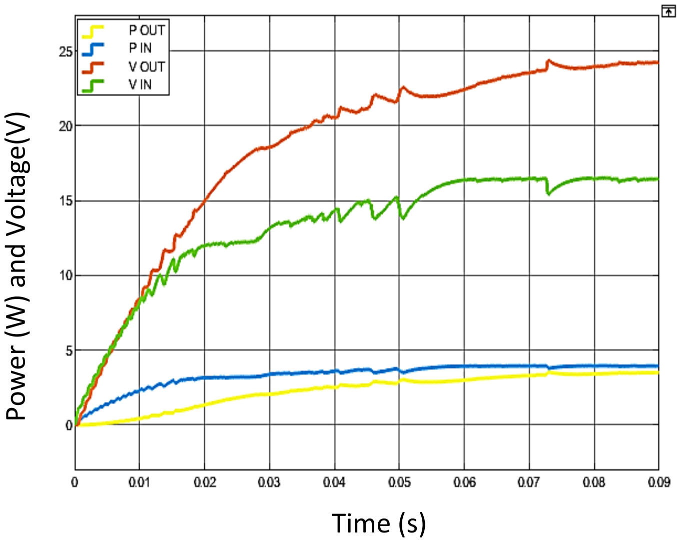


PV With Shading fault

Figure III- 17:: Power and Voltage curves before and after boost converter in summer day F3.

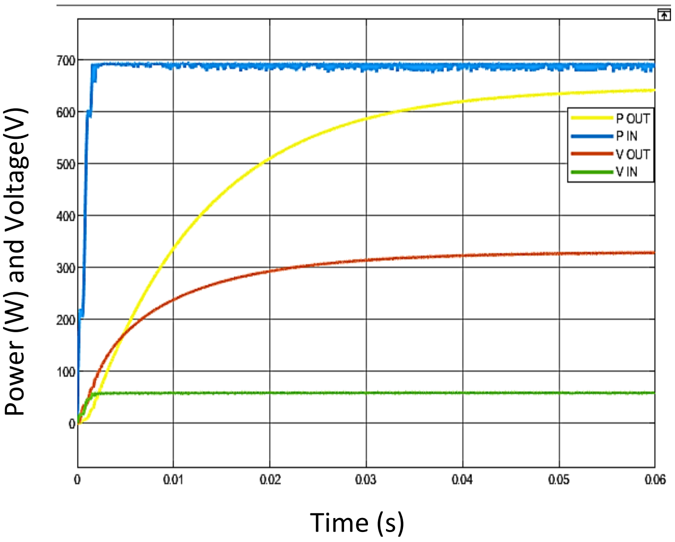


Reference PV

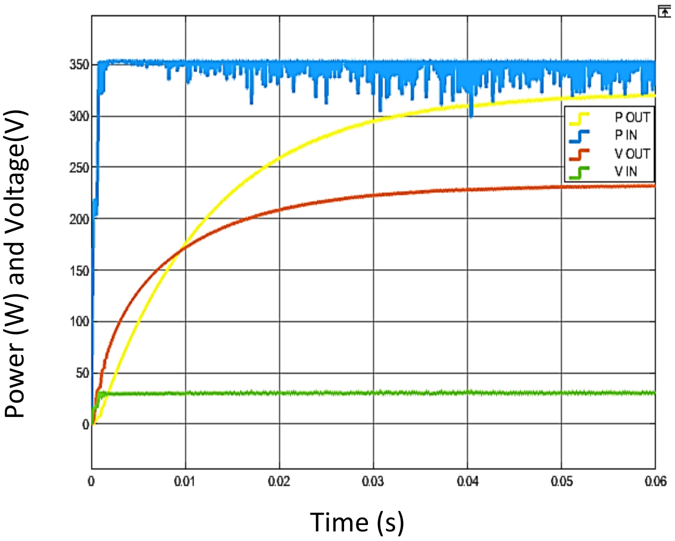


PV With Shading fault

Figure III- 18:Power and Voltage curves before and after boost converter in summer night F3.

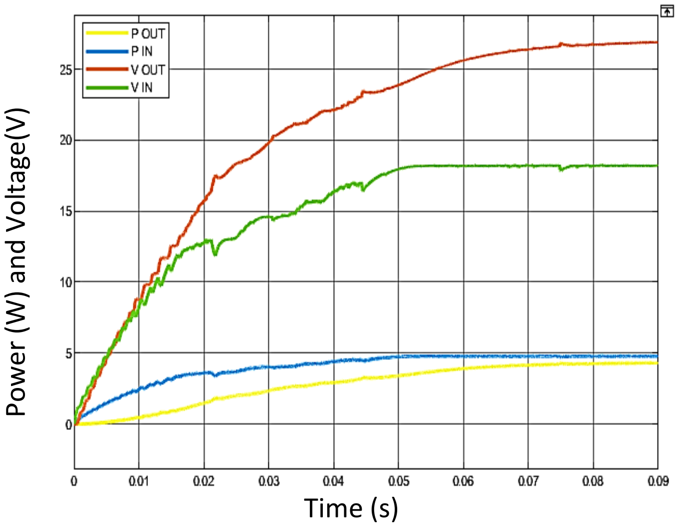


Reference PV

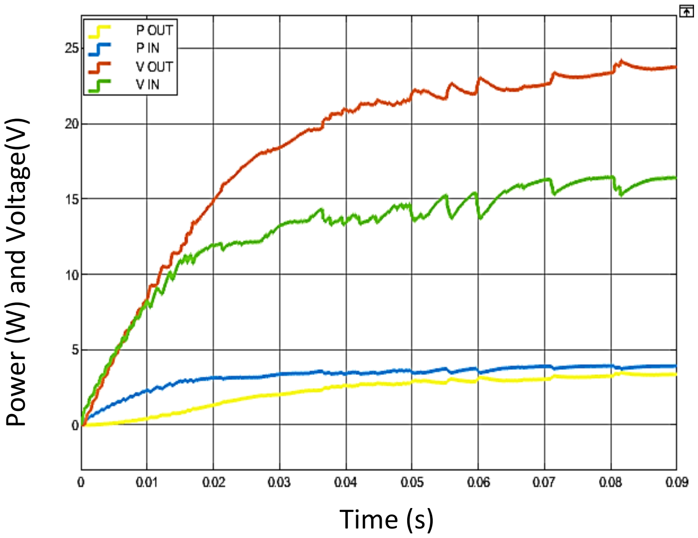


PV With Shading fault

Figure III- 19:Power and Voltage curves before and after boost converter in winter day F3.



Reference PV



PV With Shading fault

Figure III- 20:Power and Voltage curves before and after boost converter in Winter night F3.

According to the simulation results obtained from this type of defect, it can be noted in this table.

Table III- 3:results of shading a PV module fault before and after the boost converter:

Shading		Before dc /dc Converter	After dc/dc Converter	Consequence
STC		• diminution of I_{sh} by 35% • When V_{oc} decreases by 55 %, there is a loss of 50% of power, and when it dips by 2%, there is a loss of 26% of power.	• When V_{oc} decreases by 36%, there is a loss of 62% of power, and when it dips by 18%, there is a loss of 31% of power.	• The mpp in the characteristics P V curve has two peaks, the first one representing the failed string (the one with shaded module), whose value is half of the mpp of the sane PV array, which indicates that only one module is working, and the second peak representing all of the PV array power, which is diminished by a specific percentage in each case from the sane PV array mpp, as previously mentioned.
Winter	**Day**	• diminution of I_{sh} by 31% • When V_{oc} decreases by 51 %, there is a loss of 49% of power, and when it dips by 3%, there is a loss of 29% of power.	• There is a loss of 46% power when V_{oc} drops by 25%.	
	Night	• diminution of I_{sh} by 45% • When V_{oc} decreases by 57 %, there is a loss of 39% of power, and when it dips by 17%, there is a loss of 34% of power.	• There is a loss of 25% power when V_{oc} drops by 13%.	
Summer	**Day**	• diminution of I_{sh} by 30% • When V_{oc} decreases by 57 %, there is a loss of 50% of power, and when it dips by 3%, there is a loss of 26% of power.	• When V_{oc} decreases by 51%, there is a loss of 29% of power, and when it dips by 41%, there is a loss of 26% of power	
	Night	• diminution of I_{sh} by 45% • When V_{oc} decreases by 58 %, there is a loss of 41% of power, and when it dips by 8%, there is a loss of 35% of power.	• There is a loss of 11% power when V_{oc} drops by 25%.	

III.3.4. Open circuit (F4):

The fault of the open circuit PV cells is simulated by separating the photovoltaic cells using gain (I_{ph} ~0) as shown in the figure 4, then the following figures shows the obtained graphs. we varied irradiation to introduce day /night, and temperature to introduce the season variation.

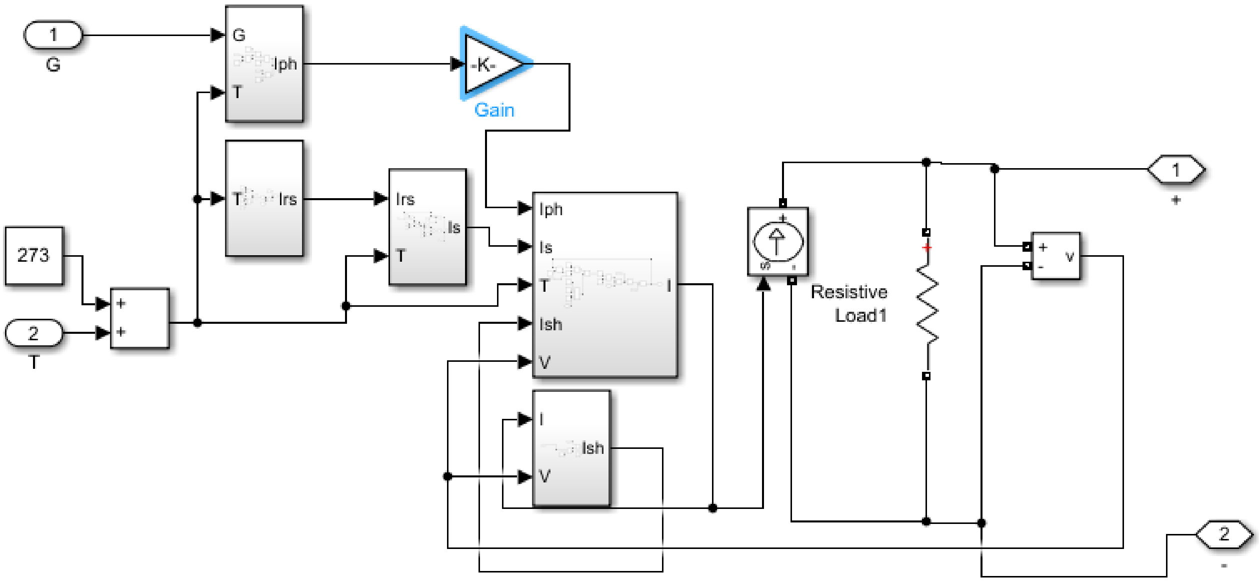
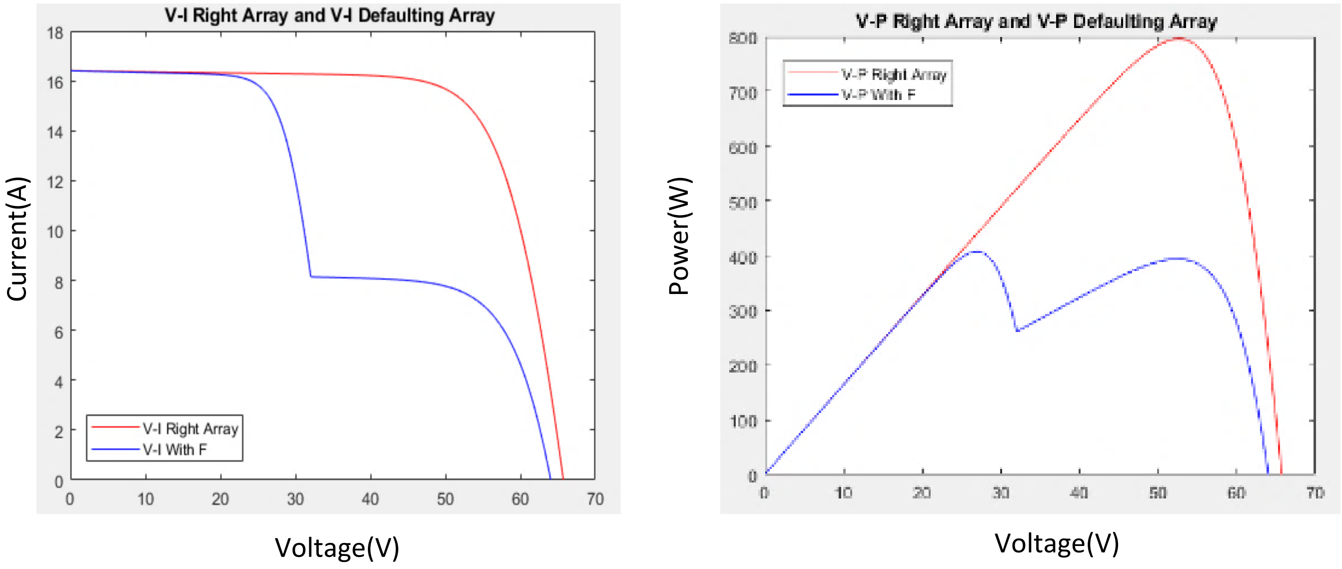


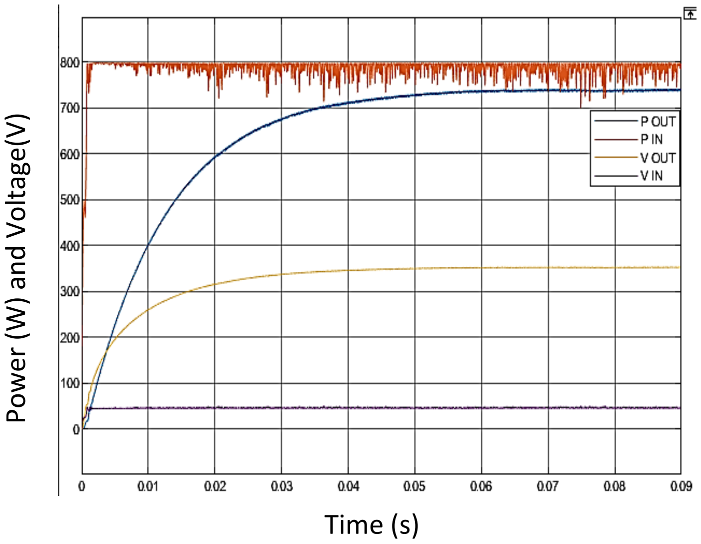
Figure III- 21:Open circuited PV cells of module



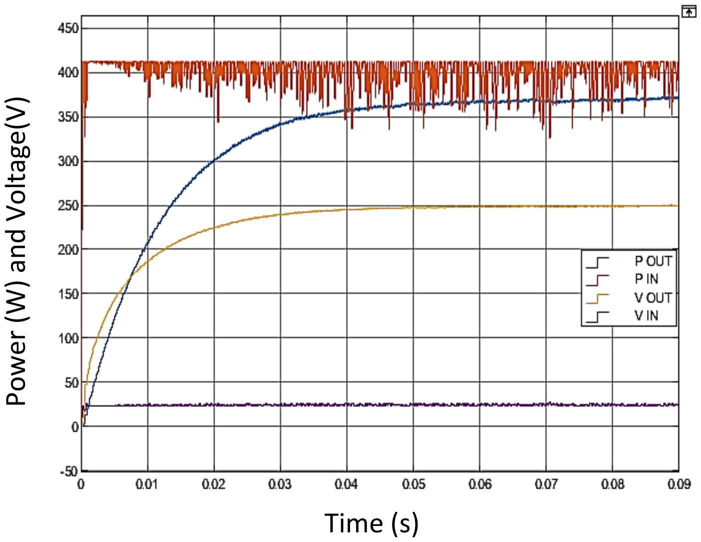
I_V Characteristic curve

P_V Characteristic ccurve

Figure III- 22:Curves in STC Conditions with F4.

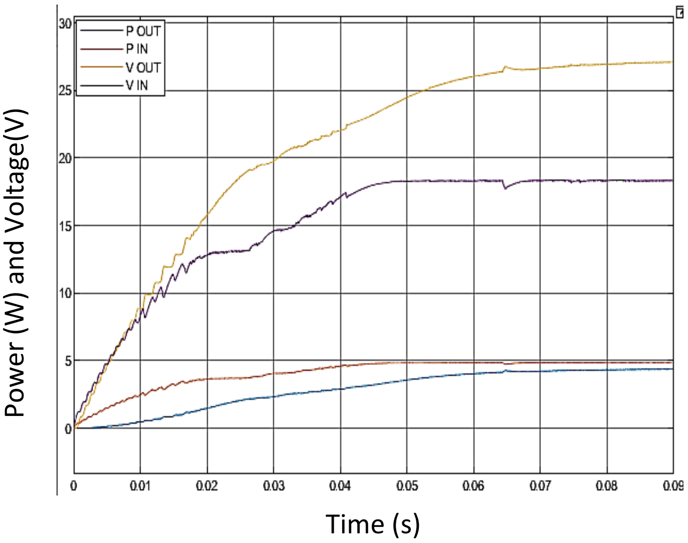


Reference PV

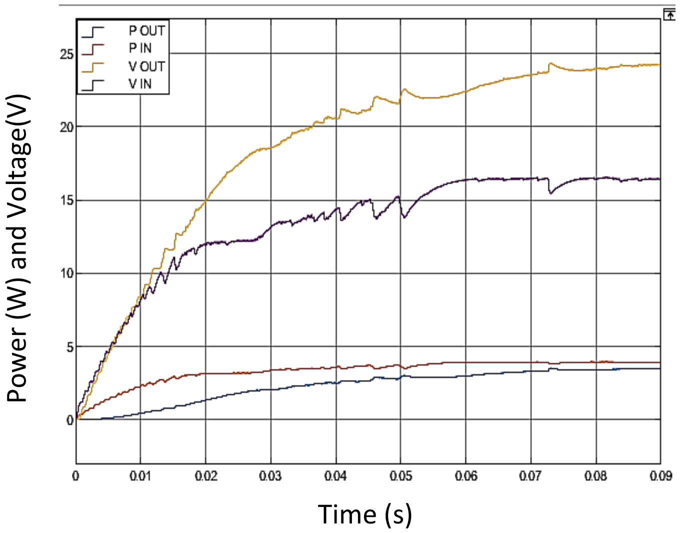


PV With open circuit fault

Figure III- 23:Power and Voltage curves before and after boost converter in summer day F4.

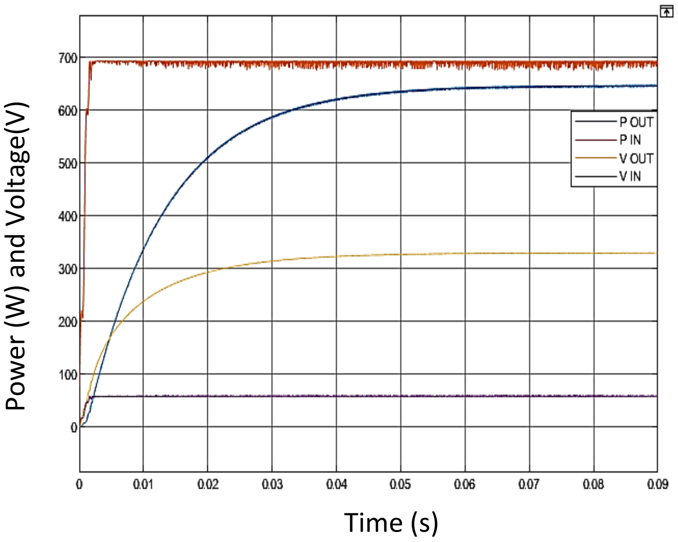


Reference PV

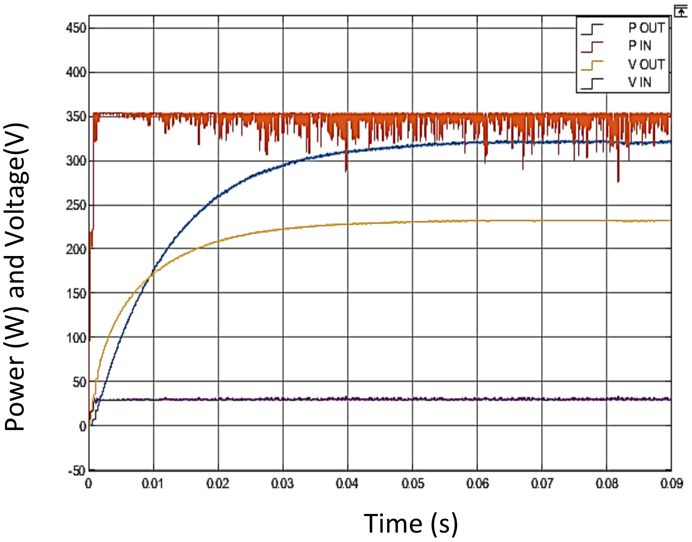


PV With open circuit fault

Figure III- 24:: Power and Voltage curves before and after boost converter in summer night F4.

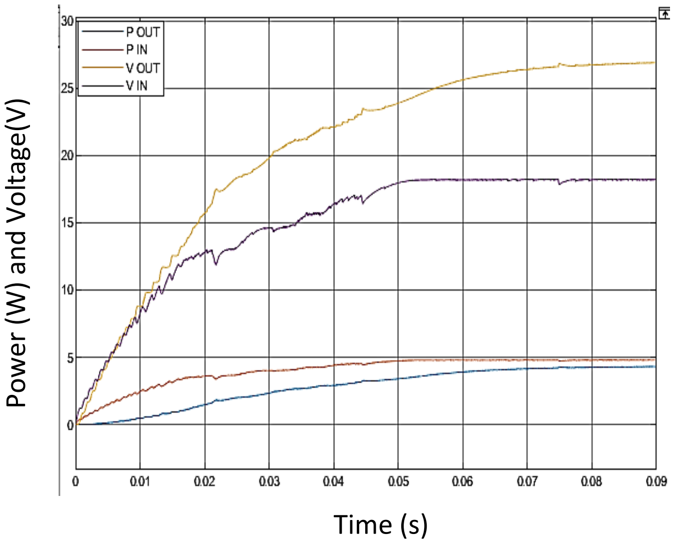


Reference PV

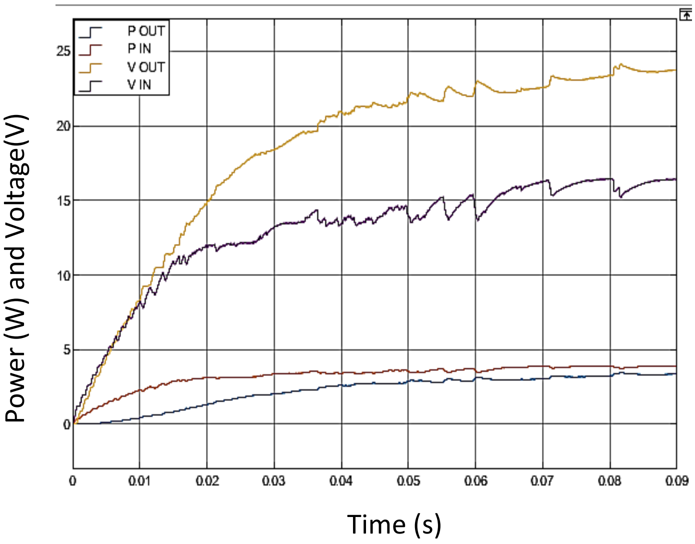


PV With open circuit fault

Figure III- 25:Power and Voltage curves before and after boost converter in winter day F4.



Reference PV



PV With open circuit fault

Figure III- 26:Power and Voltage curves before and after boost converter in winter night F4.

The table below represents our comments on the curves obtained from the open circuit fault, as it is cleared in the top of the chapter figure.

Table III- 4:results of open circuited module fault before and after the boost converter:

Open circuit		**Before dc /dc Converter**	**After dc/dc Converter**	**Consequence**
STC		• diminution of I_{sh} by 47% • When V_{oc} decreases by 50 %, there is a loss of 57% of power, and when it dips by 51%, there is a loss of 15% of power.	• There is a loss of 52% power when V_{oc} drops by 28%.	• The mpp in the characteristics P V curve has two peaks, the first one representing the failed string (the one with open circuit module), whose value is half of the mpp of the sane PV array, which indicates that only one module is working, and the second peak representing all of the PV array power, which is diminished by a specific percentage in each case from the sane PV array mpp, as previously mentioned.
Winter	**Day**	• diminution of I_{sh} by 54% • When V_{oc} decreases by 50 %, there is a loss of 48% of power, and when it dips by 33%, there is a loss of 49% of power.	• There is a loss of 25% power when V_{oc} drops by 46%.	
	Night	• diminution of I_{sh} by 70% • When V_{oc} decreases by 48 %, there is a loss of 39% of power, and when it dips by 28%, there is a loss of 62% of power.	• There is a loss of 75% power when V_{oc} drops by 10%.	
Summer	**Day**	• diminution of I_{sh} by 50% • When V_{oc} decreases by 59 %, there is a loss of 51% of power, and when it dips by 5%, there is a loss of 50% of power.	• There is a loss of 51% power when V_{oc} drops by 29%.	
	Night	• diminution of I_{sh} by 69% • When V_{oc} decreases by 48%, there is a loss of 40% of power, and when it dips by 23%, there is a loss of 60% of power.	• There is a loss of 25% power when V_{oc} drops by 9%.	

III.4. Intern resistance faults:

III.4.1. Serial resistance fault:

Figure 27 shows how the serial resistance has an impact on the solar cell's characteristic I(V) and P(V). In the region where the photodiode functions as a voltage generator, the serial resistance affects the slope of the characteristic. When it is high, it lowers the short circuit current value but has no effect on the voltage of the open circuit. The slope of the power curve decreases as the serial resistance increases.

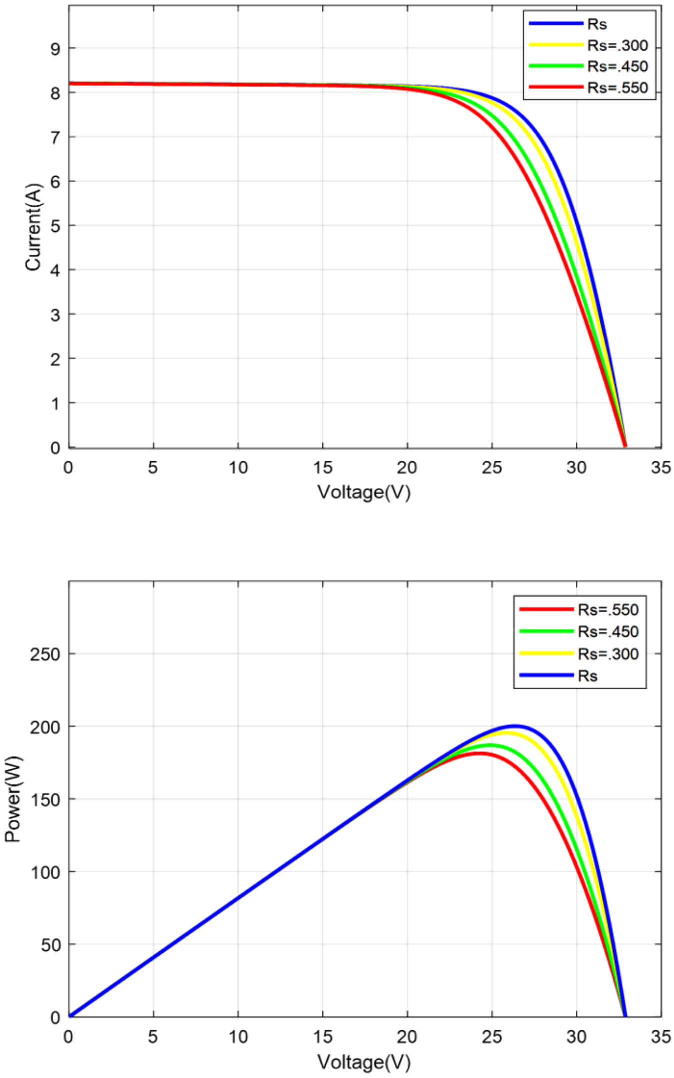


Figure III- 27:Serial resistance influence on I-V P-V curves.

III.4.2. The shunt resistance fault:

The shunt resistance is a resistance that accounts for the unavoidable loss of current between a photo battery's terminals. The current generating component in particular exhibits the effects of the very high shunt resistance.

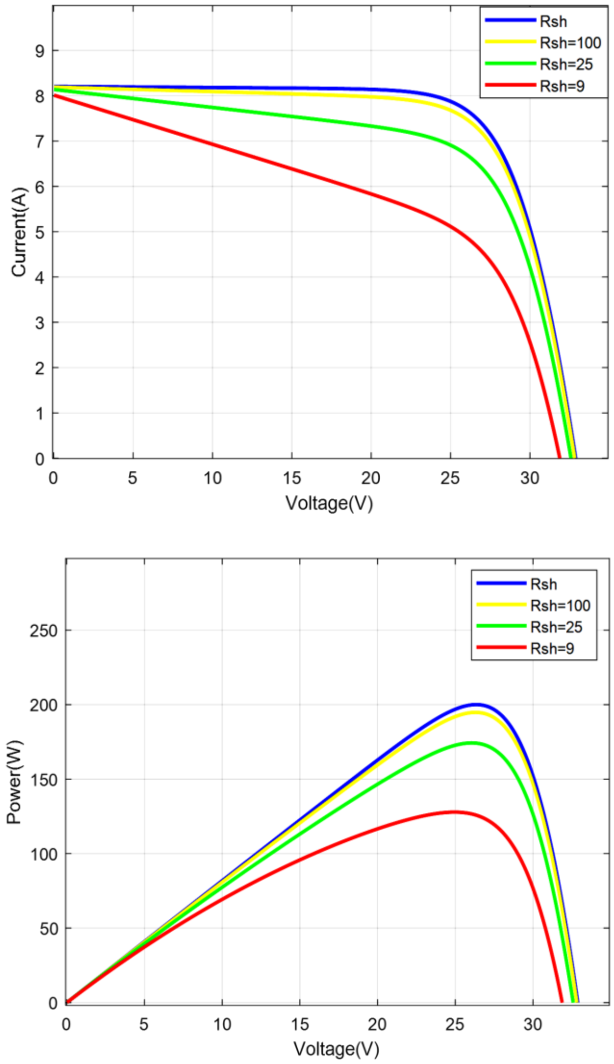


Figure III- 28:Influence of shunt resistance on I-V P-V curves.

A small decrease in the open circuit voltage and an increase in the slope of the cell's I-V curve in the region corresponding to operating as a current source are the effects of the shunt resistor's influence on the current-voltage characteristic.

Fig III-27 illustrates how a solar cell's power output fluctuates with its parallel resistance, with higher parallel resistance resulting in higher power output.

III.4. Conclusion:

In this chapter, we represented some faults simulation as short circuit, open circuit, shading and shading with bypass diode absence and how their presence effects on PV array in summer and winter.

We conclude that the high temperature of summer even in a good irradiation, effect negatively on PV efficiency, the high irradiation effect positively on PV efficiency

General conclusion

The work presented in this thesis concerns the study of a photovoltaic system equipped with an MPPT regulator based on fuzzy logic control. The main objective of this work is to improve the performance of the PV system, by recognizing the different faults that can reduce the photovoltaic system efficiency.

we proceeded to model the photovoltaic generator using the single diode model. The simulation carried out allowed us to obtain characteristics very close to those of the real GPV, which allowed us to validate our model.

Modeling of the static DC/DC converters (boost chopper) is also covered in this thesis.

The study carried out on the adaptation conditions, ensured that the converter boost takes the voltage to generate GPV on its input and raise it at the output of the converter.

The use of fuzzy logic theory makes it possible to have a fast PPM tracking device (improved the response time of the photovoltaic system) and free from oscillations (considerably reduced or even canceled fluctuations around the point of maximum power) in steady state during variations in meteorological parameters. This shows the efficiency of the fuzzy controller for complex and nonlinear systems such as the photovoltaic system.

The bibliographic study on the different models of a photovoltaic cell. Then we studied the influence of some parameters of the model chosen according to the characteristics of the cell.

Then we presented the main faults most encountered in a photovoltaic installation and their classification into two categories. four types of defects were selected for modeling and simulation.

That simulations were in different seasons, in different times on day. to be more precised in winter and summer at day and night.

The hight temperature obstructing the flow of the current, and from it, the productivity of the PV generator decreases.

The relationship between the photovoltaic generator and the irradiation is a proportional relationship. The higher the irradiation, the higher the generator’s productivity of current.

Many faults can affect the productivity of the photovoltaic system, some of them affect directly. Among these faults, are the open circuit, short circuit, shading and aging factors faults, which are represented in the internal resistances of the photovoltaic generator.

Faults presence effects directly on the PV system’s produced energy, their presence has a notable negative effect on GPV’s efficiency and even the other devices which can reach a reduce of more than 50% of the generated energy compared with the reference PV system.

This thesis was a starting step for other researchers to consider the multiple physical defects of the photovoltaic system in different climatic factors in order to extract a large useful database for the creation of a MPPT that makes the control and the detection faults.

Bibliography

[1] "Y.Haddad,"Etude d’une nouvelle approche de détection des défauts dans un système pv",Master Memory,Mohamed El Bachir El Ibrahimi of Bordj Bou Arréridj Univercity," Mohamed El-Bachir El-Ibrahimi Univercity - Bordj Bou Arreridj, 14 09 2021.

[2] "PHOTOVOLTAIC SYSTEMS," *Andrej Čotar, dipl.ing. Darko Jardas,* 2012.

[3] "news-insights/solar-cell-technology," New York, Available: https://codibly.com.

[4] "N. H. Ramly*, Noor Zaihah Jamal, Abdul Nasir Abd Ghafar and Devin Babu ,"Emergency Portable Solar Power Supply",Faculty of Electrical & Electronic Engineering Technology, University Malaysia Pahang,," 12 2019.

[5] "N. Abouchabana," Etude d’une nouvelle topologie buck-boost appliquée à un MPPT" Magister Memory,Ecole Nationale Polytechnique, Alger, Algérie," 2009.

[6] "ML.Louazene,"Etude technico-économique d'un système de pompage photovoltaïque sur le site de Ouargla",Magester Memory ,University of El Hadj Lakhdar-Batna," 2008.

[7] "M.Sasi,"Fuzzy Logic Control of MPPT Controller for PV Systems",Master of Engineering,University of Newfoundland," 05 2014.

[8] "M.Ghebbache,"Stratégies de commande d'un système photovoltaïque connecté au réseau électrique dans le but d'optimiser la qualité de l'énergie"Master Memory, Québec Univercity," 2019.

[9] "M.Boudiaf,"Etude Et Simulation D’une Commande MPPT",master memory,M’SILA Univercity," 2016.

[10] "L.Thierry, "Cours d’électronique de puissance", IUT GEII 2ième année, Option EEP," 2004/2005.

[11] "L.Stoyanov,"Etude de différentes structures de systèmes hybrides àsources d’énergie renouvelables " master memory," 28 octobre 2011.

[12] "K,Merbah,"Etude technicoéconomique d’une installation photovoltaïque pour application dans la région de Ouargla",Master Memory," 2019/2020.

[13] "E.Garoudja,F.Harrou,Y.Sun, K.Kara, A.Chouder,S.Silvestre,"Statistical fault detection in photovoltaic systems,Solar energy"," 01 07 2017.

[14] "B.Assam,"Contribution à l’etude d’un système photovoltaïque",Master Memory,University of M'sila," 11 2020.

[15] "A.Bennaceur ,I.Bouderbala "Étude et modélisation des défauts d’un générateur photovoltaïque",master memory," University of M’sila, 2018.2019.

[16] "A.Amazigh, I.Zahir,"Etude et simulation du comportement d'un Systeme photovoltique"," 26 06 2016.

[17] "news-insights/solar-cell-technology," New York , Available: https://codibly.com/.

[18] "Energreen," Avenue Franklin 5C, 1300 Wavre, Available: https://www.energreen.be/.

[19] "Lequeu Thierry, "Cours d’électronique de puissance", IUT GEII 2ième année, Option EEP," 2004/2005.

[20] "Electronics-toutorials," Available: https://www.electronics-tutorials.ws/.

[21] E. H. F. S. Y. K. K. C. A. S. S. Garoudja, "Statistical fault detection in photovoltaic systems. "Solar energy"," 1 JULY 2017.

[22] " The Comprehensive Study of Electrical Faults in PV Arrays," *Journal of Electrical and Computer Engineering* , 2016.