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### THEME

**Study and realization of DC-DC converter in a  
photovoltaic energy conversion chain, Application  
for Control of DC machine**

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*We dedicate with deep gratitude and sincere words this  
modest graduation work to:*

*Our dear parents, for their sacrifices*

*And their precious advice, my God grants them  
happiness and long life. We also dedicate this work to  
our families and all those we care about.*

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# List of Symbols

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## List of symbols

$\delta$ : Declination of the sun ( $^{\circ}$ )

$\lambda$ : Wave length (m)

$I_{ph}$ : is the current supplied by the cell (A)

$I_s$ : The saturation current (A)

$R_s$ : the series resistance representing the various resistances of contacts and connections ( $\Omega$ )

$R_p$ : the shunt resistance characterizing the leakage currents of the junction ( $\Omega$ )

$V_t$ : the thermodynamic potential (V)

T: the effective temperature of the cell in Kelvin (K)

$e$  (C): the charge of the electron, the non-ideality factor of the junction ( $1.602 \cdot 10^{-19}$  C)

K: Boltzmann constant ( $1.381 \cdot 10^{-23}$  J/K)

$I_{sc}$ : Short circuit current (A)

$V_{oc}$ : Open circuit voltage (V)

V: Cell voltage or terminal (V)

I: Current delivered by the cell (A)

$P_{max}$ : Maximum power supplied by the cell (W)

$V_{max}$ : Maximum voltage supplied by the cell (V).

$I_{max}$ : Maximum current supplied by the cell (A).

$P_{inc}$ : Incident solar power (W)

S: is a solar cell area

E: is an incident flow

$N_s$ : Number of cells in series

$N_p$ : Number of cells in parallel

$I_{sc}$  : short-circuit current of  $N_s$  cells in series (A)

$V_{oc}$ : the sum of the open circuit voltages of  $N_s$  cells in series (V)

$I_{sc}$ : the sum of the short circuit currents of ( $N_p$ ) cell in parallel

$V_{oc}$ : the open circuit voltage of ( $N_p$ ) cells in parallel

$I_{sc}$ : short-circuit current of the resulting module

T: Switching period (s)

D: Switch duty cycle

C: Capacitor capacity (F)

L: Inductance (H)

## List of Symbols

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- P: The active power (W)
- S: The apparent power (VA)
- K: the power factor
- P<sub>pvn</sub>: the new power (W)
- P<sub>pvn-1</sub>: the old power over time (t-1) (W)
- P: the energy product (W)
- V<sub>mp</sub>: Voltage at Maximum Power (V)
- P<sub>mp</sub>: STC Power Rating P<sub>mp</sub> (W)
- V<sub>out</sub>: the exit voltage (V)
- U<sub>ex</sub>: Excitation voltage (V)
- R<sub>ex</sub>: Inductor resistance ( $\Omega$ )
- L<sub>ex</sub>: Inductance of inductor (H)
- V<sub>a</sub>: Armature voltage (V)
- R<sub>a</sub>: Armature resistance ( $\Omega$ )
- R<sub>ad</sub>: Rheostat connected to the armature terminals ( $\Omega$ )
- I<sub>a</sub>: Armature current (A)
- L<sub>a</sub>: Armature inductance (H)
- $\Omega$ : the angular speed (rad /s)
- E: Counter electromotive force f.e.m (V)
- T<sub>e</sub>: Electromagnetic torque (Nm)
- P<sub>e</sub>: electromagnetic power (w)
- C<sub>r</sub>: Resistant torque (Nm)
- K: Motor-specific constant quantity (V/rad.s<sup>-1</sup>)
- C: Useful engine torque (Nm)
- I: Armature current (A)
- U: Supply voltage (V)
- J: the moment of inertia of the rotor (Kg.m<sup>2</sup>)
- f: viscous coefficient of friction (Nm.s/rad)
- $\frac{d\Omega(t)}{dt}$  : Angular acceleration
- K<sub>m</sub> : torque constant

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# General Introduction

# General Introduction

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## Introduction

The sun's light energy is regarded as one of the most abundant and readily available energy sources. It is a significant renewable energy source. The sun's heat can also be captured as thermal energy and used for solar-powered heating systems. The solar power conversion process is classified as active or passive solar depending on the type of energy capture and delivery. The active solar technique makes use of Solar Photovoltaic (PV) systems heating systems, whilst the passive solar technique makes use of materials with thermal properties and light dispersion properties. In practice, CSP power system is the heat generated by the reflection of sunlight using mirrors and lenses [1]. The PV power system, which is discussed in this work, is a conversion of photons to electric current. The energy held in photons from the sun is absorbed by electrons in semiconductor materials, and electricity is created in the form of a DC current. Typically, a single PV cell can typically provide 1 to 2 Watts of power, and it is linked in series and parallel with other PV cells to create a PV module. Similarly, a group of PV modules can be linked together to create a PV array.

Consequently, the power output of a PV module depends on the number of cells in the module, the type of cells and the total surface area of the cells. Manufacturers rate all modules based on their peak power under specified test circumstances. The goal of determining the maximum power tracking of each cell, on the other hand, is to determine the maximum power tracking of the entire PV array.

The abundant use of conventional energy (oil & gas) leads to a degradation of the environment (greenhouse effect) consequently, global warming, compromise the living conditions on earth. this is why it is necessary to reduce greenhouse gas emissions. that's why, states around the world want to replace oil and gas with renewable energy (solar & wind).

In our project; the DC voltage recovered from the photovoltaic panel was used to start a DC motor via a boost converter. to do so, our project presented three chapters closed with a general conclusion:

Chapter I: General information on Photovoltaic Systems

Chapter II: Study and simulation of DC-DC converters

Chapter III: Representation and modeling of the DC motor

# Chapter I

General information on  
Photovoltaic systems

## I-1 Introduction :

The Photovoltaic solar energy product from the transformation of the solar energy into electrical energy. This energy conversion takes place through a so-called photovoltaic (PV) cell based on a physical phenomenon called the photovoltaic effect which consists of producing an electromotive force when the surface of this cell is exposed to light. These photovoltaic cells are made of semiconductors based on silicon (Si), germanium (Ge), selenium (Se), etc. Silicon is currently the material most used to manufacture photovoltaic cells. The voltage generated may vary depending on the material manufacture the cell [1].

## I-2 Solar energy

Solar radiation can be used to produce either electricity directly using photovoltaic semiconductors, or solar thermal heat for heating or electricity production. Solar energy presents itself as an alternative to other sources of energy, it represents considerable potential. Indeed, the earth receives more than 3000 hours of sunlight per year with a high level of illumination. With an optimization of the reception angles, the annual daily average is 5 to 7 kWh /m<sup>2</sup>/day.

Algeria has approximately 3200 hours of sunshine per year, benefiting from a favorable climatic situation for the application of solar techniques [2].

### I-2-1 Solar spectrum

The solar spectrum and spectral distribution as a function of wavelength ( $\lambda$ ) or frequency ( $\nu$ ).

The Sun emits electromagnetic radiation within a wavelength band that varies between 0.22 to 10  $\mu\text{m}$ .

**Figure (I.1)** represents the variation of the energy spectral distribution. The energy associated with this solar radiation breaks down approximately as follows:

- 6,4% dans la bande des ultraviolets ( $0,20 < \mu < 0,38 \mu\text{m}$ ).
- 48% dans la bande visible ( $0,38 < \mu < 0,78 \mu\text{m}$ ).
- 45,6% dans la bande des infrarouges ( $0,78 < \mu < 10 \mu\text{m}$ ).

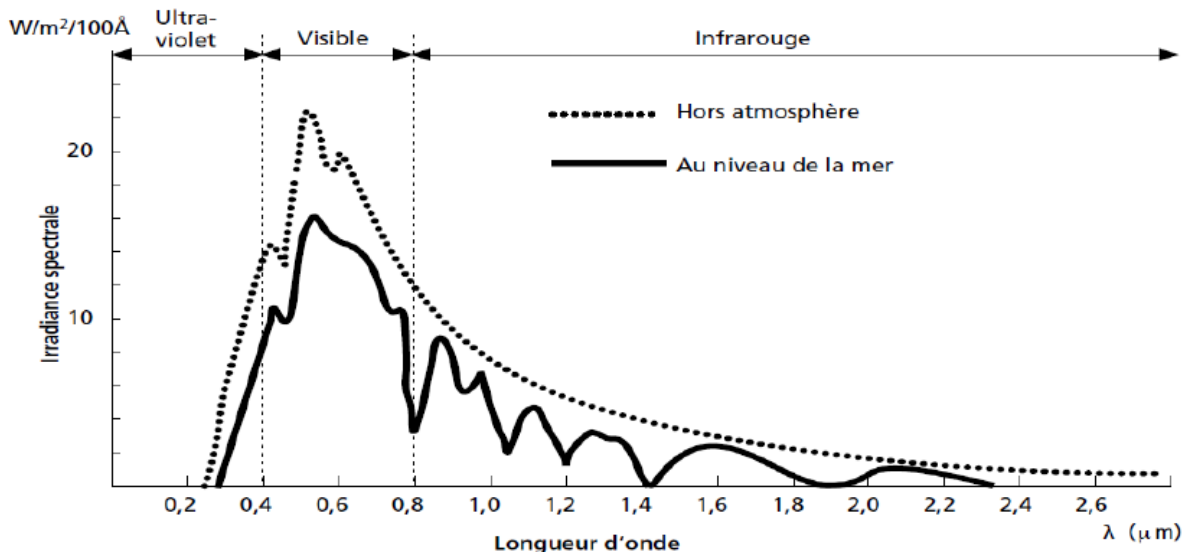


Figure (I.1): Spectral analysis of solar radiation [3].

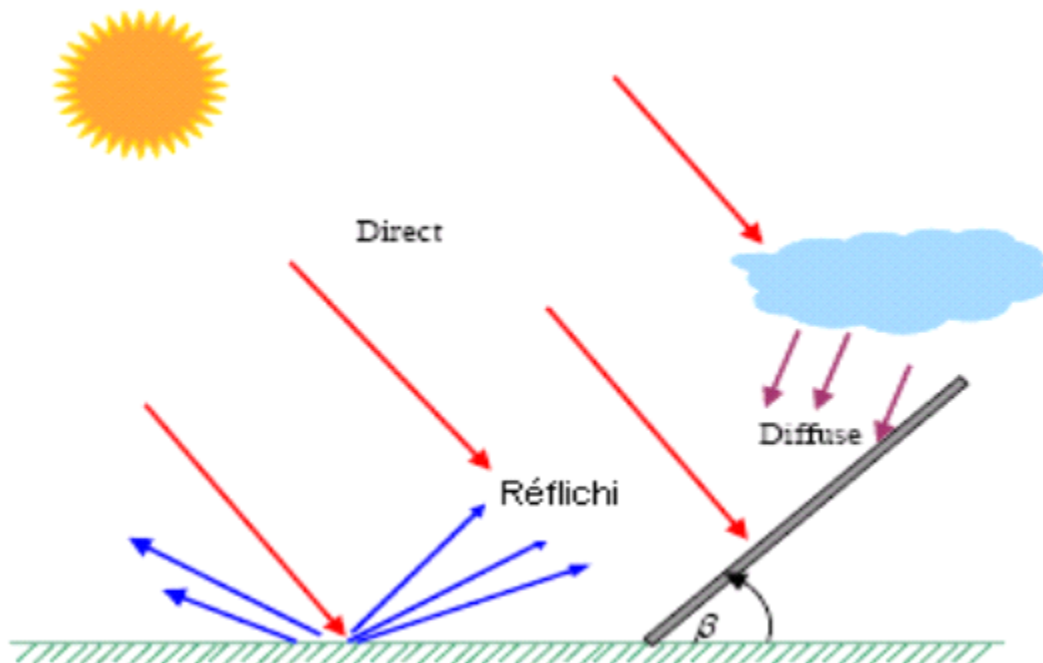
### I-2-2 Solar radiation

The energy transmitted by the sun to the surface of the atmosphere by radiation is equal to 1350 Watts/m<sup>2</sup> (this is the solar constant). However, while passing through the atmosphere, parts of this radiation are reflected, absorbed or scattered as shown in figure I.6, which significantly decreases this value. This reduction is all the stronger as the layer of atmosphere is important. Thus, the energy that the sun transmits to us depends on several factors such as the thickness of the atmosphere where we are or the position of the sun and its value reaches in the best conditions 900 to 1000 Watts/m<sup>2</sup> [4].

- **Direct radiation**, the most powerful, which comes directly from the sun without any obstacles in its path (clouds, buildings, etc.). It is he who blinds us when we try to look at the sun "straight in the eye" in open weather.
- **Diffuse radiation**, comes from multiple diffractions and reflections of direct solar radiation by clouds. It is to him that we owe the "daylight" which allows us to see clearly even when the weather is overcast.
- **Albedo or reflected radiation**, results from the reflection of direct solar radiation by the ground, which is all the more important when the surface is clear and reflective (snow, body of water, etc.). It is he who can make us catch sunburn in the mountains or at the sea without us feeling them coming.
- **Global radiation on a horizontal surface**, is the some of the radiations: Direct and

Diffuse

- **Global radiation on an inclined surface** is the some of the radiations: Direct, Diffuse and Reflected [5].



**Figure (I.2):** components of global solar radiation [5].

### I-2-3 Declination of the sun

It is the angle formed by the direction of the sun and the earth's equatorial plane [6].

Its value in degrees is given by the following Cooper relation:

$$\delta = 23.45 \cdot \sin \left[ 2\pi \cdot \left( \frac{284+j}{365} \right) \right] \quad (\text{I.2})$$

Where

j: is the number days of the year (n=1 for January 1, n=32 for January 1 February, etc.) The declination varies between  $-23.45^\circ$  on December 21 and  $+23.45^\circ$  on June 21.

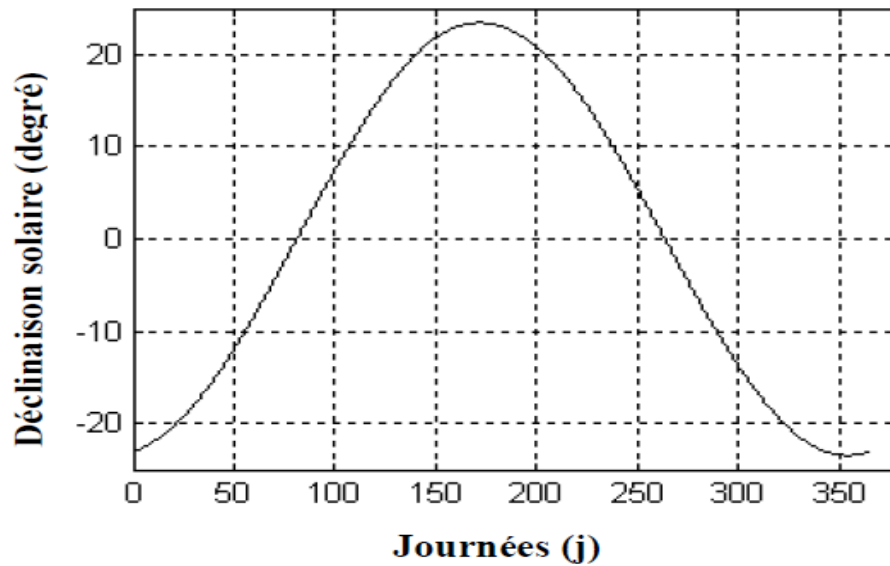


Figure (I.3): Declination curve of the sun [7].

### I-3 Photovoltaic solar energy

Photovoltaic solar energy refers to the energy recovered and transformed directly into electricity from sunlight by photovoltaic panels. It results from the direct conversion in a semiconductor of a photon into an electron.

Photovoltaic solar energy is a non-polluting source of energy is available in abundance all over the earth's surface, and despite significant attenuation as it passes through the atmosphere, the amount that remains is still significant enough until it reaches the ground. We can thus count on 1000 W/m<sup>2</sup> peak in temperate zones and up to 1400 W/m<sup>2</sup> when the atmosphere is slightly polluted [8].

#### I-3-1 History

-1839: Antoine Becquerel publishes a memoir on the electrical effects produced under the influence of the sun's rays relating to an experiment conducted by his son Edmond with a battery consisting of electrodes of platinum and oxidized copper immersed in an acidic electrolyte solution. This stack is capable of supply current.

- 1877: WG Adams and RE Day discover the photovoltaic effect of selenium, and C. Fritts develops the first cell-based photovoltaic panel in Selenium.

-1905: Albert Einstein publishes an article on the photoelectric effect, for which he

Obtained a Nobel Prize in 1921.

-1954: DM Chaplin, CS Fuller and GL Pearson, two Bell engineers

Telephone Laboratories (United States), announce the development of a cell

Whose energy conversion efficiency reaches 6%, thus marking

Truly the birth of photovoltaic electricity.

-1959: the United States launches Vanguard, the first powered satellite, into orbit

By photovoltaic cells.

-1970s: Oil crises increase interest and credit for

Photovoltaic energy.

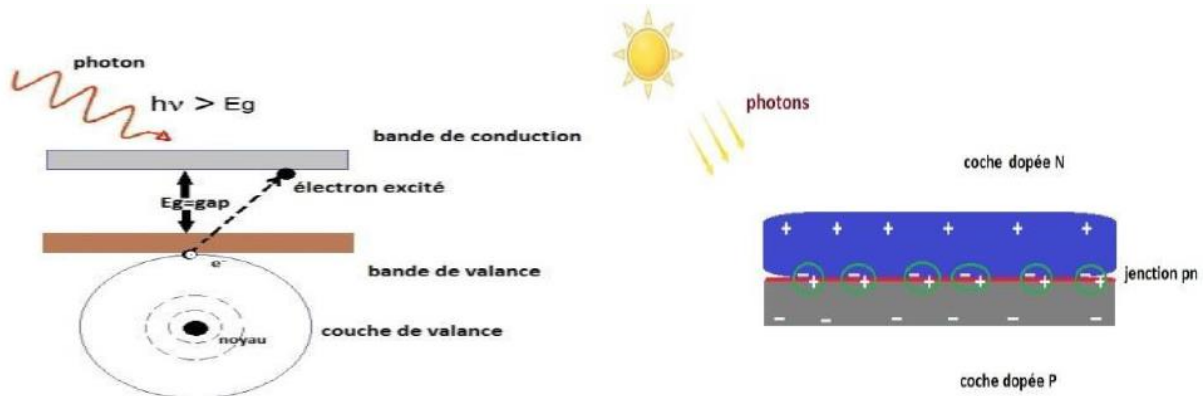
-1978: the first megawatt peak installed is reached in 1978.

-From 2010 to 2016: the installed capacity of the worldwide photovoltaic park was

Multiplied by 6 between the end of 2010 (50 GW) and the end of 2016 (305 GW) [9].

### **I-3-2 The photovoltaic effect**

The photovoltaic effect occurs when a photon is absorbed in a material composed of p (positive) and n (negative) doped semiconductors, referred to as pn junction (or np). Under the effect of this doping, an electric field is present in the material of permanently (as a magnet has a permanent magnetic field). When an incident photon (grain of light) interacts with the electrons of the material, it releases its energy ( $h\nu$ ) to the electron which finds itself released from its valence band and therefore undergoes the intrinsic electric field. Under the effect of this field, the electron migrates towards the upper face giving way to a hole which migrates in the opposite direction. Electrodes placed on the upper and lower faces make it possible to collect the electrons and make them carry out electrical work to reach the hole on the front face, thus creating an electric current [10].



**Figure (I.4):** Excitation of valence electrons by photons and junction (PN) [11].

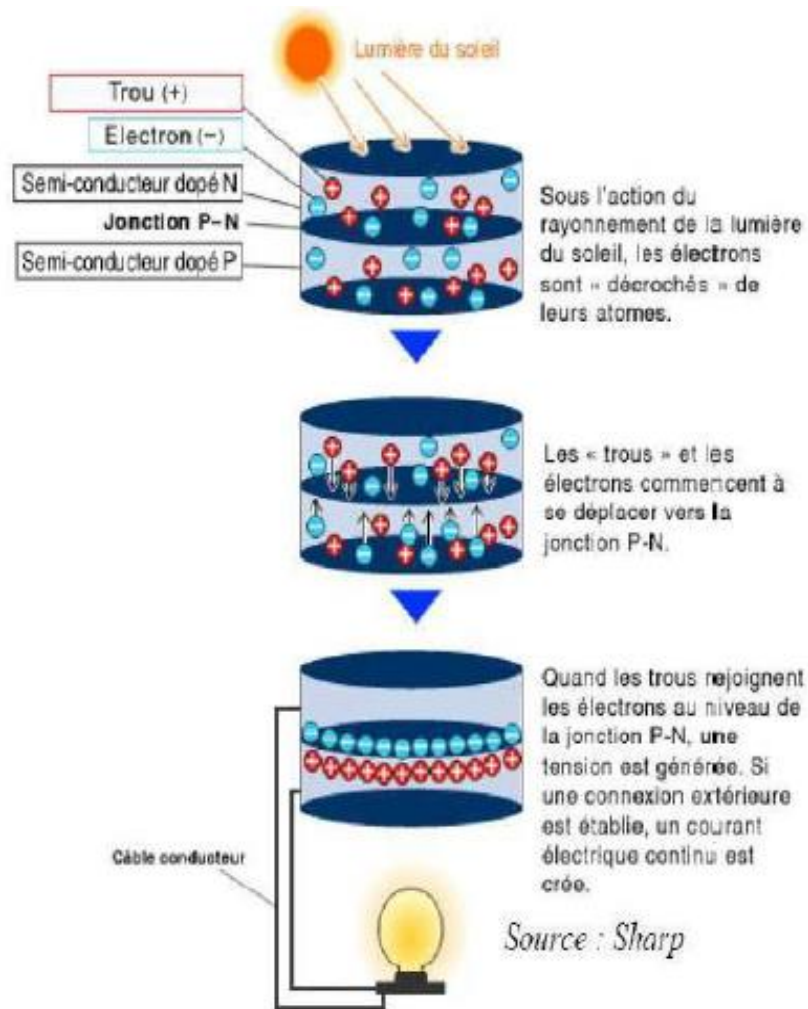
#### I-4 Principle of operation of a photovoltaic (PV) installation

The operating principle of a photovoltaic solar installation is relatively simple: it involves converting the sun's radiation into electricity.

This operation is based on a physical phenomenon called the photovoltaic effect. This mechanism was discovered in 1839 by Antoine Becquerel but it was only explained near a century later by Albert Einstein, which won him the Nobel Prize in Physics in 1921.

Very schematically. The photovoltaic effect occurs when a photon is absorbed in a material composed of p (positive) and n (negative) doped semiconductors, referred to as a pn (or np) junction. Under the effect of this doping, an electric field is permanently present in the material (like a magnet has a permanent magnetic field).

When an incident photon (grain of light) interacts with the electrons of the material, it yields its energy to the electron which finds itself released from its valence band and therefore undergoes the field intrinsic electricity. Under the effect of this field, the electron migrates towards the upper surface giving way to a hole that migrates in the opposite direction. Electrodes placed on the faces upper and lower allow the electrons to be harvested and made to do work electric to join the hole of the anterior face. A photovoltaic cell is made of one of these materials, generally silicon, and designed in such a way that the emitted electrons are recovered to form a Electric power. The cells are assembled to create a sufficiently high current to be exploited; this assembly of cells is called photovoltaic module or, more often, solar panel [12].

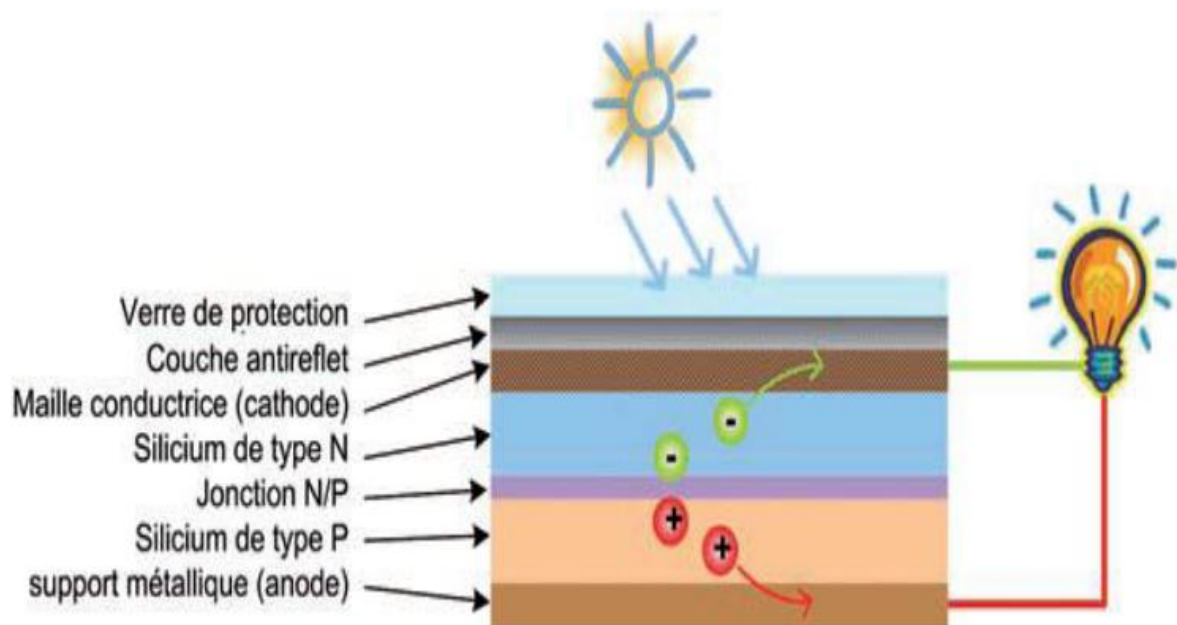


**Figure (I.5):** photovoltaic operating principle [12].

### I-5 Photovoltaic cell

The photovoltaic cell is the basic element that allows the direct conversion of solar energy (ray of light), to electrical energy. This mode of conversion is based on a well-known principle which is the photovoltaic effect. And to pass from the photovoltaic effect to the practical application, it is necessary to find semiconductor materials that optimize the two essential phases of this principle, i.e. the absorption of incident light and the collection of electrons in surface. PV cells are made from semiconductor materials that are capable of conducting or transporting electricity. More than 90% of solar cells manufactured today are made of crystalline silicon, a semiconductor. One side of the cell is n-doped (e.g. phosphorus). The other is p-doped (e.g. boron).

Metal electrodes are placed on both sides to collect the electrons and make an electrical circuit. The upper face of the cell is treated in such a way as to optimize the amount of light entering the cell by means of surface treatment, for the application of an anti-reflection layer, and another layer of glass for sealing and cell protection. Finally, the upper and lower faces are equipped with electrodes to harvest electrons [13].



**Figure (I.6):** Constitution of a photovoltaic cell [14].

### I-5-1 Photovoltaic cell technologies

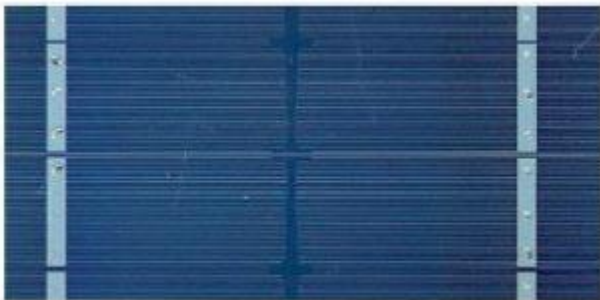

Different materials and structures are used to improve the performance of PV cells and increase efficiency. There are several types of solar cells according to their structures: thin film solar cells, organic solar cells and silicon solar cells. We will present only the latter mentioned, as they are the most widespread [14].

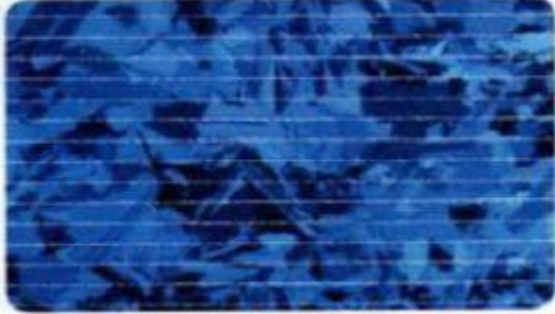
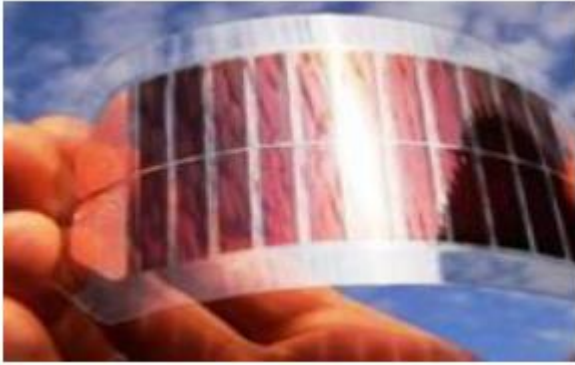
**1). Cells based on monocrystalline silicon:** The cells are made with perfectly crystallized silicon cut into bars. It is the most common material, and moreover it has the advantage of having a very good yield, between 12% and 16%. is the price, due to a long and energy-intensive manufacturing process. It is used outdoors for high and medium power (dwellings, relays, telecommunications, etc.) [13].

**2). Cells based on polycrystalline silicon:** Polycrystalline silicon cells are cut from reconstituted silicon bars; atoms are not all crystallized. The yield is less good, between 11% and 14%. The advantage of these cells by compared to those in monocrystalline silicon lies in their price, then that their manufacture, producing little waste, requires 2 to 3 times less energy and is faster. They have the same applications as monocrystalline silicon cells [13].

**3). Amorphous silicon cells:** This silicon is much less powerful than the two previous ones, because the atoms are arranged in a disordered way due to the fact that the cells are made by spraying silicon onto another material, such as glass or plastic. This very thin layer of silicon nevertheless meets many needs related to lighting (exterior or interior). Its yield is 5% to 7%. It is used for electronics, in calculators for example [13].

**4). the basic organic and plastic cells:** they are composed of a bilayer of molecules evaporated under vacuum, reaches 0.95% conversion yield, these cells include two "wet" cell pathway and the organic polymer cell pathway also called "plastic" cells. The progress of these technologies is very rapid, records performance are very frequently beaten (currently close to 6%). They open also the way to light, nomadic and flexible applications [15].

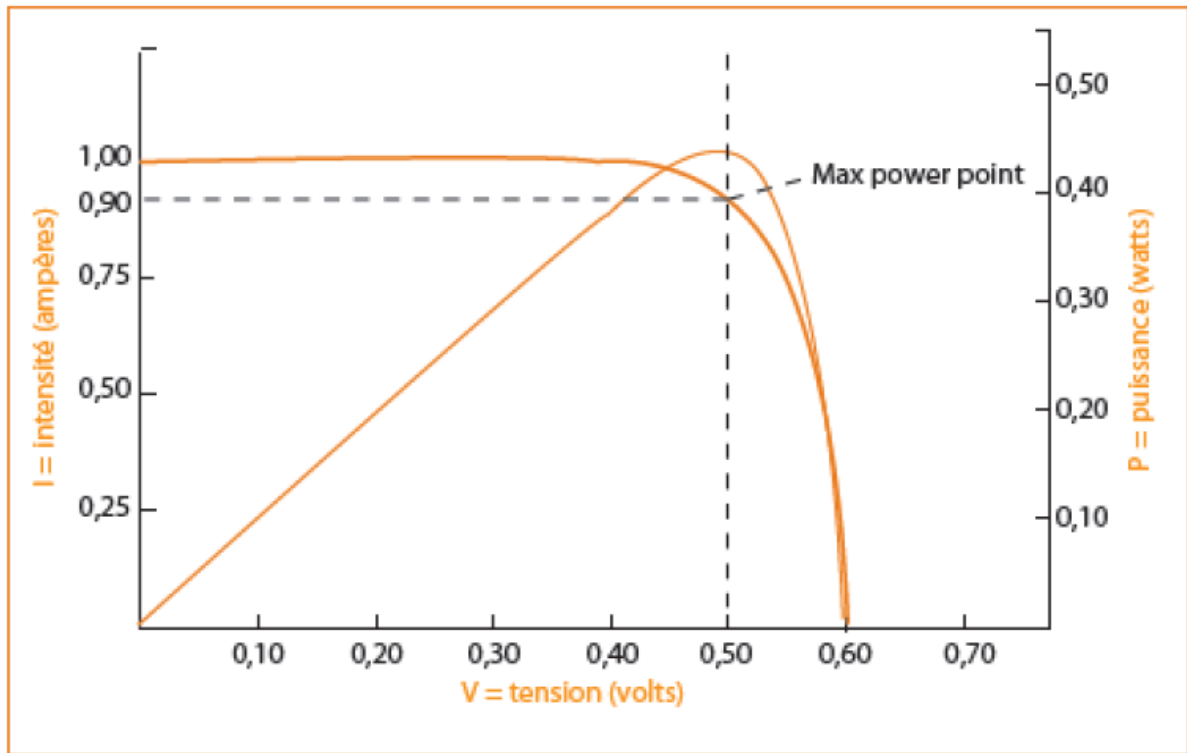
Cell type	Texture
<p><b>Silicon cell Monocrystalline</b></p>	
<p><b>Silicon cell Polycrystalline</b></p>	

<b>Silicon cell Amorphous</b>		
<b>Organic based cells and plastics</b>		

**Table (I.7):** Different types of photovoltaic cells [16].

### **I-5-2 Characteristics of photovoltaic cells**

The electrical properties of the cell are synthesized in a graph called the current-voltage characteristic as shown in **Figure (I.8)**.



**Figure (I.8):** Evolution of the characteristic  $I = f(V)$  and  $P = f(V)$  of a cell [17].

- **The short-circuit current  $I_{sc}$ :**

This is the current obtained by short-circuiting the terminals of the cell. He believes linearly with the illumination intensity of the cell and depends on the illuminated surface [17].

$$I_{ph} = I_{cc} - I_s \left[ \exp\left(\frac{V_{cell} + I_{ph} R_s}{nV_t}\right) - 1 \right] - \frac{V_{cell} + I_{ph} R_s}{R_p} \quad (I.2)$$

Where:

$I_s$  (A): is the saturation current.

$V_t$  (V): the thermodynamic potential.

$K$  ( $JK^{-1}$ ): the Boltzmann constant.

$T$  (K): the effective temperature of the cell in Kelvin.

$e$  (C): the charge of the electron, the non-ideality factor of the junction.

$I_{ph}$  (A): is the current supplied by the cell.

$V_{cell}$  (V): the voltage at its terminals.

$I_{sc}$  (A): the Cell short-circuit current depending on irradiance and temperature.

$R_p$  ( $\Omega$ ): the shunt resistance characterizing the leakage currents of the junction.

$R_s$  ( $\Omega$ ): the series resistance representing the various resistances of contacts and connections.

- **The open circuit voltage  $V_{co}$ :**

The open circuit voltage is obtained when the current flowing through the cell is zero. It decreases with temperature and varies little with light intensity [17].

$$V_{co} = V_t \log \left( \frac{I_{ph}}{I_s} + 1 \right) \quad (I.3)$$

- **Maximum Power  $P_{max}$ :**

For an ideal solar cell, the maximum power  $P_{max}$ , would therefore correspond to the maximum voltage multiplied by maximum current [17].

$$P_{max} = V_{max} * I_{max} \quad (I.4)$$

- **The form factor  $FF$ :**

It is the ratio between the maximum power that a cell can provide and the power that it is theoretically possible to obtain (optimal power) [17].

$$FF = \frac{P_{max}}{V_{co} * I_{cc}} \quad (I.5)$$

- **The yield  $\eta$ :**

The efficiency of the cell which corresponds to the ratio between the maximum electrical power supplied by the cell and the incident solar power [17].

$$\eta = \frac{V_{max} I_{max}}{P_{inc}} \quad (I.6)$$

$$\eta = \frac{P_{max}}{E.S} \quad (I.7)$$

Where:

S: is a solar cell area.

E: is an incident flow.

### I-6 Photovoltaic panel

The solar cell, round or square in shape, is the basic element of a solar system.

A set of cells forms a solar module, in a module the cells are connected electrically between them and encapsulated, therefore protected from external agents. Several Modules form a solar panel. Several panels form a system or field Solar, to which are added protections, a regulator, a storage system for Energy (battery) control and measuring devices.

The term GPV photovoltaic generator is used to designate, depending on the application considered, a PV module or panel, however, it can allude to the entire PV system.

The general form of the I(V) characteristic of a solar or photovoltaic module is identical to that of an elementary solar cell [14].

### I-6-1 Series association

To increase the voltage of the PV generator, have a number ( $N_s$ ) of cells in series. The cells are then traversed by the same current and the characteristic resulting from the series grouping is obtained by adding the elementary voltages of each cell.

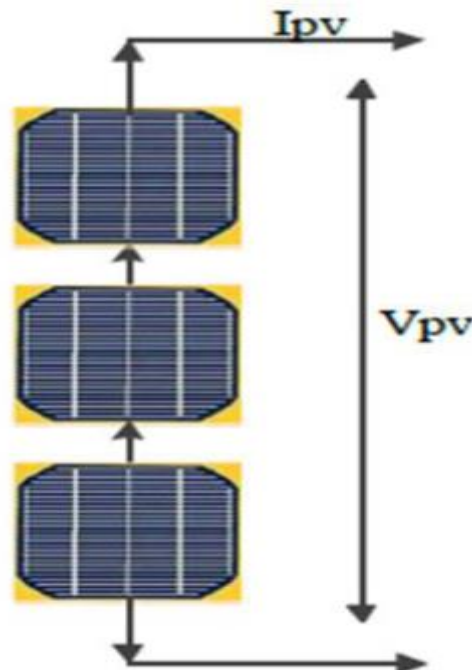
The following equation summarizes the electrical characteristics of a series association of ( $N_s$ ) cells [10].

$$V_{cos} = N_s * V_{co} \quad (I.8)$$

$$I_{ccs} = I_{cc} \quad (I.9)$$

$V_{cos}$  : the sum of the open circuit voltages of  $N_s$  cells in series.

$I_{ccs}$  : short-circuit current of  $N_s$  cells in series.



**Figure (I.9):** Plan 3 photovoltaic cells connected in series [14].

### I-6-2 Combination in parallel

To increase the current of the PV generator, have a number ( $N_p$ ) of Cells in parallel. The cells are subjected to the same voltage and the characteristic Resultant of the grouping is obtained by addition of the currents.

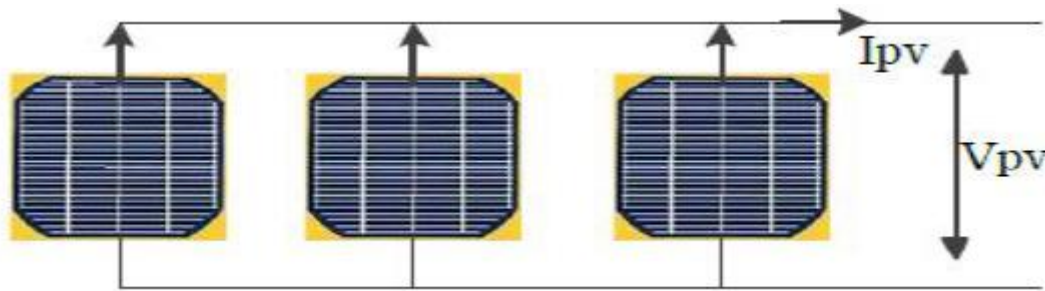
The following equation summarizes the electrical characteristics of a parallel association of ( $N_p$ ) cells [10].

$$I_{ccp} = N_p * I_{cc} \quad (\text{I.10})$$

$$V_{co} = V_{cop} \quad (\text{I.11})$$

$I_{ccp}$  : the sum of the short circuit currents of ( $N_p$ ) cell in parallel.

$V_{cop}$  : the open circuit voltage of ( $N_p$ ) cells in parallel.



**Figure (I.10):** Diagram of 3 photovoltaic cells associated in parallel [14].

### I-6-3 Series/parallel association

This type of association is generally used to obtain high voltage and a suitable high current. In order to obtain powers of a few kW, under a suitable voltage, it is necessary to associate the modules in panels and to mount the panels in rows of series and parallel panels to form what is called a GPV [18].

According to the series and parallel association of these cells, the values of the total short-circuit current and the total open-circuit voltage are given by the following relations:

$$I_{sc} = N_p * I_{cc} \quad (\text{I.12})$$

$$V_{co} = N_s * V_{co} \quad (\text{I.13})$$

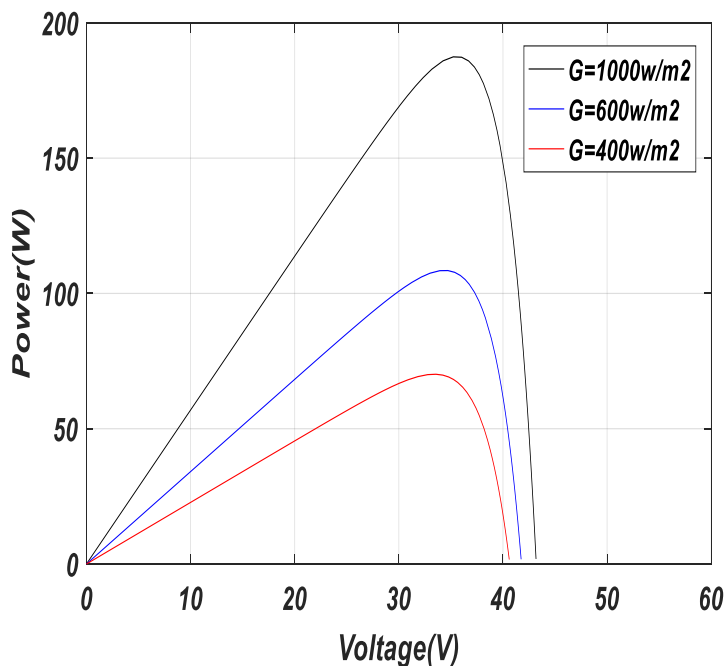
$I_{sc}$ : short-circuit current of the resulting module.

$V_{co}$  : Open circuit voltage of the resulting module.



A decrease in sunlight causes a decrease in the creation of electron-hole pairs with a current changed to darkness. The solar panel current being equal to the subtraction of the photo current and the diode current in the dark, there is a drop in the solar current  $I_{cc}$  proportional to the variation in sunshine accompanied by a very slight decrease in the voltage  $V_{co}$  and therefore a shift of the  $P_{max}$  point of the solar panel to the lower powers.

The previous graph represents the I (V) characteristic of a photovoltaic generator for a constant temperature ( $T=25^{\circ}\text{C}$ ) and variable sunshine.



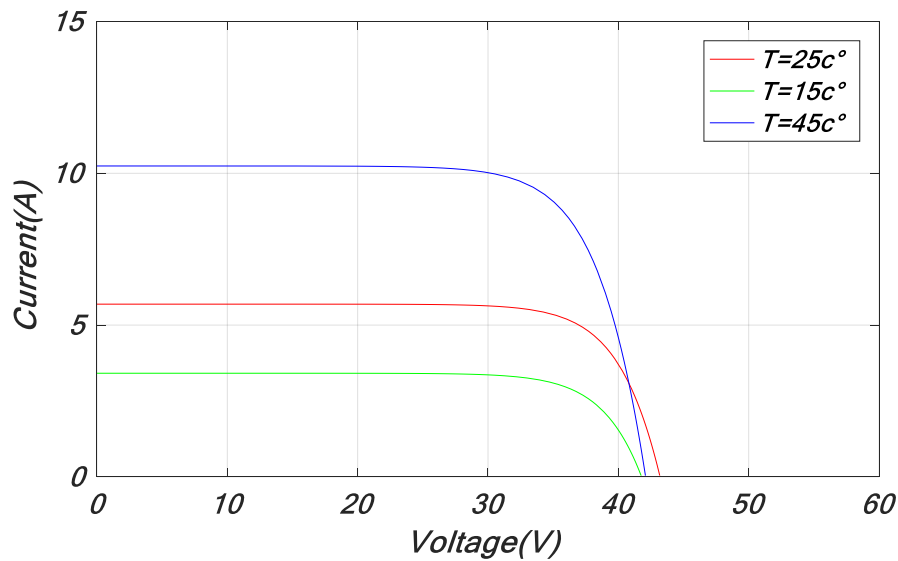
**Figure (I.13):** The influence of illumination on the characteristic  $P = f(V)$ .

The **Figure (I.13)** represents the P(V) characteristic of a photovoltaic generator for a constant temperature ( $T=25^{\circ}\text{C}$ ) and variable insolation.

It is clear that the value of the short-circuit current is directly proportional to the intensity of the radiation. On the other hand, the open circuit voltage does not vary in the same proportions, but remains almost identical even at low illumination.

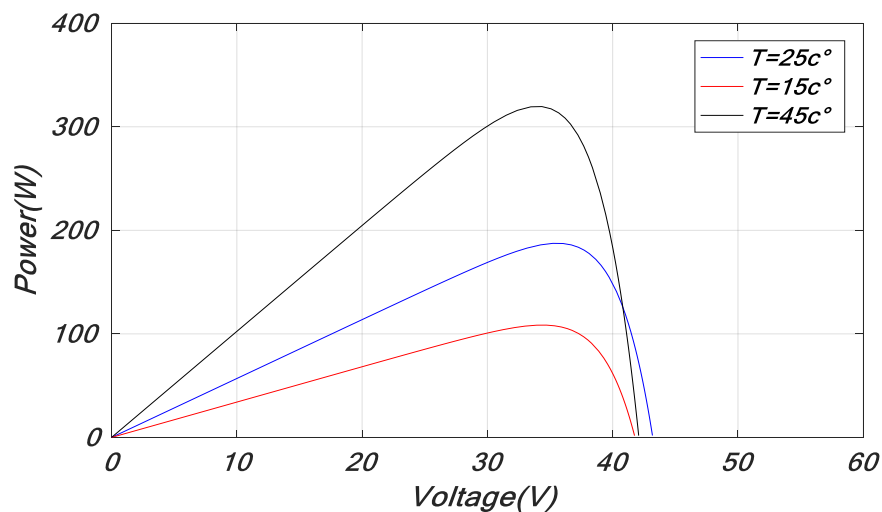
This implies that:

- The optimal power of the cell ( $P_{max}$ ) is practically proportional to the illumination.
- The maximum power points are at approximately the same voltage.
- The following figure represents I(V) curves for different operating temperatures of the photovoltaic module at constant irradiation.



**Figure (I.14):** The influence of temperature on the characteristic  $I = f(V)$ .

It can be seen that the current delivered by each cell depends on the internal temperature of the PN junction which constitutes. If we consider the heating of a PV module from  $10^{\circ}\text{C}$  to  $25^{\circ}\text{C}$  and if we consider as a first approximation that the rear face temperature of each cell is close to the temperature of the PN junction, then we can consider the influence of temperature. It can be seen that the open circuit voltage decreases as a function of an increase in temperature. Consequently, the power available at the terminals of the PV module is lost. The following graph represents  $P(V)$  curves for different operating temperatures of the photovoltaic module at constant irradiation.



**Figure (I.15):** The influence of temperature on the characteristic  $P = f(V)$ .

We notice that the temperature has a negligible influence on the value of the short-circuit current. On the other hand, the open circuit voltage drops quite sharply when the temperature increases.

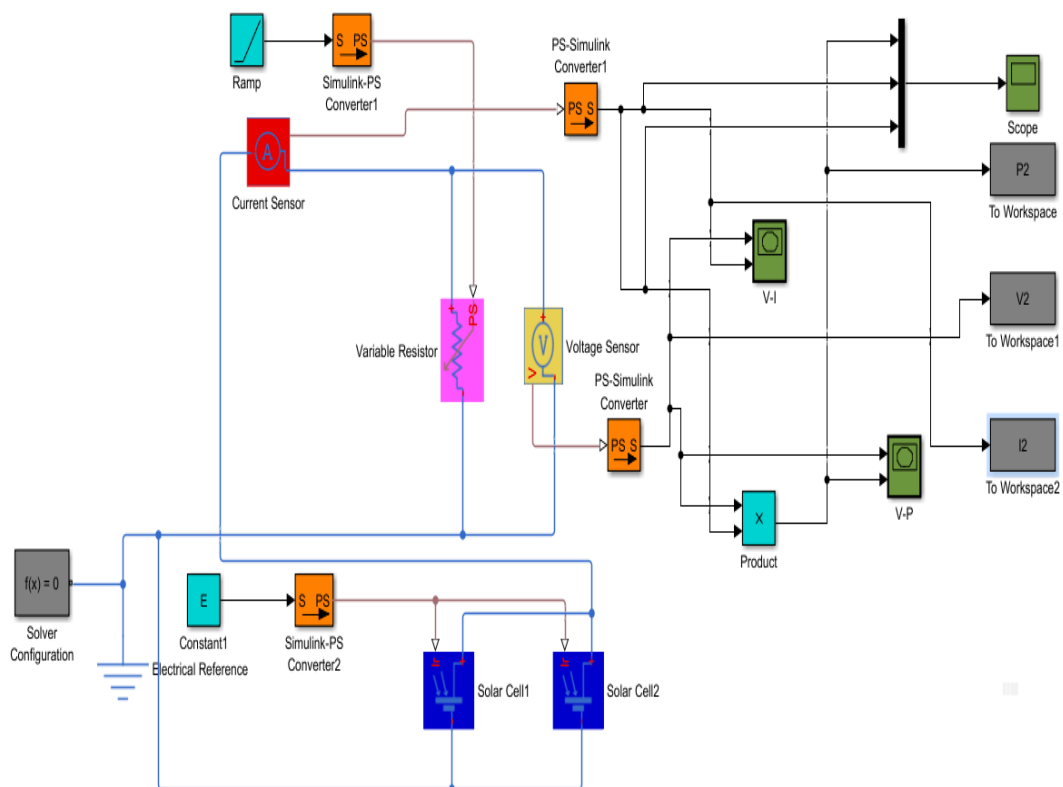
It can therefore be deduced that the panel can supply a correct voltage, even at low lighting, consequently the extractable power decreases. When sizing an installation, the variation in site temperature must be taken into account. It is important to know that the power of the panel decreases approximately 0.5% for each degree of increase in cell temperature above 25°C.

The effect of temperature on the I(V) characteristic can be observed. As shown in the **Figure (I.14)**, the temperature has a slight effect on the current, but an increase in the temperature causes an apparent decrease in voltage.

### I.7.2 Block diagram in Matlab

- *Case of a panel with 2 branches (2 cells in parallel) and 72 cells in series*

The following **Figure (I.16)** represents the block diagram of simulation under Matlab



**Figure (I.16):** Block diagram of a photovoltaic panel.

## Simulation Results

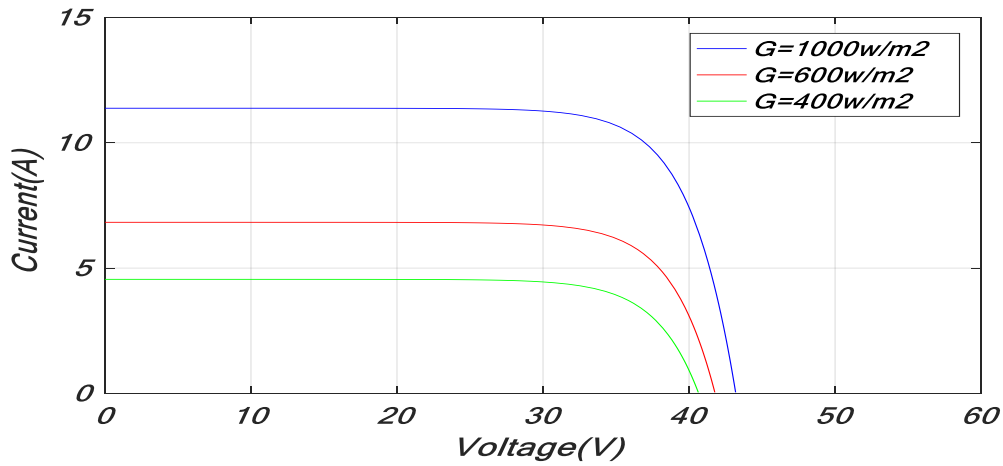


Figure (I.17): The influence of illuminance on the characteristic  $I = f(V)$ .

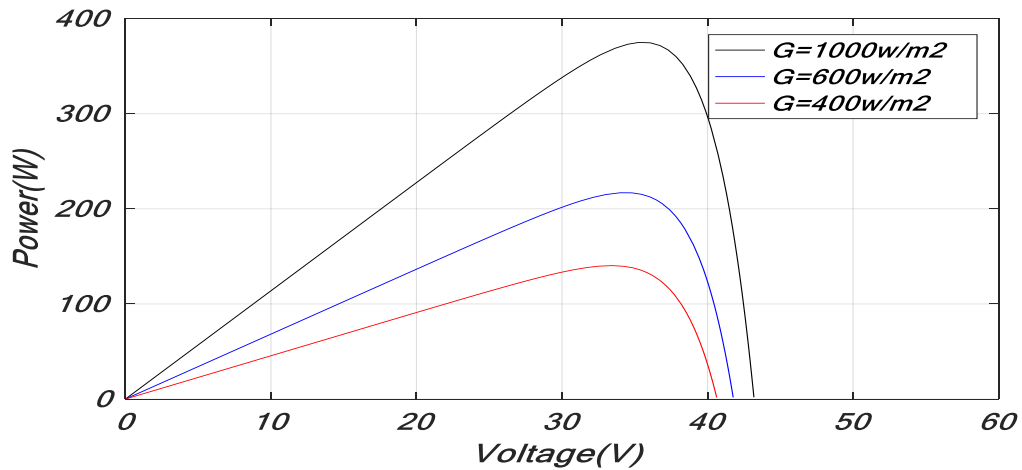


Figure (I.18): The influence of illumination on the characteristic  $P = f(V)$ .

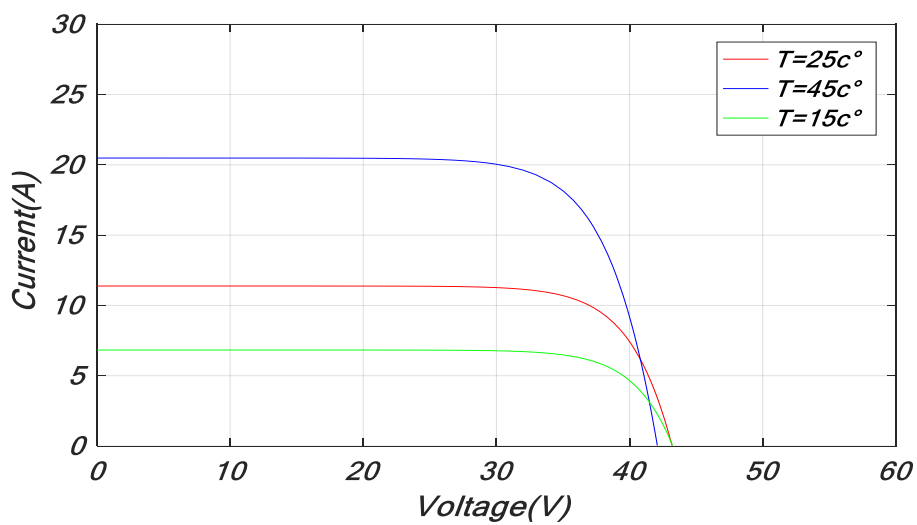
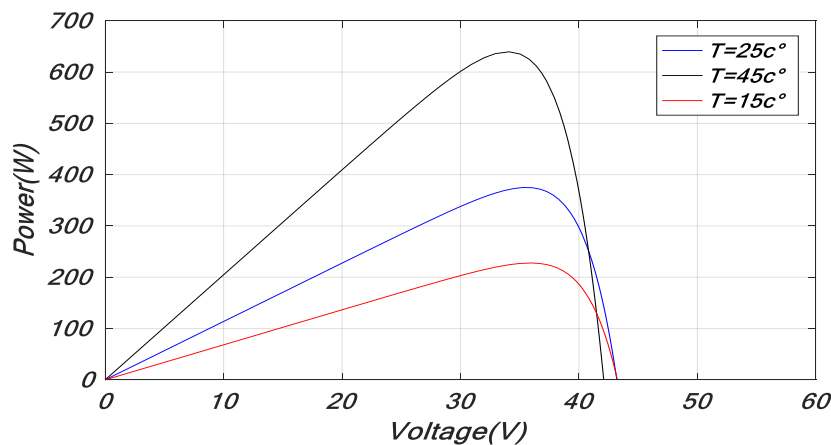


Figure (I.19): The influence of temperature on the characteristic  $I = f(V)$ .



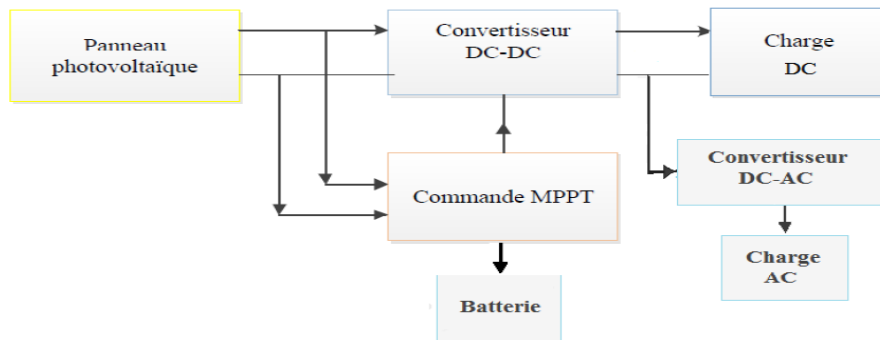
**Figure (I.20):** The influence of temperature on the characteristic  $P = f(V)$ .

### I-8 Composition of a photovoltaic system

Photovoltaic systems appear to be a preferred solution for the Production of low or medium power electricity in an isolated site and particularly for the houses. This PV system is made up of several elements, mainly the PV modules which represent the collection field for the solar rays; the batteries that make up the storage field is where we store the energy produced by the modules; the regulator which protects the battery against overcharging so it regulates the value of the nominal voltage; the inverter which ensures the conversion of the direct current into alternating current which the users need; the wiring that connects the various components of the system to each other [19].

Generally, a photovoltaic installation includes the following elements:

- A photovoltaic generator.
- A direct-to-direct (DC/DC) static converter.
- A static direct/alternate (DC/AC) converter.
- A regulation and storage system [7].

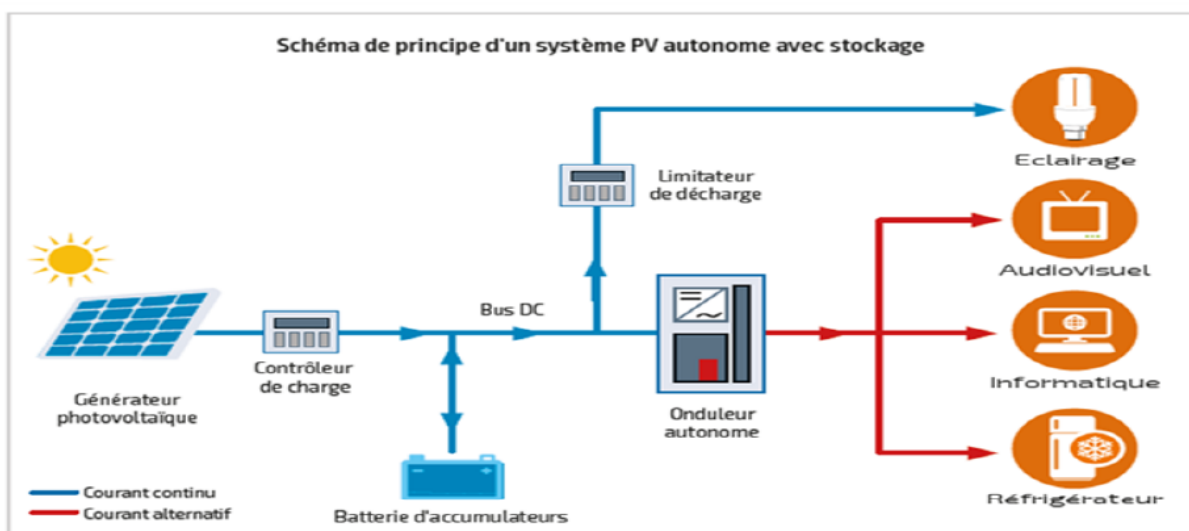


**Figure (I.21):** representation of the different components of a PV installation [7].

### I-8-1 Autonomous system

These photovoltaic systems are installed to ensure autonomous operation without recourse to other energy sources. Generally, these systems are used in isolated regions far from the network.

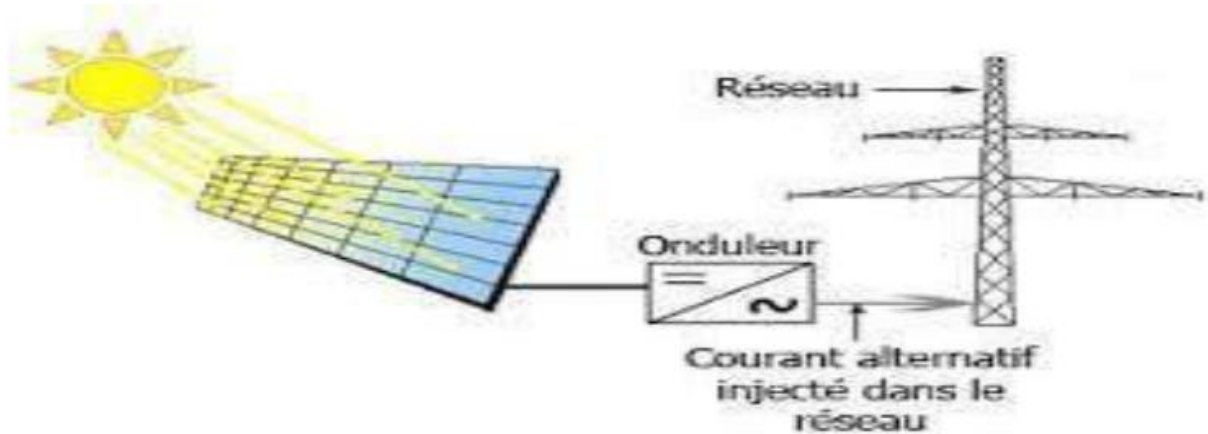
The different types of stand-alone photovoltaic systems have the possibility of direct coupling to a suitable load or coupling with an MPPT (Maximum Power Point Tracking) impedance adapter, operation over the sun or with electrical energy storage. Direct coupling involves operation over the sun, therefore with essentially variable power during the day. Typical direct current loads that can satisfy the criterion (constant voltage at variable power) are electrochemical accumulators. Alternative loads are water pumps or storage is nevertheless present in the form of stored water (in a tank). In most cases, an impedance match must be performed by inserting an electronic device between the generator and its electrical load which forces the system to operate at its maximum power [20].



**Figure (I.22):** Autonomous PV system [20].

### I-8-2 System connected to the network

The photovoltaic field is directly coupled to the electrical grid using a DC/AC converter. Since energy is normally stored in the network itself, accumulators are not needed unless you didn't want a self-contained form of energy during power outages. Energy Produced is consumed on site, the surplus being injected into the network, which supplies the Houses at night or during sunless days [20].



**Figure (I.23):** Grid-connected PV system [20].

### I-8-3 hybrid system

Hybrid energy systems combine at least two renewable energy sources or one or more conventional energy sources. Renewable energy sources, such as photovoltaics and wind turbines, do not deliver constant power, but given their complementarities, their association makes it possible to obtain continuous electricity production.

Hybrid energy systems are generally autonomous from large interconnected grids and are often used in isolated regions. The various sources in a hybrid system can be connected in two configurations, DC bus architecture and AC bus architecture.

In the first configuration, the power supplied by each source is centralized on a DC bus. Thus, alternating current (AC) energy conversion systems first supply their power to a rectifier to then be converted to direct current (DC). The generators are connected in series with the inverter to supply the AC loads. The inverter must supply the AC loads from the DC bus and must follow the setpoint set for the amplitude and the frequency.

The specific function of the supervision system is the start and stop control of the generators and the storage system. The advantage of this topology is simplicity of control. In the second configuration, all the components of the hybrid system are connected to the AC load [21].

**I-9 Advantages and disadvantages of photovoltaic energy**

Photovoltaic energy has enormous advantages such as:

- Free of this resource and enormity of its potential spread over the globe
- Cleanliness during use,
- High reliability
- Low maintenance
- High production flexibility (ranging from milli watts to megawatts)
- Autonomous and decentralized use [22].

Despite these interesting advantages, there are also disadvantages such as:

- Diffuse source of solar radiation that requires large areas
- Expensive technology
- Low load factor
- Difficult storage
- Difficulty recycling system components High investment dependent on political decisions [22].

**I-10 Conclusion:**

In this chapter we have studied the principle of conversion of solar energy into electrical energy by photovoltaic cell, as well as the types of photovoltaic cells, its characteristics and the technologies used in the design of these cells. Then we integrated the panels and identified their properties of energy, current, tension and temperature.

We noticed the difference of a photovoltaic system installation. The advantages and disadvantages during the production of electrical energy based on photovoltaic solar energy have also been described.

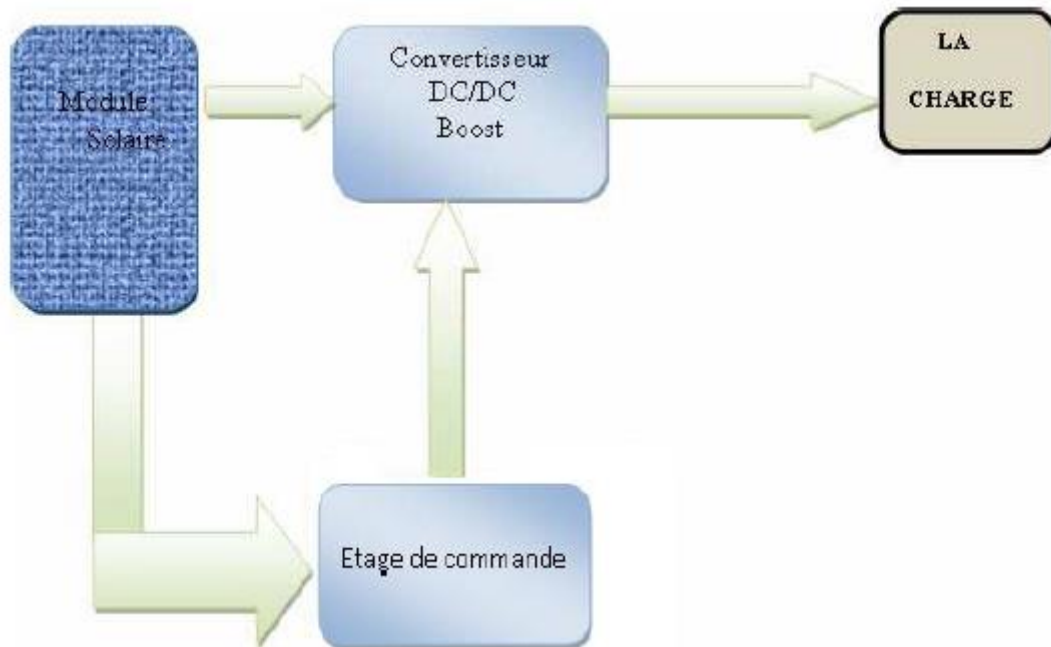
## Chapter II

Study and simulation of  
DC-DC converters

### II-1 Introduction:

A photovoltaic conversion string means a photovoltaic generator (GPV) connected to a load via a converter. Depending on the intended application, the photovoltaic energy is either used as it is by the load, or stored or injected directly into the electrical network.

In order to extract at each instant the maximum power available at the terminals of the photovoltaic generator and to transfer it to the load, the technique used is to add an adaptation stage (chopper) between the source and the load **Figure (II.1)**, this stage makes it possible to control the power, to reduce the amount of energy lost and that the transfer of energy can be carried out under optimal operating conditions for the PV source and the load [22].



**Figure (II.1):** Stage adaptation between a GPV and a load [22].

### II-2 DC-DC converters

Choppers are DC-DC type converters for controlling the electrical power in circuits operating in direct current with great flexibility and high efficiency.

The chopper consists of capacitors, inductor and switches. In the case ideally, all these devices do not consume any active power, which is why we have good yields for choppers [23].

The **Figure (II.2)** shows the representation of a DC-DC converter, which can be used as an interface between source and load [24].

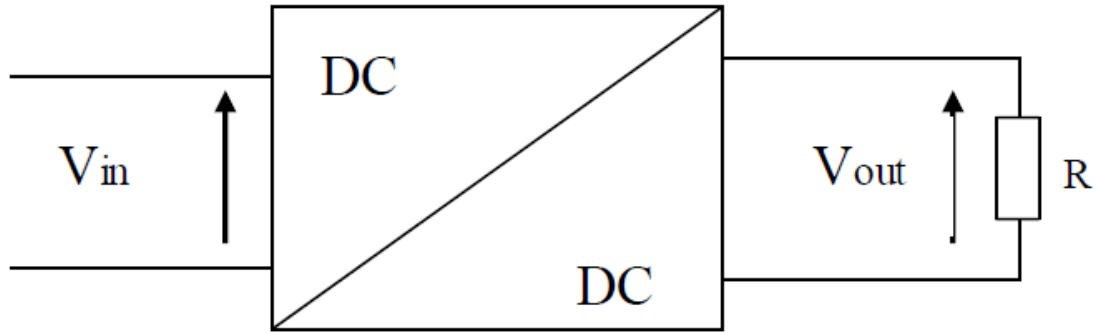


Figure (II.2): DC/DC converter [24].

### II-3 Methods for studying power converters

For each power converter, the study method essentially consists of:

- To present the waveforms characterizing the operation, possibly for various power transfers.
- To deduce the relationships between the mean or effective values of the currents and voltages at the input and output of the converter.
- Consider power transfer control.
- To plan the components to be used according to the type of conversion and the desired nominal power, it is then necessary to consider the losses in these components.
- To plan and set up the protections of the components and of the whole of the converter [25].

### II-4 Basic structure of DC-DC converters

We consider in the presentation of chopper assemblies that:

- The input source of the converter is a DC voltage source  $V_e$ .
- The output is also considered as a DC voltage source  $V_s$ .
- The load is similar to a resistance  $R$ .

The circuit of a chopper basically consists of capacitor, inductor and semiconductor. In the ideal case, all these devices do not consume any active power, which is the reason why these converters have a good efficiency [26].

### II-5 Field of use of choppers

One of the major areas of use of choppers is the speed variation of the DC motor (MCC). They are fitted, for example, to the majority of medium-traction vehicles, such as

those used for the metro. The first generation of TGV is equipped with direct current chopper-motor assemblies.

We also find choppers in all equipment intended for the use of wind or solar energy [27].

## II-6 Different types of choppers

There are several types of DC-DC converters which include converters with galvanic isolation between the input and the output and converters which have a common terminal between the input and the output.

In energy storage converters, three types of static converters are distinguished:

- “Buck converter” step-down chopper
- “Boost converter” step-up chopper
- Buck-Boost converter step-down chopper [27].

### II-6-1 “BOOST” boost converter

Boost Chopper, Boost Chopper, Parallel Chopper, 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  $S$  can be replaced by a transistor since the current is always positive and the switching must be controlled (on blocking and on starting) [28].

#### II-6-1-1 Converter diagram

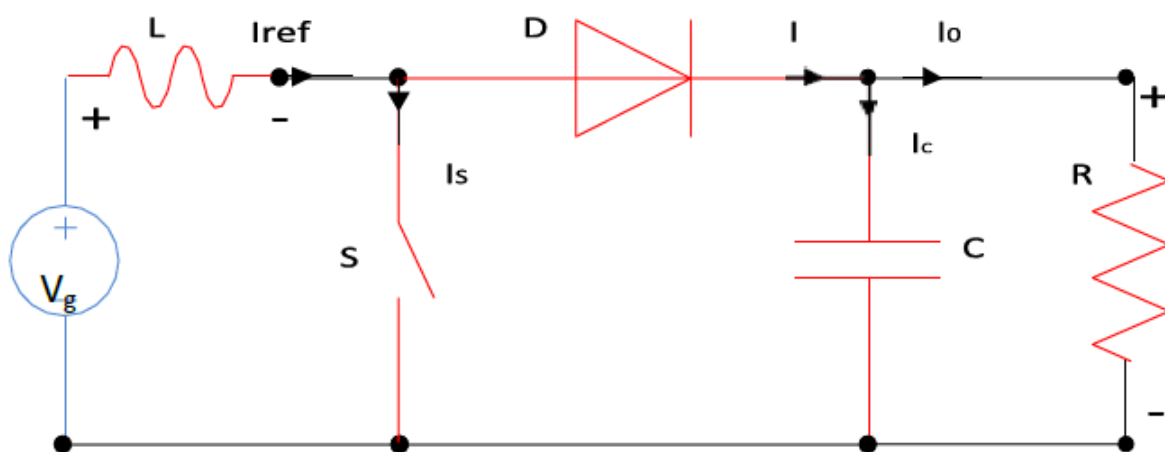


Figure (II.3): boost converter [29].

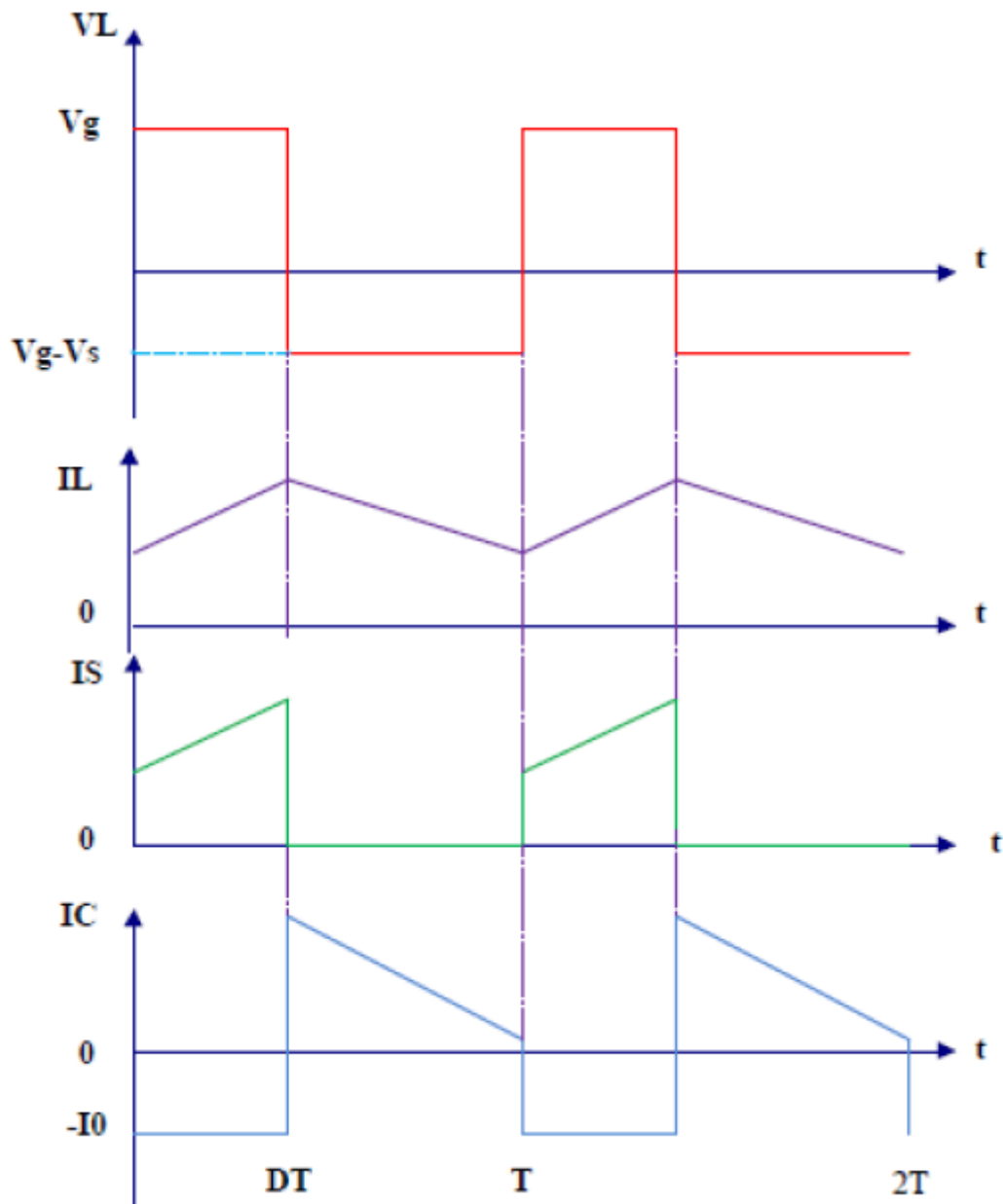
#### II-6-1-2 Principle of operation

The switch  $S$  is closed for a time  $t_{on}$ , the current flowing through the inductance  $L$

increases linearly and capacitor C charges and maintains the voltage across its terminals until switch S opens. The voltage across diode D being negative, no current passes through it. Switch S is open for a time  $t_{off}$ . The diode becomes conductive in order to ensure the continuity of the current in the inductor L. The current crossing the inductor L decreases and the capacitor C discharges through the diode D on the load R.

When switch S is on, the diode is reverse biased. Source E is not connected to load R. When switch S is off, diode D is forward biased and conducts. What connects load R to source  $V_g$  [29].

In the **Figure (II.4)** it is necessary to represent typical voltage and current waveforms.



**Figure (II.4):** Characteristic of the voltage and current of the booster chopper [29].

### 1. Converter model

When switch S is on,  $D=1$ , we obtain the following dynamic:

$$V_L = V_{in} \quad (II.1)$$

$$L \frac{di}{dt} = V_{in} \quad (II.2)$$

$$C \frac{dv}{dt} = \frac{-V_{out}}{R} \quad (II.3)$$

From equation (II.28)

$$I(t) = \frac{V_{in}}{L} t + I_{min} \quad (II.4)$$

The current increases linearly with time until it reaches its maximum at

$$t \rightarrow t_{on} = DT:$$

$$I_{max} = \frac{V_{in}}{L} DT + I_{min} \quad (II.5)$$

From the above equation we have:

$$\Delta I = \frac{V_{in}}{L} DT \quad (II.6)$$

When the switching function is  $D = 0$ , we get the following dynamics:

$$V_L = V_{in} - V_{out} \quad (II.7)$$

$$L \frac{di}{dt} = V_{in} - V_{out} \quad (II.8)$$

$$I(t) = \frac{v_{in}-v_{out}}{L} t + I_{max} \quad (II.9)$$

$$C \frac{dv}{dt} = -\frac{V_{out}}{R} \quad (II.10)$$

When  $t \rightarrow t_{we}$  the current through the inductor decreases linearly from its maximum value to its minimum value:

$$I_{min} = \frac{v_{in}-v_{out}}{L} (1 - D)T + I_{max} \quad (II.11)$$

SO :

$$\Delta I = \frac{v_{out}-v_{in}}{L} (1 - D)T \quad (II.12)$$

By combining these two relations (II.6) and (II.12), we can establish the expression of the output voltage:

$$\frac{V_{in}}{L} DT = \frac{v_{out}-v_{in}}{L} (1 - D)T \quad (II.13)$$

Which implies :

$$V_{out} = \frac{1}{(1-D)} V_{in} \quad (II.14)$$

### 2. Determination of L, C:

During phase 1 which lasts  $DT$ , the capacitor only provides energy to the load. The flow of output being supposed constant, one can calculate the charge provided by the condenser:

$$\Delta S = \frac{V_{out}}{R} DT \tag{II.15}$$

If we admit a ripple  $\Delta V_{out}$  of the output voltage, we can write:

$$\Delta S = C \Delta V_{out} \tag{II.16}$$

We deduce the capacitance of the output capacitor:

$$C = \frac{\Delta S}{\Delta V_{out}} \tag{II.17}$$

The value of the inductance, we established the relationship:

$$\Delta I = \frac{V_{in}}{L} DT \tag{II.18}$$

We get the value of the inductance:

$$L = \frac{DV_{in}}{f\Delta i} \tag{II.19}$$

### II-6-1-3 Simulation of the BOOST chopper

In order to know the nature of the current and the voltage after having passed through the buck chopper we enter the following values:  $V_s = 15V$ ,  $R = 10$ ,  $L = 45 \text{ mH}$ ,  $C = 150 \mu F$  with a PWM signal duty cycle  $DC = 0.6$ .

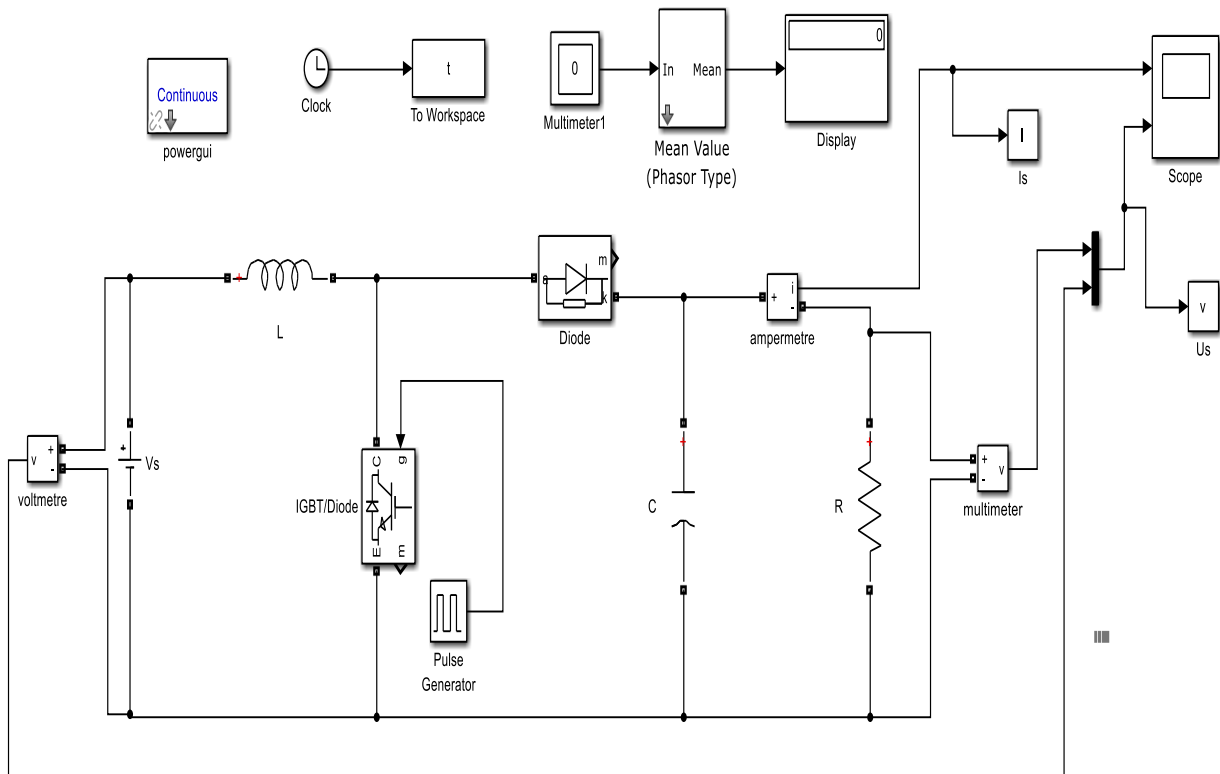
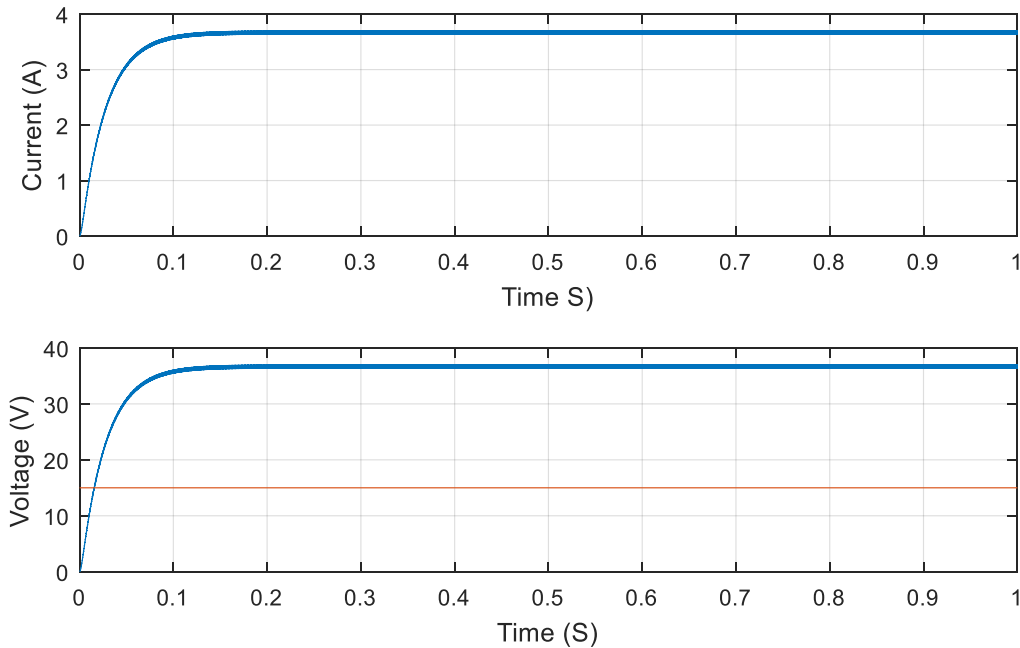


Figure (II.5): Block diagram of a boost converter.

## 1) Simulation results:



**Figure (II.6):** The average value of the voltage across the terminals of load and output current.

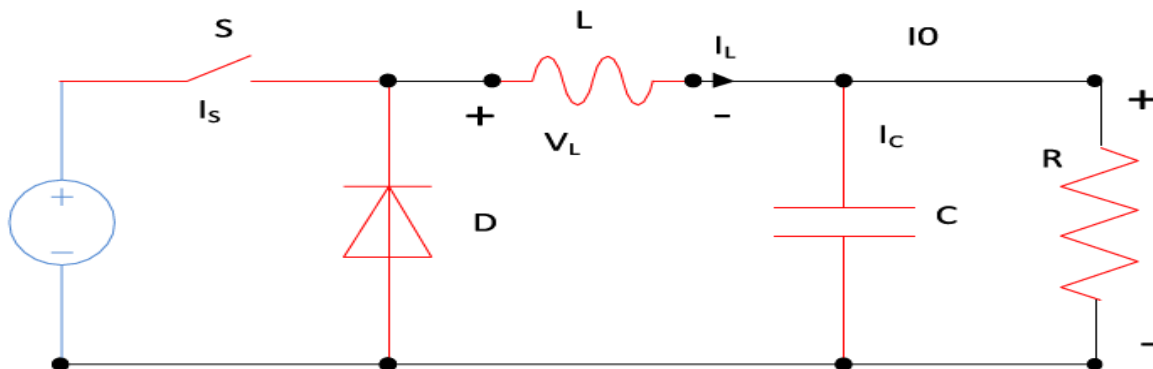
## 2) Interpretation of the results obtained

AT From these results, we noticed that the circuit fulfilled its function correctly. Because the output voltage is higher than the input voltage.

## II-6-2 "BUCK" step-down converter

Buck Chopper, Buck Chopper, Serial Chopper, Buck Chopper. The serial chopper is a direct DC–DC converter. The input source is a DC voltage type and the DC output load is a current source type. The switch  $S$  can be replaced by a transistor since the current is always positive and the switching must be controlled (on blocking and on starting) [28].

## II-6-2-1 Converter diagram



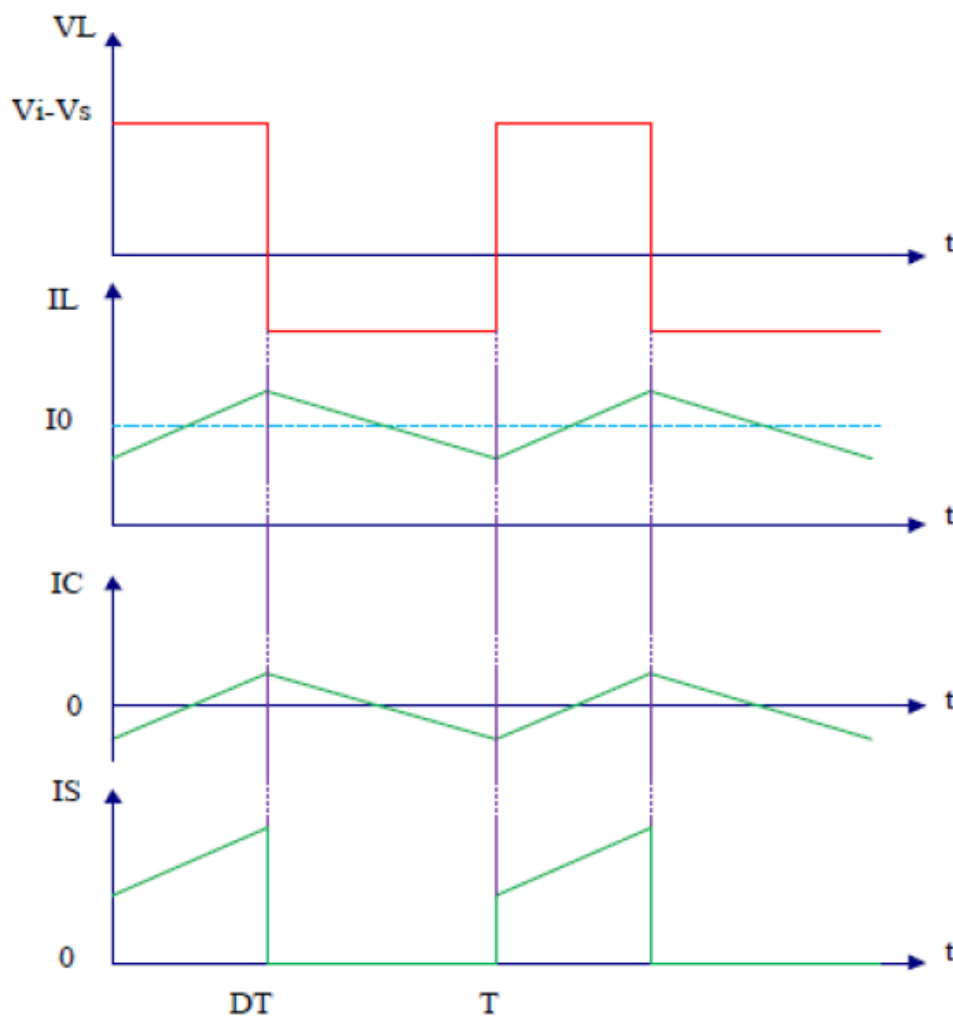
**Figure (II.7):** converter buck [29].

### II-6-2-2 Principle of operation

In the ideal case, the operation of the buck chopper can be divided into two phases depending on the state of transistor S.

S is closed during  $DT$  of switching period  $T$ . The photovoltaic source supplied the energy the load  $R$  and the inductance  $L$ , the voltage  $V_{out} = V_{pv}$ . When transistor S is blocked, the voltage across the terminals of the inductance is reversed, the freewheel diode ensures the continuity of the current and the discharge from  $L$  to  $R$ . The voltage  $V_{out} = 0$ .

The output voltage is adjusted by acting on the ratio  $\alpha$  and the waveforms in conduction are presented in the **Figure ()** [29].



**Figure (II.8):** Characteristic of voltage and currents in the transistor and the inductance of a Buck converter [29].

#### 1. Converter model

If we consider that the switch is in the position  $D=1$ , and applying Kirchhoff's laws to the resulting circuit, we obtain the following equations:

$$V_L = V_{in} - V_{out} \quad (II.20)$$

$$L \frac{di}{dt} = -V_{out} + V_{in} \quad (II.21)$$

$$L \frac{dv}{dt} = I - \frac{V_{out}}{R} \quad (II.22)$$

From equation (II.21)

$$I(t) = \frac{V_{in} - V_{out}}{L} t + I_{min} \quad (II.23)$$

The current increases linearly with time until it reaches its maximum.

$t \rightarrow t_{on} = DT$ :

$$I_{max} = \frac{V_{in} - V_{out}}{L} DT + I_{min} \quad (II.24)$$

From the above equation we have

$$\Delta I = \frac{V_{in} - V_{out}}{L} DT \quad (II.25)$$

$$\Delta I = \frac{V_{in} - D(1-D)}{L_f} \quad (II.26)$$

The relation (II.26) shows that the ripple of the current in the receiver is all the lower as the chopping frequency is high, therefore a strong increase in this frequency would require the use of fast-switching components. When the switch is in position  $D=0$  which gives us:

$$V_L = -V_{out} \quad (II.27)$$

$$L \frac{dI}{dt} = -V_{out} \quad (II.28)$$

$$I(t) = \frac{-V_{out}}{L} t + I_{max} \quad (II.29)$$

$$C \frac{dv}{dt} = I - \frac{V}{R} \quad (II.30)$$

$$I_{max} = \frac{-V_{out}}{L} (1 - D)T + I_{max} \quad (II.31)$$

SO

$$\Delta I = \frac{V_{out}}{L} (1 - D)T \quad (II.32)$$

From the two equations (II.25) and (II.32) we will have:

$$\frac{V_{out}}{L} (1 - D) T = \frac{V_{in} - V_{out}}{L} DT \quad (II.33)$$

Which implies :

$$V_{out} = D V_{in} \quad (II.34)$$

Equation (II.34) shows the possibility of controlling the average output voltage  $V_{out}$  by playing on the duty cycle  $D$ .

**2. Determination of L, C:**

According to **Figure (II.7)**, the continuous conduction is limited by  $I_{min} = 0$ , so:

$$\Delta I = 2I_o \quad (\text{II.35})$$

Substituting in (II.26), we find:

$$I_{limit} = \frac{V_{in} - D(1-D)}{2fL} \quad (\text{II.36})$$

Then, the converter always works in the mode of continuous conduction if:

$$L > L_{limit} \quad (\text{II.37})$$

Current ripple  $\Delta I$  is maximal for  $D = 0.5$ :

$$\Delta I_{max} = \frac{V_{in}}{2fL_{max}} \quad (\text{II.38})$$

$$L_{max} = \frac{V_{in}}{8fI_o} \quad (\text{II.39})$$

Or :

$L_{limit}$ : is the value of L at the limit of continuous conduction.

$\Delta I_{max}$ : corresponds to the current ripple for  $D = 0.5$

$L_{max}$ : corresponds to the value of the inductance for  $D = 0.5$

From the **Figure (II.8)** we have :

$$I_c = I - I_o \quad (\text{II.40})$$

So the capacitor charges for  $I > I_o$  and discharges for  $I < I_o$  **Figure ( )**.

**II-6-2-2 Buck chopper simulation**

In order to know the nature of the current and the voltage after having passed through the buck chopper we enter the following values:  $V_s = 25V$ ,  $R = 50$ ,  $L = 170 \mu H$ ,  $C = 235 \mu F$  with a PWM signal duty cycle  $DC = 0.5$ .



## 2) Interpretation of the results obtained

AT From these results, we noticed that the circuit fulfilled its function correctly. Because the output voltage is lower than the input voltage.

### II-6-3 "BUCK - BOOST" inverter converter

Inverter chopper, step-down-step-up, buck-boost type. The inverting chopper is an indirect DC–DC converter with inductive storage. The input source is of the DC voltage type (capacitive filtering in parallel with a voltage source) and the DC output load of the voltage source type (capacitor in parallel with the resistive load). The buck-boost converter combines the properties of the two previous converters, it is used as an ideal transformer of any input voltage for any desired output voltage; its basic scheme is illustrated in [30].

#### II-6-3-1 Converter diagram

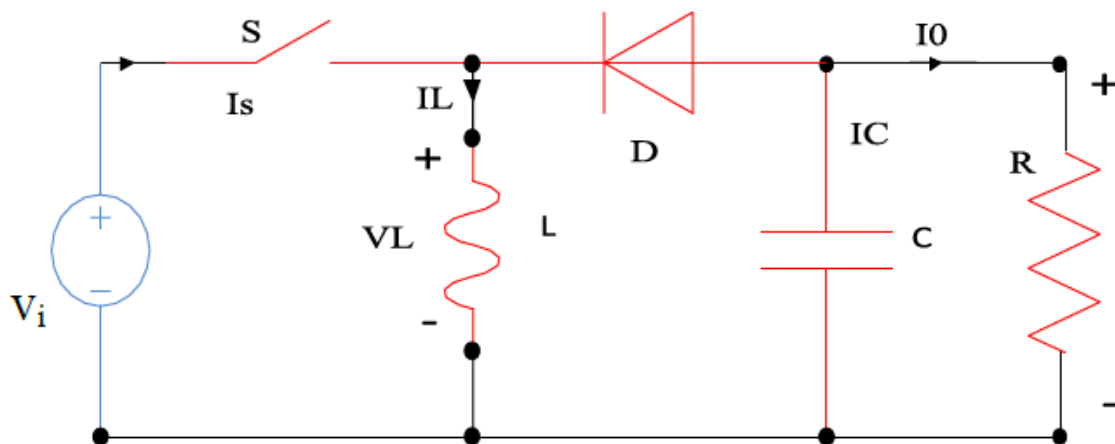
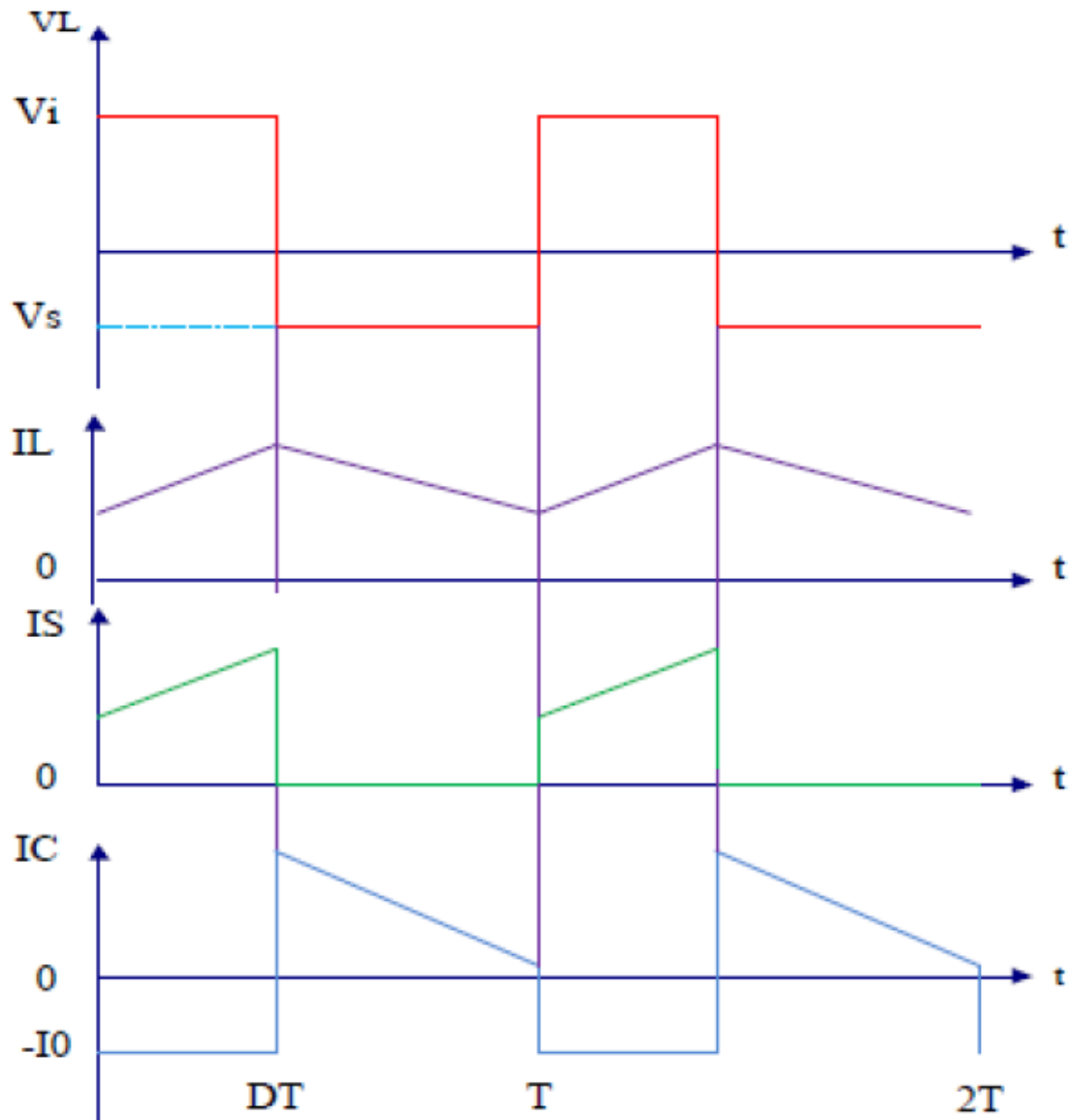


Figure (II.11): Basic electrical circuit of the boost chopper/buck [29].

#### II-6-3-2 Principle of operation

While the switch  $S$  is in the (on) position the current in the inductor increases, the energy is stored; and when the switch  $S$  goes to the (off) position. The voltage across the inductor is reversed and the stored energy transfers to the load via the diode. in this case, the equation of the voltage across the load describing operation in continuous conduction is given as follows:

The basic electrical circuit of the chopper boost/buck and the load current and voltage characteristics are given by the **Figure (12)** [29].



**Figure (II.12):** Characteristic of converter voltage and current boost/buck [29].

### 1. Converter model

If we consider that the switch is in position  $D = 1$ , and applying the laws of kirchhoff to the resulting circuit, we obtain the following equations:

$$V_L = V_{in} \quad (\text{II.41})$$

$$L \frac{di}{dt} = V_{in} \quad (\text{II.42})$$

$$C \frac{dv}{dt} = \frac{V_{out}}{R} \quad (\text{II.43})$$

From equation (II.42)

$$I(t) = \frac{V_{in}}{L} t + I_{min} \quad (\text{II.44})$$

The current increases linearly with time until it reaches its maximum at

$t \rightarrow t_{we} = DT$ :

$$I_{\max} = \frac{V_{\text{in}}}{L} DT + I_{\min} \quad (\text{II.45})$$

From the above equation we have:

$$\Delta I = \frac{V_{\text{in}}}{L} DT \quad (\text{II.46})$$

When the switching function is  $D=0$ , we obtain the following dynamic:

$$V_L = -V_{\text{out}} \quad (\text{II.47})$$

$$L \frac{dI}{dt} = V_{\text{out}} \quad (\text{II.48})$$

$$I(t) = \frac{-V_{\text{out}}}{L} t + I_{\max} \quad (\text{II.49})$$

$$C \frac{dv}{dt} = I - \frac{V_{\text{out}}}{R} \quad (\text{II.50})$$

When  $t \rightarrow t_{\text{oh}}$  The current through the inductor decreases linearly from its maximum value at its minimum value:

$$I_{\min} = \frac{-V_{\text{out}}}{L} (1-D) T + I_{\max} \quad (\text{II.51})$$

SO :

$$\Delta I = \frac{V_{\text{out}}}{L} (1-D) T \quad (\text{II.52})$$

By combining these two relations (II.46) and (II.52), we can establish the expression of the output voltage:

$$\frac{V_{\text{in}}}{L} DT = \frac{V_{\text{out}}}{L} (1-D) T \quad (\text{II.53})$$

Which implies :

$$\left\{ \begin{array}{l} V_{\text{out}} = \frac{D}{1-D} V_{\text{in}} \\ I_{\text{out}} = -\frac{1-D}{D} I_{\text{in}} \\ R_{\text{out}} = \left(\frac{D}{1-D}\right)^2 R_{\text{in}} \end{array} \right. \quad (\text{II.54})$$

The output voltage of the Buck-Boost converter is negative with respect to the input voltage. Its amplitude can be greater or less than that of the input voltage depending on the value of the duty cycle. It is a voltage buck-boost-inverter.

## 2. Determination of L, C

The shape of the current through the inductor is shown in Figure II.6:

From **Figure (II.12)**:

$$I_{L \min} + \frac{V_{\text{in}}}{L} DT = I_{L \min} \frac{\Delta i}{2} = I_0 \quad (\text{II.55})$$

According to **Figure (II.12)**, continuous conduction is limited by  $I_{L \min} = 0$ , SO :

$$\Delta I = 2I_0 \tag{II.56}$$

Substituting in (II.46), we find:

$$L = \frac{V_{in}}{\Delta I f} D \tag{II.57}$$

The capacitor current wave is shown in **Figure (II.12)** :

The current waveform in **Figure (II.12)**; allows us to determine the variation of the voltage across the capacitor. During the time the switch is closed, the charge on the capacitor decreases as the capacitor supplies current to the load. The load variation is:

$$\Delta S = - \frac{V_{out}}{R} DT \tag{II.58}$$

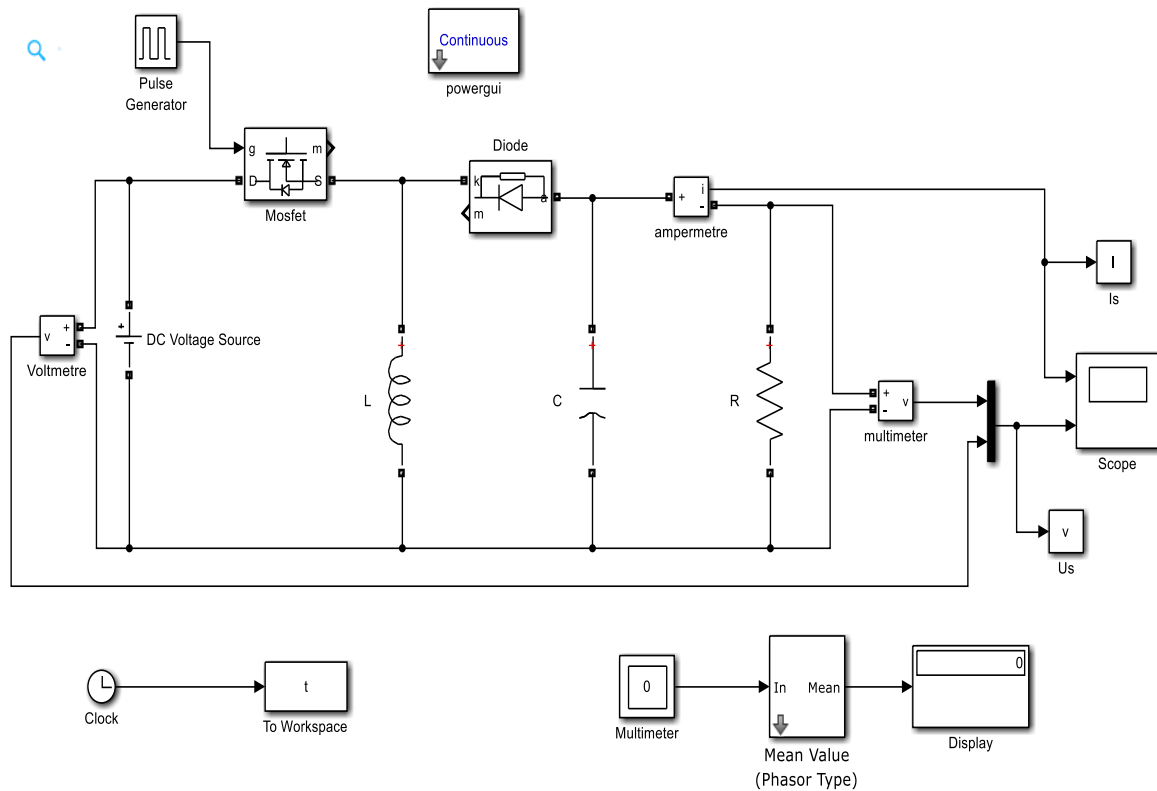
$$|\Delta V| = \frac{\Delta S}{C} = \frac{V_{out}}{RC} DT \tag{II.59}$$

We deduce the capacitance of the output capacitor:

$$C = \frac{V_{out}}{R \Delta V_{out}} DT \tag{II.60}$$

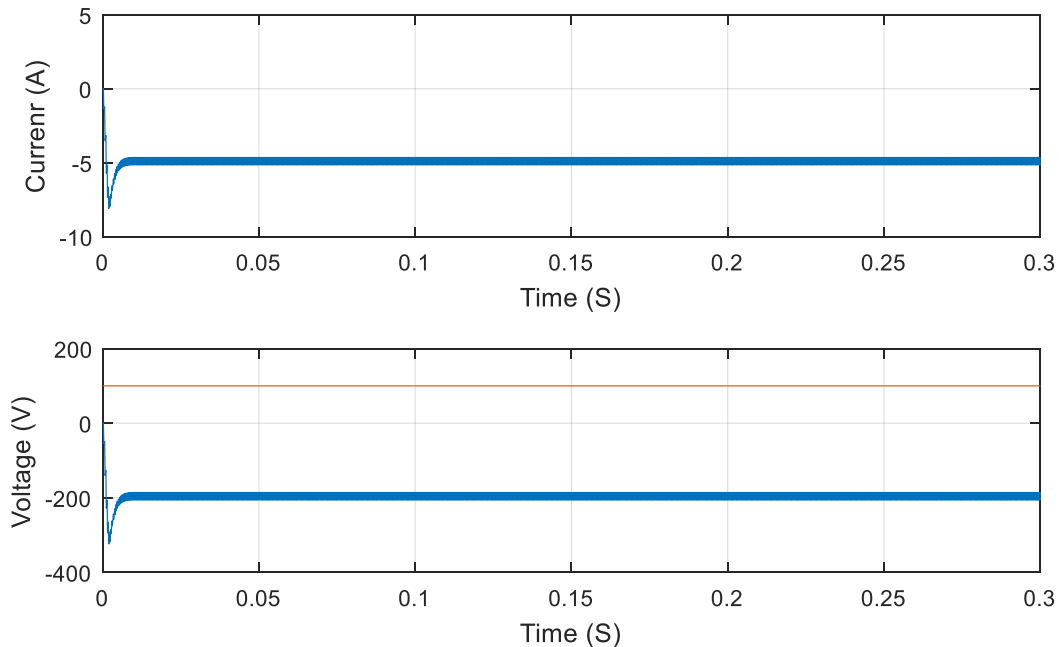
### II-6-3-3 Simulation of the BUCK – BOOST chopper

In order to know the nature of the current and the voltage after having passed through the buck boost chopper We enter the following values:  $V_s = 100V$ ,  $R = 40$ ,  $L = 0.88mH$ ,  $C = 67\mu F$  with a PWM signal duty cycle  $DC = 0.6$ .



**Figure (II.13):** Block diagram of a buck boost converter.

### 1) Simulation results:



**Figure (II.14):** the average value of the voltage across the terminals of load and output current.

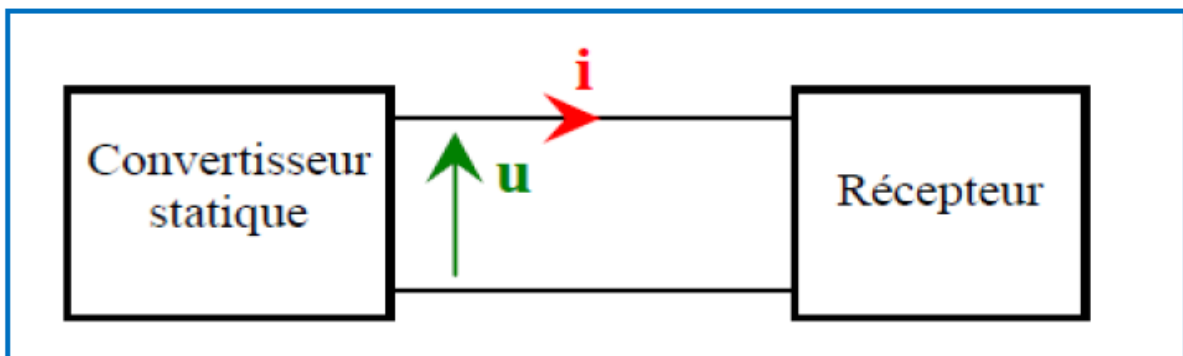
### 2) Interpretation of the results obtained

AT From these results we find that the circuit performs its effect correctly because the output voltage is equal to the input voltage.

## II-7 Converter powers

### II-7-1 Definitions

Consider any static converter connected to a receiver. We will adopt the "generator" convention for the converter and therefore the "receiver" convention for the receiver [30].



**Figure (II.15):** Converter coupling with a receiver [30].

### II-7-2 Instantaneous power

The instantaneous power is, as in continuous operation, defined by the product "current \* voltage". In principle, this power is variable over time [30].

$$P(t) = u(t) \cdot i(t) \quad (\text{II.61})$$

If  $p > 0$  then the converter supplies the power.

### II-7-3 Active power

The active power  $P$  (watt) is the mean value of the instantaneous power  $p(t)$  [30]:

$$P = P_{\text{mean}} = \langle u(t) \cdot i(t) \rangle \quad (\text{II.62})$$

It is only in alternating sinusoidal mode that we have:

$$P = UI \cos\varphi \quad (\text{II.63})$$

### II-7-4 Apparent power

The apparent power  $S$  is defined by the product " $U_{\text{eff}} \times I_{\text{eff}}$ ". It is a greatness which is used to size the generators [30]:

$$S = UI \quad (\text{II.64})$$

### II-7-5 Power factor

In many cases, the product " $U_{\text{eff}} \times I_{\text{eff}}$ " has a high value compared to the average value  $P$ . To evaluate this phenomenon, we define the power factor  $k$  ( $k < 1$ ):

$$K = \frac{\langle u(t) \cdot i(t) \rangle}{U_{\text{eff}} \cdot I_{\text{eff}}} \quad (\text{II.65})$$

$$\text{Let: } K = \frac{P}{S} \quad (\text{II.66})$$

For a bad power factor ( $k$  close to 0), the current  $I$  can become very high [30].

It is only in sinusoidal mode that we have:

$$k = \cos\varphi \quad (\text{II.67})$$

## II-8 Use of choppers in PV systems

The Buck topology is used for low voltages. In PV applications, the Buck converter is commonly used as a battery charger and in water pumping systems.

The boost topology is used to increase the voltage. Power generation systems employ a boost converter to boost the output voltage to the utility level before the inverter stage. Then, there are topologies able to increase and decrease the tension such as the buck-boost, the cuk, and the sepic [31].

## II-9 DC-DC converter control

### II-9-1 PWM command

In DC-DC converters, the output voltage must be regulated to be constantly equal to a reference voltage, since the supply voltage and the characteristics of the load can vary.

One method of regulating the output voltage to obtain a fixed average voltage is to continuously adjust the control duty cycle of  $\alpha$  without modifying  $T_s$ .

This method which consists in varying the width of the switch control pulses is called the Pulse Width Modulation (PWM) method or PWM (Pulse Width Modulation) [32].

#### II-9-1-1 Generation of an MLI

This technology manifests itself with a constant periodic signal and an adjustable duty cycle. It is widely used in the family of frequency converters such as:

- Cyclo-converters.
- Inverters.
- Rectifiers.
- Choppers.

This modulation has undergone considerable development for several years.

while allowing to open a wide range of application in control systems as well as other functions. Thanks to this technique, the production of chopper control circuits has become flexible and profitable [33].

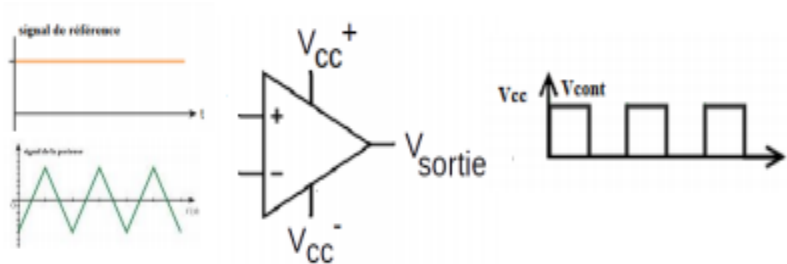
#### II-9-1-2 PWM command principle

This technique can be seen as a continuation of the principle of switching control where the duration of the pulses is not regular but seeks to eliminate the maximum number of low order harmonics which are not easy to filter. It is essentially based on the cutting of a full rectangular wave, its output voltage represents a succession of amplitude square pulses which is equal to the DC supply voltage with a variable width [34].

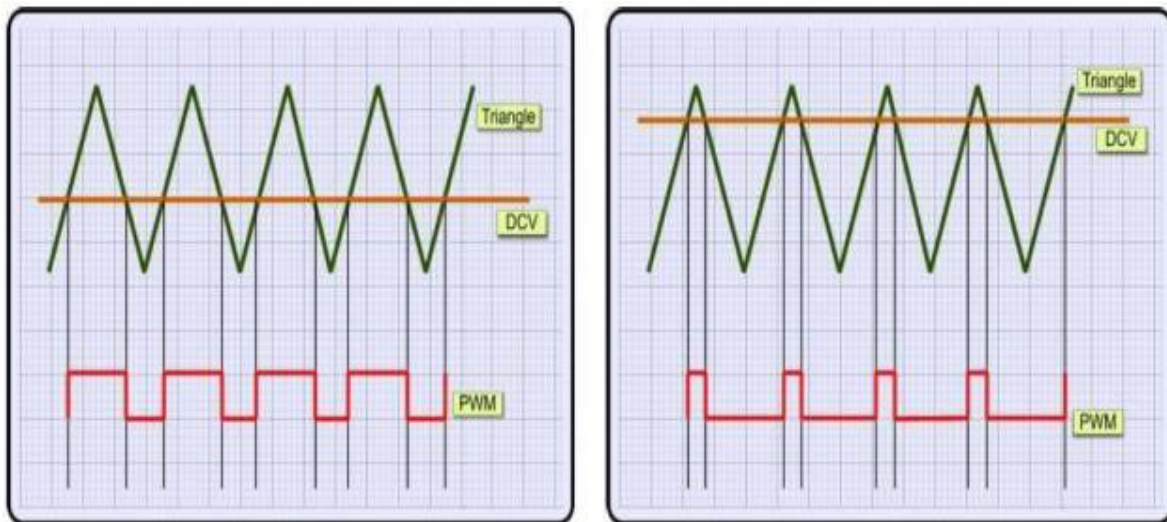
The production of a PWM signal is generally done by the technique of comparison between two signals which are:

- The reference signal which is a continuous signal.
- The signal of the carrier which represents the rate of the switching of the static switches of the converter.

- The carrier signal is a high frequency signal by comparing it with the reference signal.
- The intersection of these two signals represents the switch switching times as shown in **Figure (II.17)**.



**Figure (II.16):** Realization of a PWM signal [34].



**Figure (II.17):** Shape of a PWM signal [34].

When the two signals of the reference and the carrier intersect:

- In ascending direction, the command opens the Transistor.
- In descending direction, the command closes the Transistor.

The comparison of the two signals is done from an operational amplifier [34].

### II-9-1-3 Main advantages of an MLI

- Good harmonic neutralization compared to square waves or in a single slot.
- It facilitates filtering by pushing the harmonics of the output voltage towards high frequencies.
- Allows the variation of the fundamental values of the output voltage.
- Allows the supply of several sets of inverters, asynchronous motors with

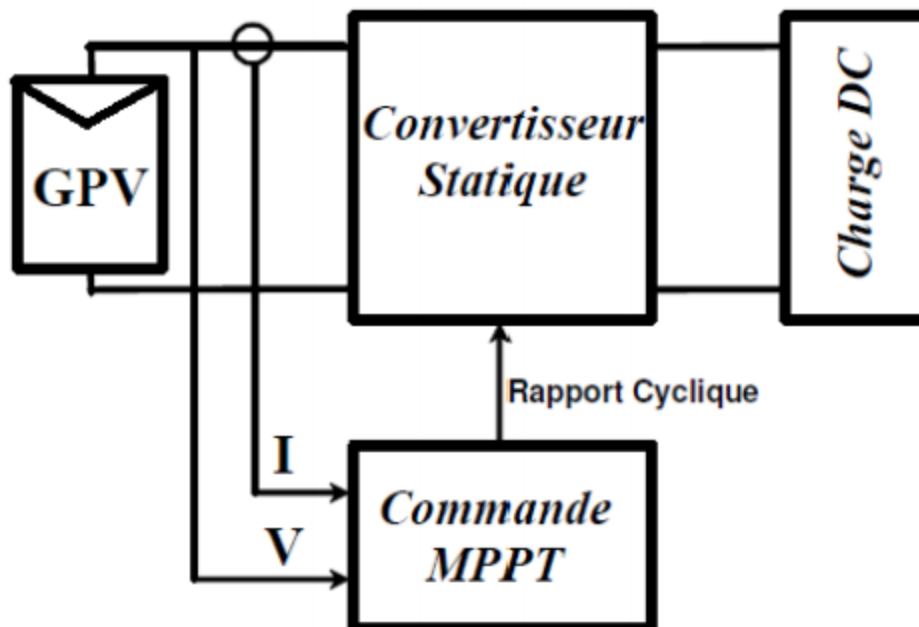
from the same continuous source [35].

### II-9-2 The MPPT command

For the photovoltaic system to operate at maximum power points of their characteristics, there are specific control laws that respond to this need.

This command is called in the literature "Search for the Power Point Maximum" or "Maximum Power Point Tracking" in English (MPPT). The principle of these commands is to seek the maximum power point (PPM) keeping a good adaptation between the generator and its load to ensure the transfer of the maximum power.

The **Figure (II.18)** represents an elementary photovoltaic conversion chain associated with an MPPT command. The MPPT command is associated with a converter static allowing to make an adaptation between the GPV and the load in such a way that the generated power corresponds to its maximum value and that it is transferred directly to the load [36].



**Figure (II.18):** Photovoltaic conversion chain with controlled static converter by an MPPT command [36].

#### a. MPPT Indirect

Indirect methods use databases grouping the characteristics of photovoltaic panels in different climatic conditions (temperature, sunshine) but also empirical mathematical equations to determine the maximum power point. These methods are often specific to each type of panel and therefore difficult to generalize [37]:

- The curve fitting method

- The “look-up table” method
- The generator open circuit voltage method
- The short-circuit method

### **b. MPPT Direct**

This type of MPPT control determines the optimum operating point (MPP) from the currents, voltages or powers measured in the system. It can therefore react to unpredictable changes in the operation of the GPV.

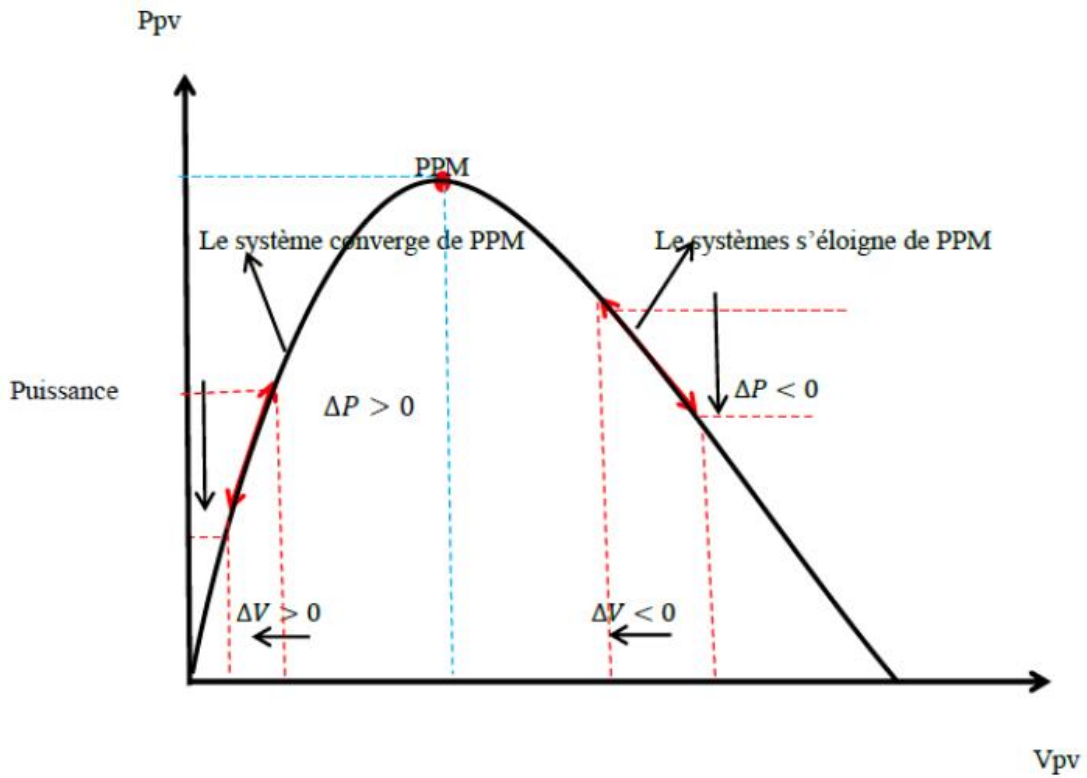
Generally, these procedures are based on a search algorithm, with which the maximum of the power curve is determined without interrupting operation. For this, the voltage of the operating point is incremented in regular intervals. If the output power is greater, then the search direction is maintained for the next step, otherwise it will be reversed. The actual operating point then oscillates around the MPP.

This basic principle can be preserved by other algorithms against misinterpretations. These errors can arise, for example, due to a wrong direction of search, resulting from a rise in power which is due to a rapid increase in the level of radiation.

The determination of the value of the power of the PV generator, essential for the research of the MPP, requires the measurement of the voltage and the current of the generator, as well as the multiplication of these two variables. Other algorithms are based on the introduction of sinusoidal variations in small signal on the switching frequency of the converter to compare the alternating component and the direct component of the voltage of the GPV and thus to place the operating point of the GPV closest possible from the MPP. The advantage of this type of commands is their precision and their speed of reaction [32].

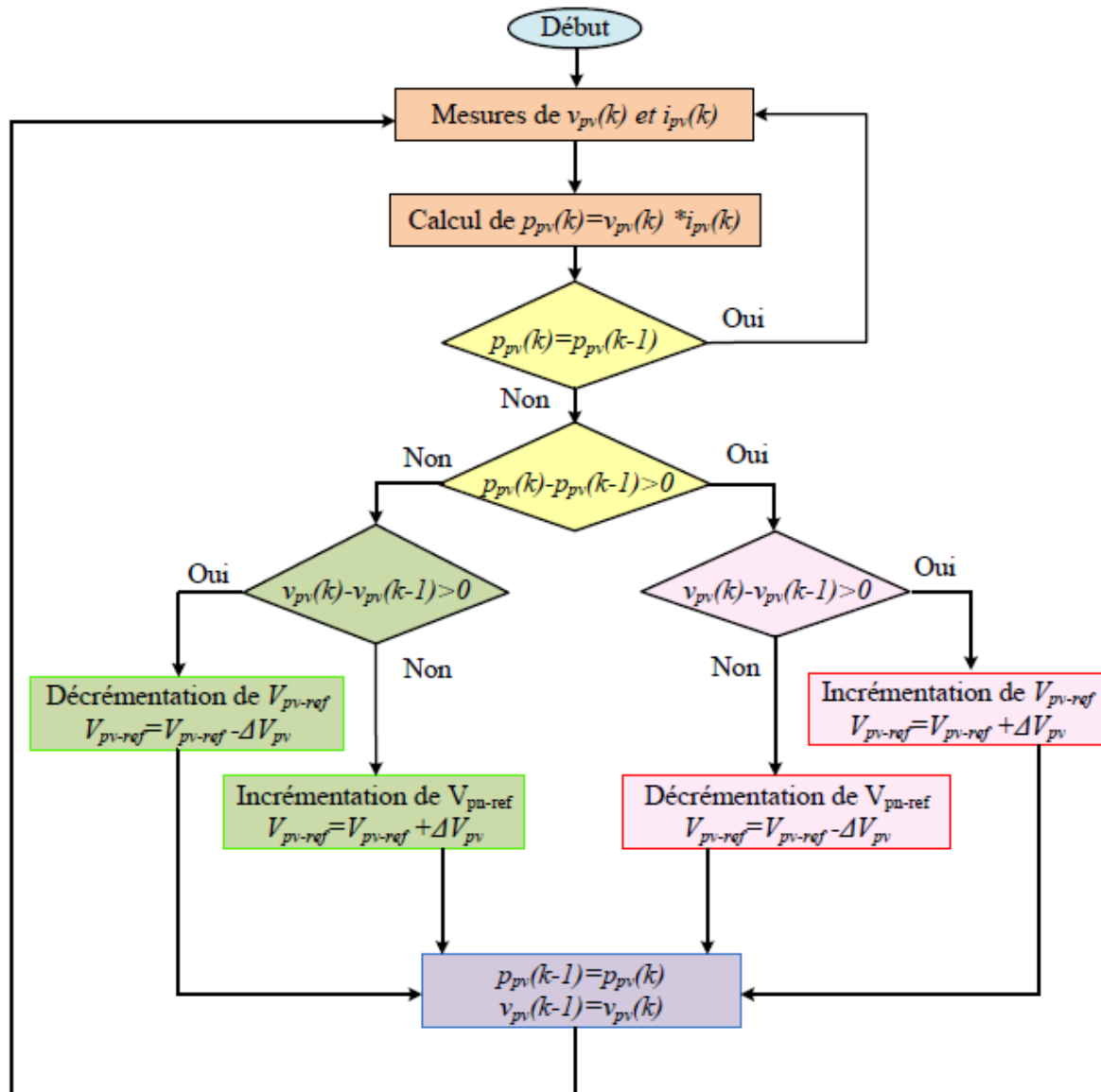
### **c. The Disturb & Observe (P&O) method)**

The principle of P&O type MPPT commands consists in disturbing the voltage VPV of a low amplitude around its initial value and to analyze the behavior of the resulting power variation PPV. Thus, as shown in **Figure (II.19)**, we can deduce that if a positive increment of the voltage VPV generates an increase in power PPV, this means that the operating point is to the left of the PPM. If, on the contrary, the power decreases, this implies that the system has exceeded the PPM. A similar reasoning can be made when the voltage decreases. From these various analyzes on the consequences of a voltage variation on the characteristic PPV (VPV), it is then easy to locate the operating point with respect to the PPM, and to make the latter converge towards the maximum power through an order of command [38].



**Figure (II.19):** scheme converges to the PPM by P&O [38].

**Figure (II.20)** represents the classic algorithm associated with an MPPT command of the P&O type, where the evolution of the power is analyzed after each disturbance of tension. For this type of control, two sensors (current and voltage of the GPV) are necessary to determine the power of the PV at each instant.



**Figure (II.20):** Algorithm of the P&O method [38].

Such as:

$P_{pvn}$  : the new power

$P_{pvn-1}$ : the old power over time (t-1).

$$\Delta V = V_{PVn} - V_{PVn-1} \quad (II.68)$$

$$\Delta P = P_{PVn} - P_{PVn-1} \quad (II.69)$$

Because of its ease of implementation, the P&O method is frequently used although it presents problems of oscillations around the PPM because research must be repeated periodically to force the system to oscillate around the PPM. In longer, and for sudden variations in climatic conditions and/or load, this method sometimes presents errors of interpretation in the direction which it is necessary to follow to reach the PPM [39].

## II-10 simulation of a PV generator with boost converter by MPPT and PI regulator

In this part we simulate a photovoltaic generator containing 2 cells in series and 40 in parallel of a type (1STH-215-P).

### 1) Photovoltaic generator design

To produce 17 kW of energy, we use 2 series and 40 parallel cells in order to obtain:

$$P = 47*10*P_{mp} = 40*2*215 = 17\text{kW}$$

$$V_{out} = V_{mp}*2 = 58\text{V}$$

STC Power Rating $P_{mp}$ (W)	215
PTC Power Rating $P_{mpp}$ (W)	189.4
PTC/STC Power Ratio	88.1%
Open Circuit Voltage $V_{oc}$ (V)	36.3
Short Circuit Current $I_{sc}$ (A)	7.84
Voltage at Maximum Power $V_{mp}$ (V)	29.0
Current at Maximum Power $I_{mp}$ (A)	7.35

**Schedule (II.1):** (1STH-215-P) cell characteristics.

In addition to what we said before, we will add boost converter and PI regulator with MPPT control.

### 2) Characteristic of a boost converter:

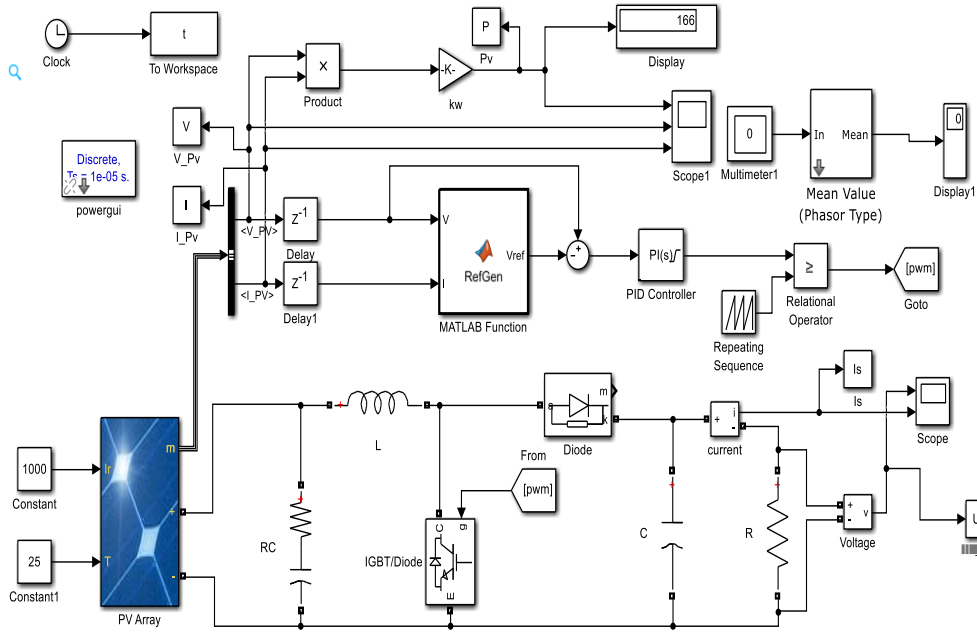
$$I_0 = P/V_0 = 200\text{A}$$

$$\Delta I = 0.05*I_0*(V_0/V_{in}) = 20\text{A}$$

$$\Delta V = 0.01*V_0 = 5\text{V}$$

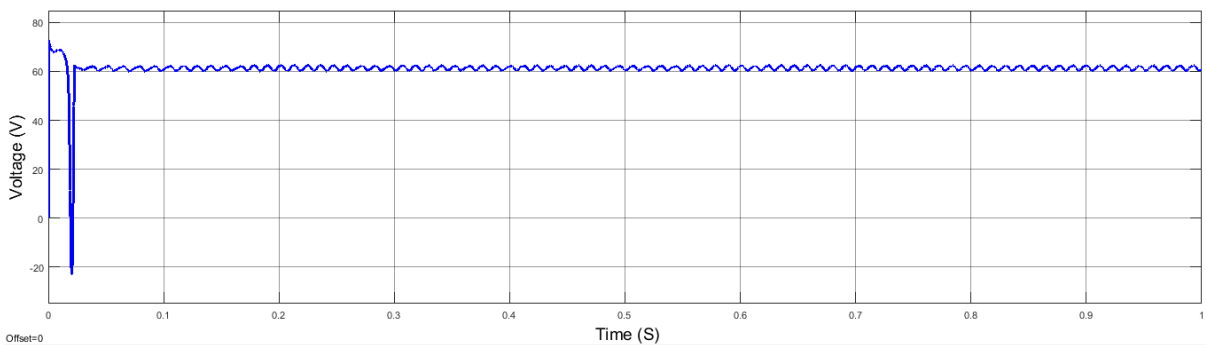
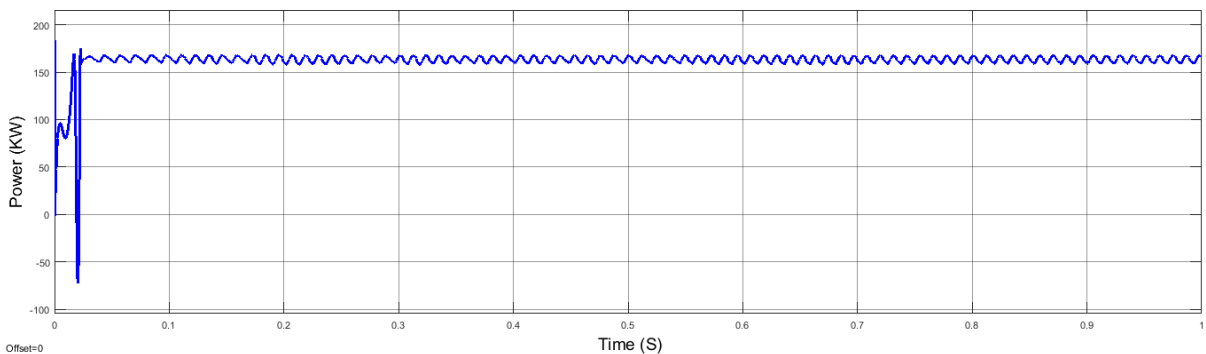
$$L = \frac{V_{in}(V_0 - V_{in})}{\Delta I * f * V_0} = 1.25\text{mH}$$

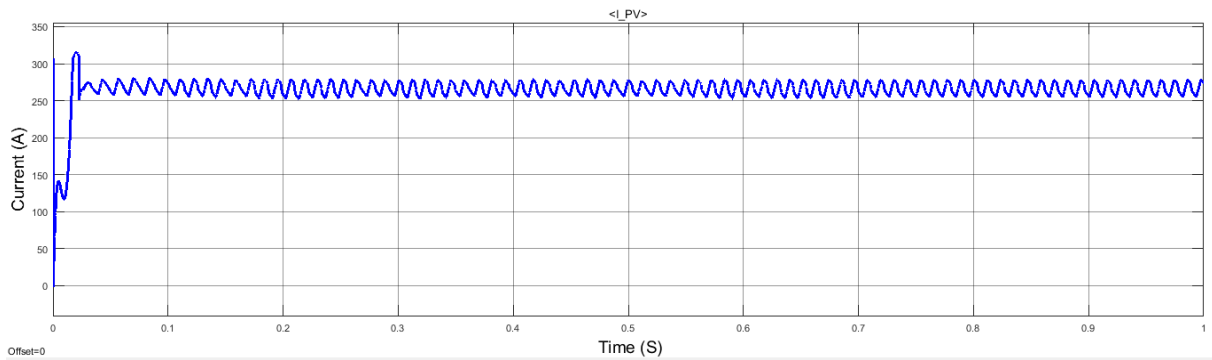
$$C = \frac{I_0(V_0 - V_{in})}{\Delta V_0 * f * V_0} = 4000\mu\text{F}$$



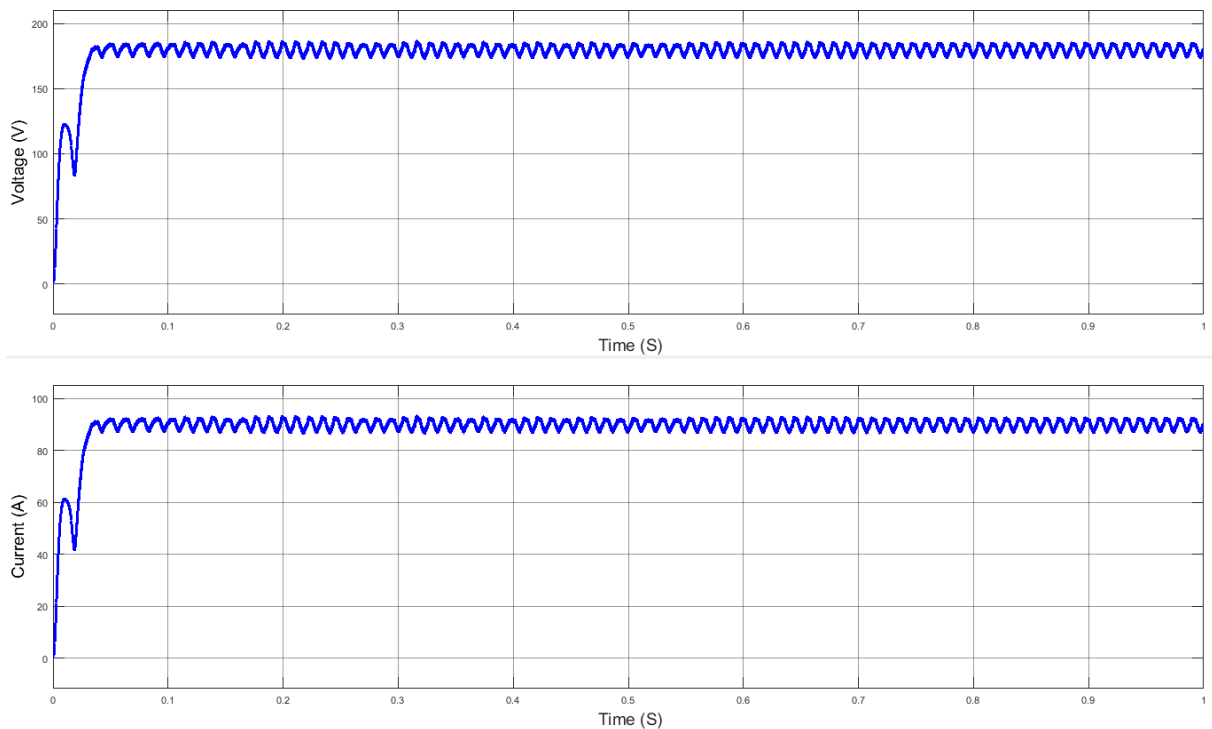
**Figure (II.21):** Block diagram of the simulation of a PV system with boost converter via MPPT and PI regulator

**1) Simulation results:**





**Figure (II.22):** Voltage-current and power simulation result of solar panels.



**Figure (II.23):** the average value of the voltage across the terminals of load and output current.

## 2) Interpretation of the results obtained

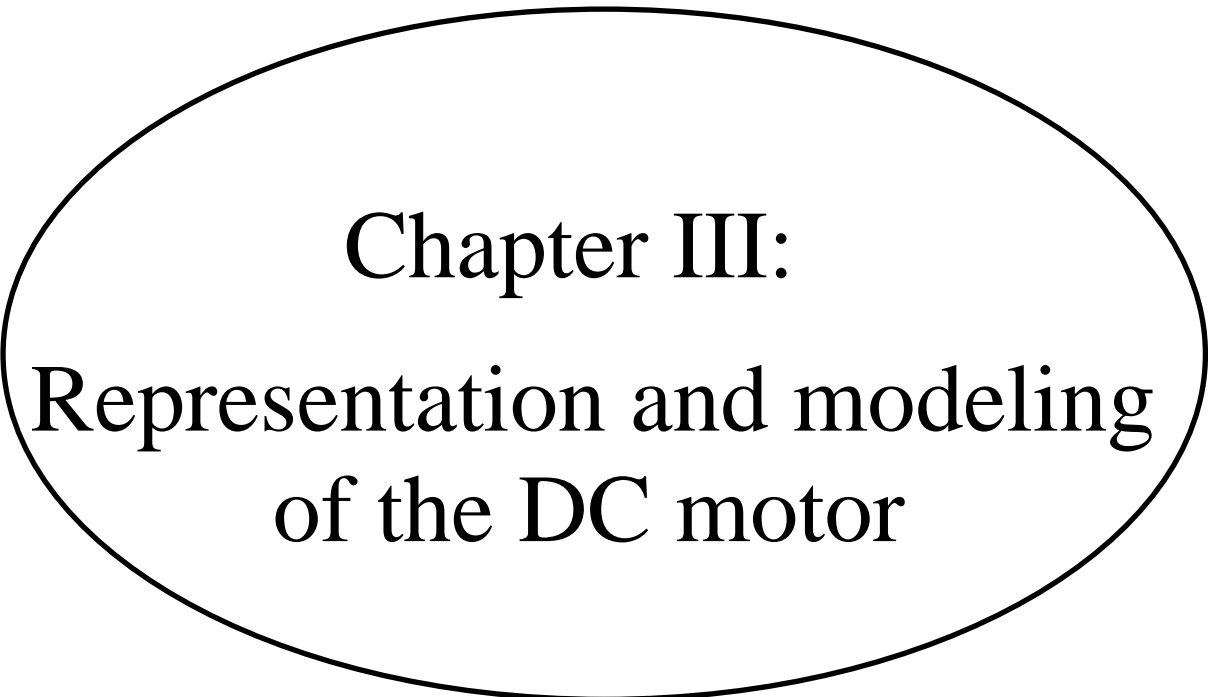
From experience, the MPPT and the DC-DC converter play their role correctly, because at the level of the load, we notice a stability of the voltage and the value of the current ( $V=180V$ ;  $I= 90A$ ).

Second, when the radiation value  $E=1000W/m^2$  The power supplied by the PV generator stabilizes around 17 KW and that supplied to the load around 16.64 KW, at the output of the panel, the voltage and the current stabilize respectively around 62V and 268 A.

Looking at the previous forms we can see the role of the DC-DC converter and the MPPT in the photovoltaic system.

### **II-11 Conclusion**

In this chapter we have talked about and simulated dc-dc converters, their method of study and their areas of use, in addition to explaining the shape of each type and the principle of its operation, its capacity and the scope of its use in PV systems and we explained in general how to control dc-dc converters either by PWM or MPPT, and in end we simulated the MPPT command to maximize the power of the photovoltaic chain using the MPPT command.



Chapter III:  
Representation and modeling  
of the DC motor

### III-1 Introduction:

Technological developments have led to the use of machines requiring precise and variable rotational speeds to drive industrial machinery, robotic systems, etc.

In our research, we were interested in DC motors because they allow an easy introduction to the operation of similar motors by giving clear benchmarks. For a long time, DC motors were the only motors capable of wide bandwidth variable speed. Like in robotics. As such, they have undergone many improvements and there are now many products on the market.

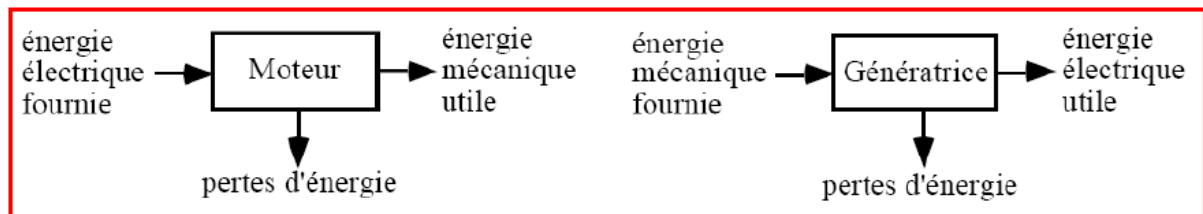
### III-2 General information on the DC motor

#### III-2-1 Definition

DC motor and energy converter, fully reversible, it can operate either as a motor, converting electrical energy into mechanical energy, or as a generator converting mechanical energy into electrical energy.

DC motors are used in servo systems where the ease of adjustment of speed, torque, torque, and direction of rotation facilitates implementation.

In this chapter, we are more interested in the part that works as a DC motor.



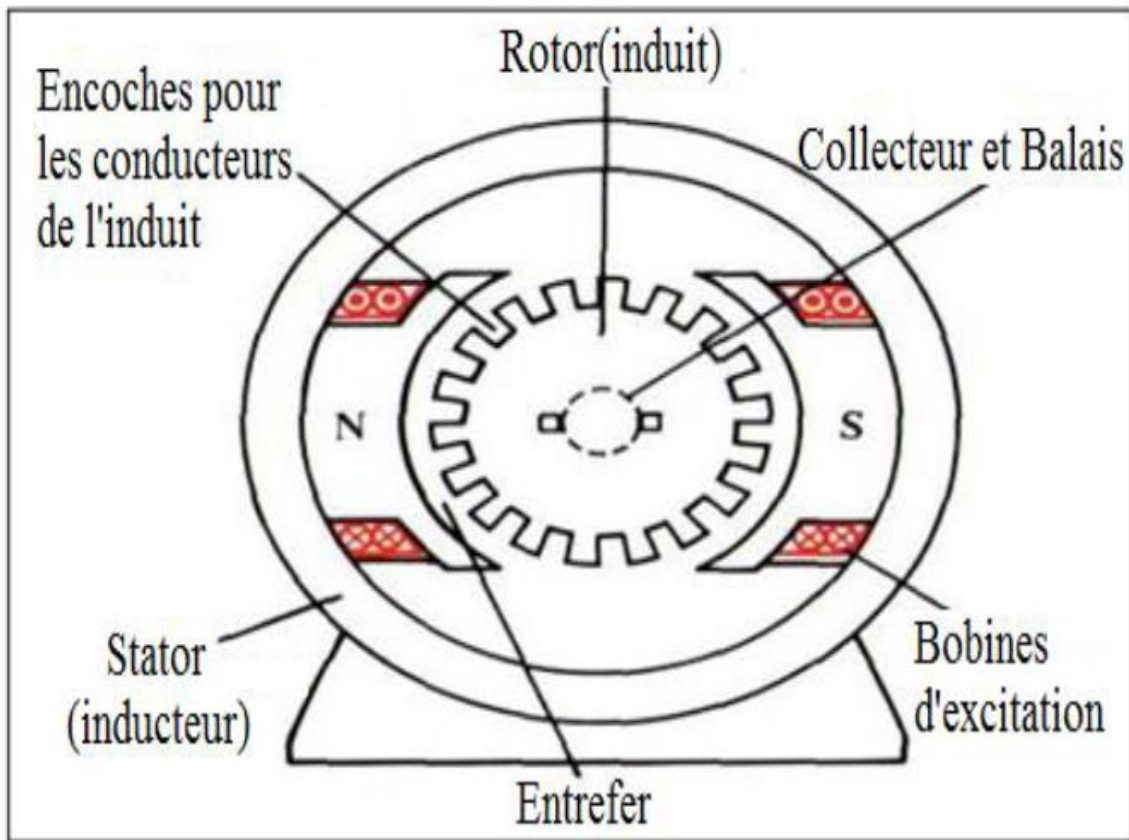
**Figure (III.1) :** Operation of DC machine.

#### III-2-2 construction of a DC motor

The DC machine consists of four main parts:

- The inductor
- The armature.
- Manifold

- broom



**Figure (III.2):** Construction of a DC motor.

### III-2-2-1 Inductor (stator)

The inductor is a fixed part of the motor which consists of :

#### Main poles

Intended to create the main magnetic flux, which may consist of permanent magnets or associated pole pieces of the field windings by direct current [40].

#### Auxiliary poles

They are placed between the main poles according to the inter-polar axes called neutral axes, the flux they produce improves switching. They reduce sparks to the brushes, these sparks being produced by the reversal of the direction of current in the sections short-circuited by the brushes. The winding of these poles is in series with the armature winding [41].

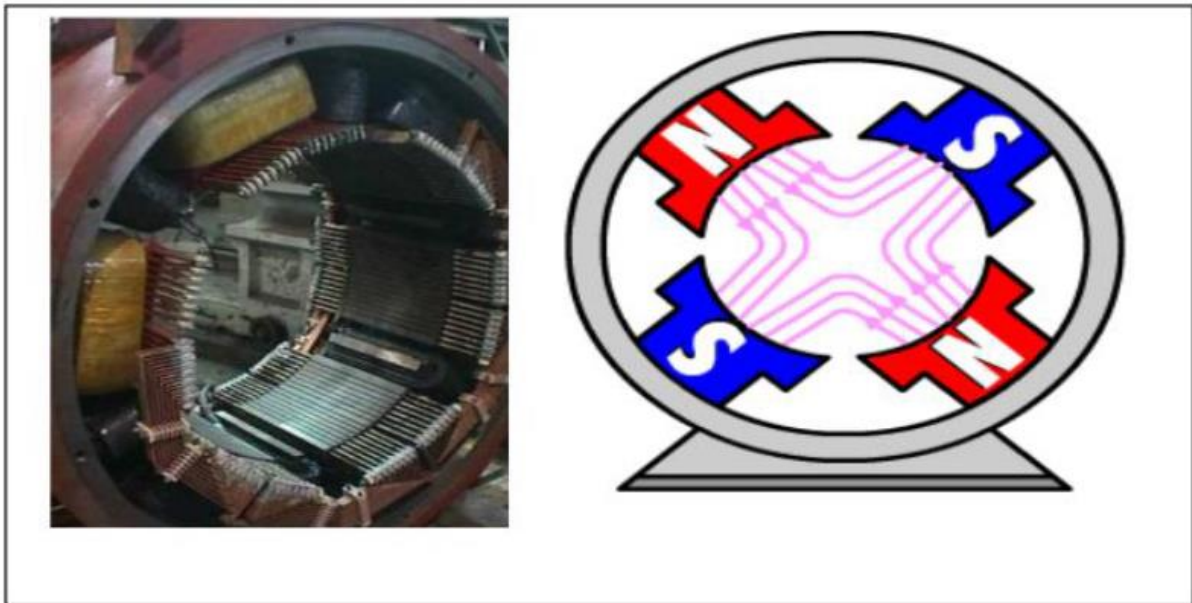


Figure (III.3): DC machine inductor.

### III-2-2-2 Armature (rotor)

The rotor consists of notches in which is wound a winding of (N) conductors supplied with direct current (I) via the collector [42].

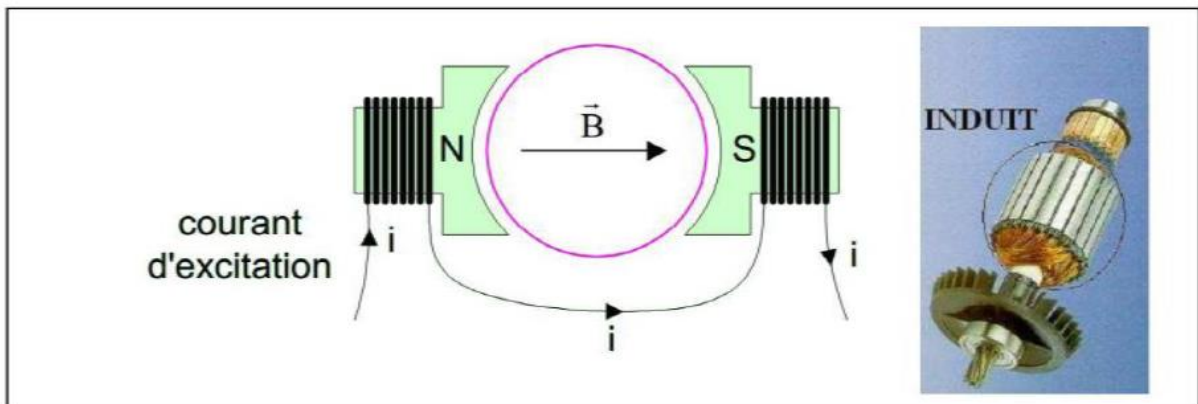


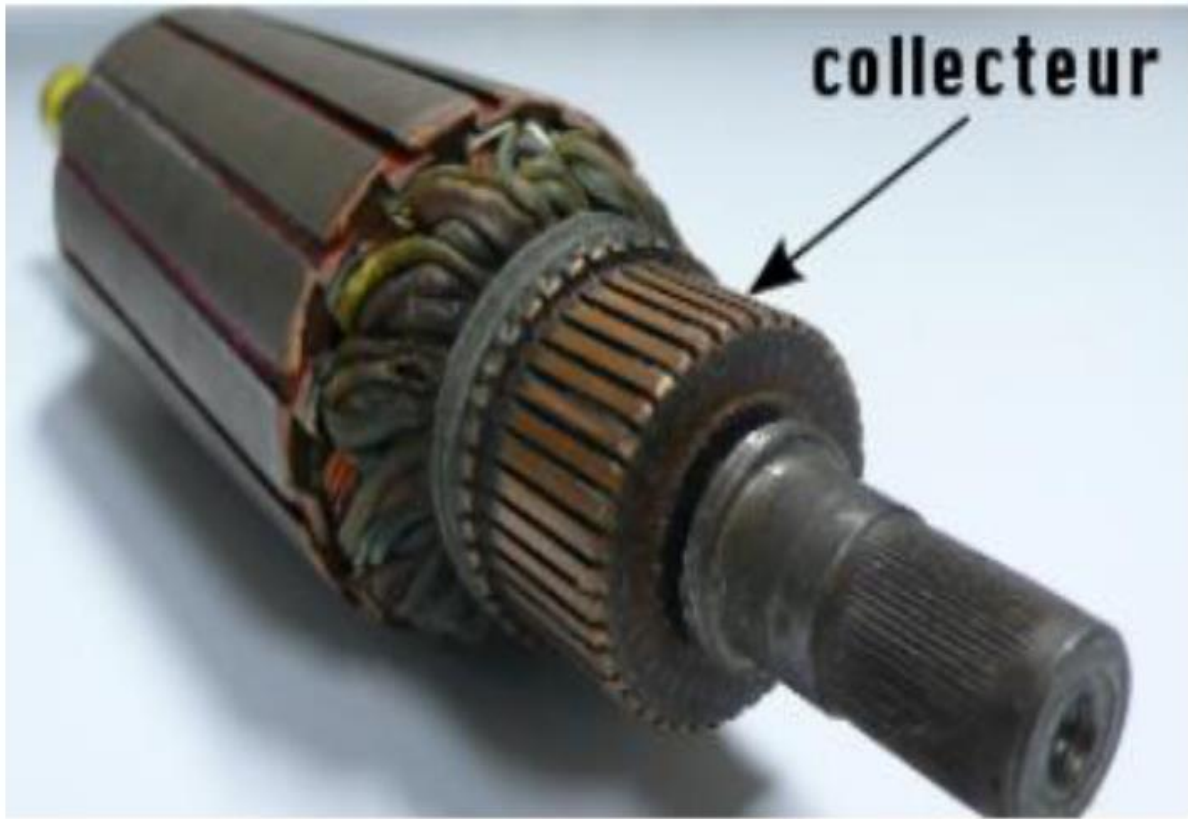
Figure (III.4): DC machine rotor.

### III-2-2-3 Collector

The commutator is made up of copper strips insulated from one another. The insulation is micanite. The supply brush plus commutator assembly ensures the connection between the rotating conductors and the fixed part.

Each blade is welded to the lead out of one section and the inlet of the next section. A section is a set of conductors which pass under a south pole and under a north pole created by the inductive field. The section is bathed in the inductive magnetic field.

The commutator maintains an angle of  $90^\circ$  between the induced magnetic field and the inducing magnetic field: condition for optimum torque transmission [43].

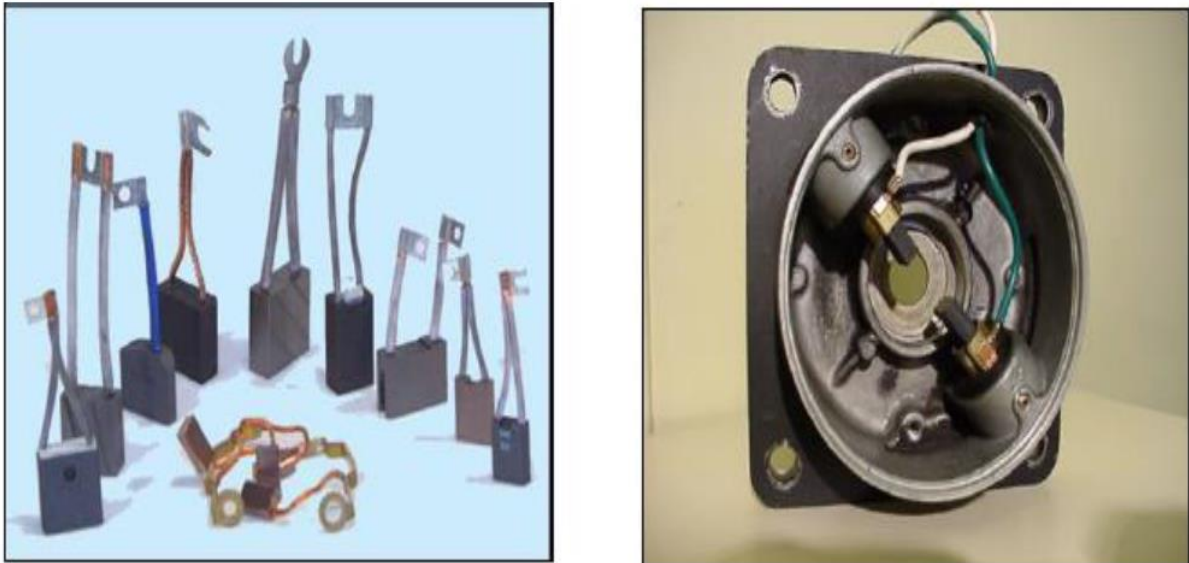


**Figure (III.5):** The Collector.

#### **III-2-2-4 Broom**

The brushes are fixed and electrically insulated from the machine frame. They ensure the electrical connection (sliding contact) between the fixed part and the rotating part. For high power machines, the paralleling of the brushes is then necessary.

For reasons of economy, they must have as long a life as possible and ensure good electrical contact. Different technologies exist: hard carbon brushes, graphitic, electro-graphitic, and metallo-graphitic. It can be considered that in a sliding contact, the losses are 35% mechanical in nature and 65% electrical in nature. To improve the conductivity of the brushes and ensure better contact with the brush holders, a copper plating is applied to them by electrolysis. Whether the carbon is copper or not, the contact between brushes and brush holder is always shunted by a small flexible copper cable [44].



**Figure (III.6):** Brooms and coals [44].

### III-3 Motor operating principle

#### III-3-1 In engine mode

When a conductor moves in a magnetic field, by cutting the lines of this field, it becomes the seat of an induced electromotive force.

It is on this principle that direct current generators were built, which include a fixed inductor system and a mobile armature composed of a cylinder of assembled and grooved sheet metal to accommodate conductors.

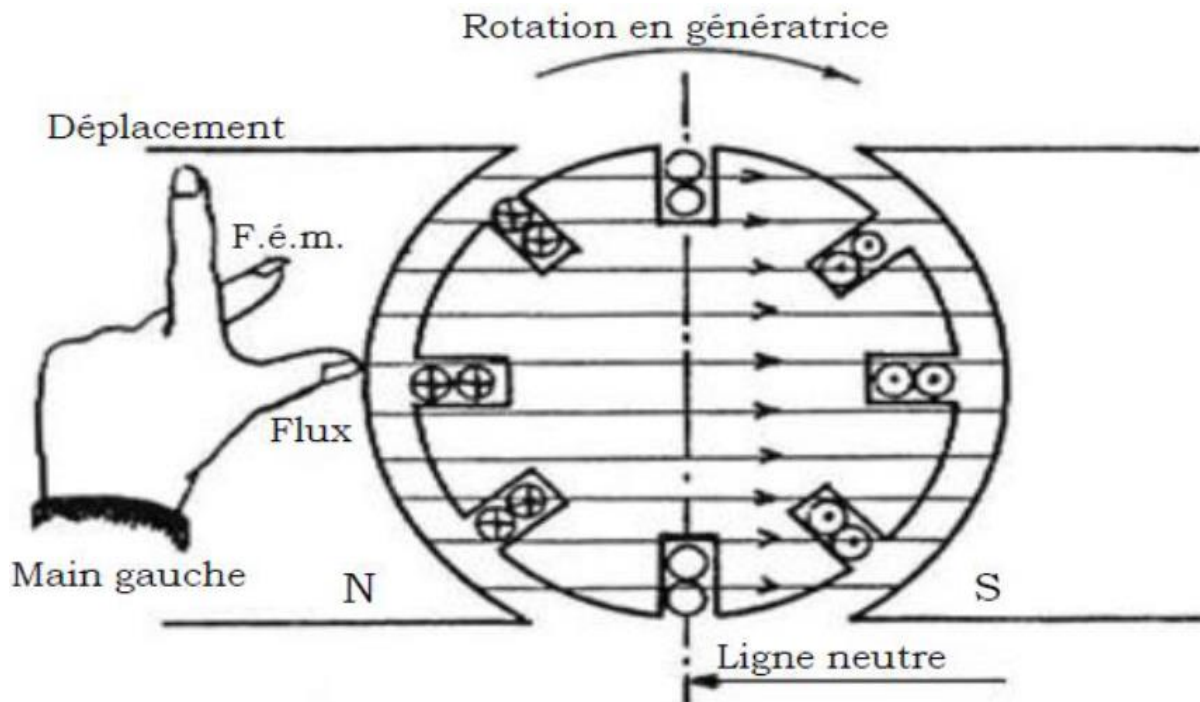
If the cylinder is rotated, the conductors it supports cut the lines of the magnetic field produced by the inductors. These conductors are the seat of an induced electromotive force directed in the opposite direction on either side of the neutral line.

The electromotive forces thus obtained are added in the conductors judiciously connected between them.

On the neutral line, the conductors that are there momentarily no longer intersect the field lines. This is where the current changes direction in the winding and is collected by the commutator and the brushes.

To determine the direction of the current in the conductors of a drum armature, the so-called “three fingers of the left hand” rule is applied.

The thumb is placed in the direction of the magnetic field, the index in the direction of rotation of the armature and the middle finger gives the direction of the current which circulates in the conductors [44].



**Figure (III.7):** Principle of operation of generators [44].

### III-3-2 In generator mode

A conductor placed in a magnetic field and traversed by a current is subjected to a mechanical force whose direction is determined by the direction of the field and that of the current.

It is on this principle that electric motors are based.

The generators are reversible, they take a rotational movement and become motors when they are powered by an electric current. The construction of these machines and the winding rules are the same.

Taking into account what is written at the beginning, it suffices to apply the rule of the three fingers of the right hand to find the direction of the force which acts on the conductors and thus gives the direction of rotation of the motor [44].

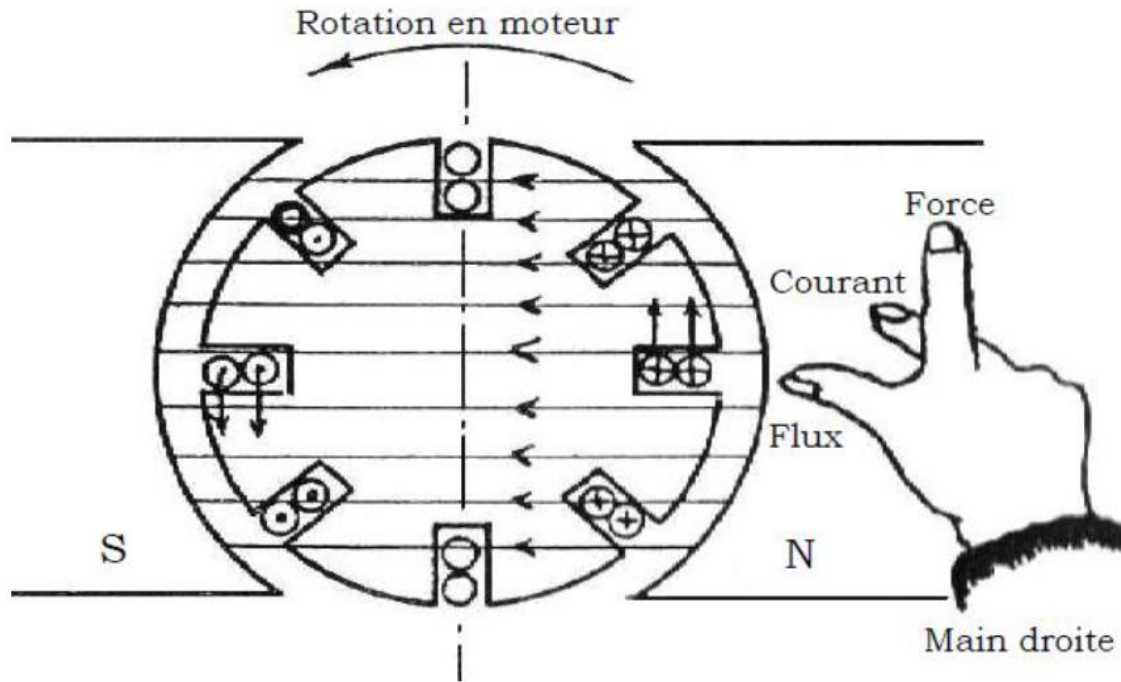


Figure (III.8): Principle of operation of DC motors [44].

### III-3-3 The power balance

The power balance contains all of your powers at the start of the power balance; the power absorbed from the power source; and ends with useful power of a mechanical nature. Between these two elements are the losses of all electrical and mechanical sources.

The diagram below summarizes the different types of energy and where it is generated.

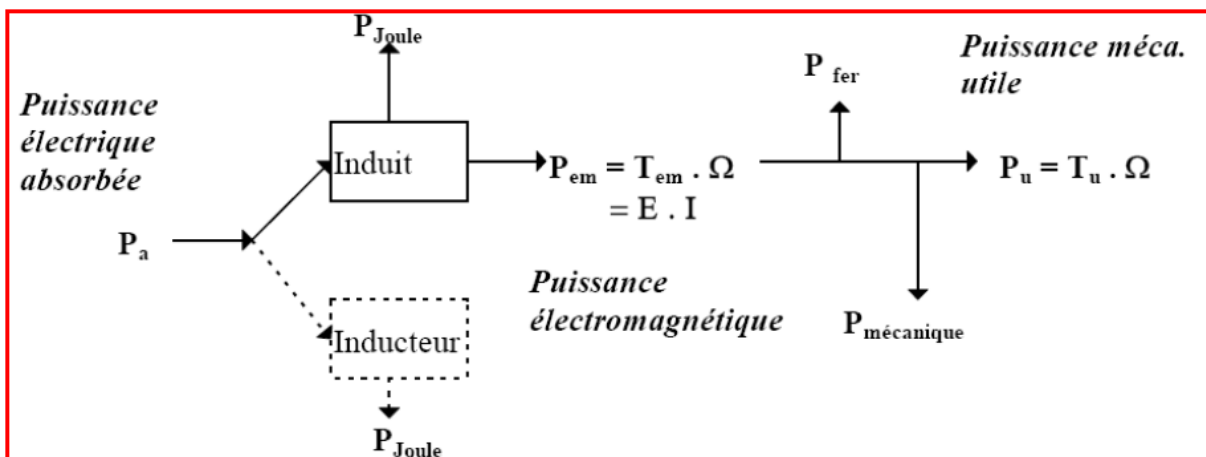


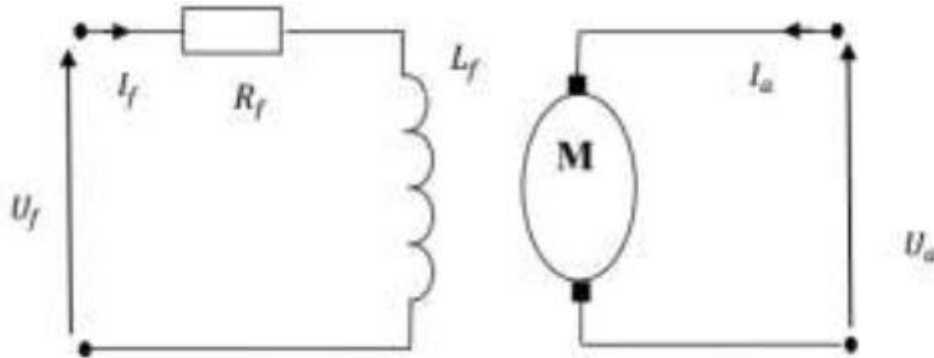
Figure (III.9): power diagram.

### III-4 Different types of a DC motor

There are four types of motors suitable for different tasks in the industrial field:

#### III-4-1 The separately excited motor

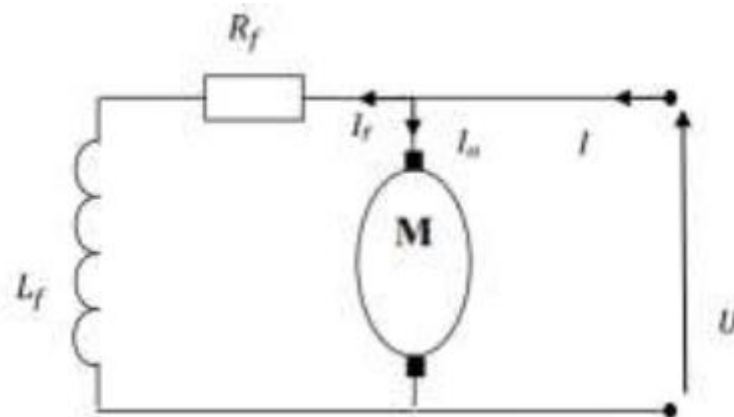
This mode of excitation requires two separate power sources. The power supply for the field winding is taken from a source independent of the main source. We change the direction of rotation by swapping the terminals of the armature or the field. The electrical circuit is represented by the following [45].



**Figure (III.10):** Separately excited motor [45].

#### III-4-2 the shunt excitation motor

The excitation winding is connected in parallel to the motor power supply, it has the same properties as the separately excited motor due to the fact that in both cases, the inductor constitutes an external circuit to that of the armature. The electrical circuit is represented by the following [45].



**Figure (III.11) :** Moteur à excitation shunt [45].

#### III-4-3 The series excitation motor

The field circuit is placed with the motor armature. Its particularity is to have an inductor which is crossed by the same current, the inductor thus has a resistance more

lower than that of other types of machines. The inductor is in series with the armature: a single enough power source. The direction of rotation is changed by swapping the connections of armature and inductor [45].

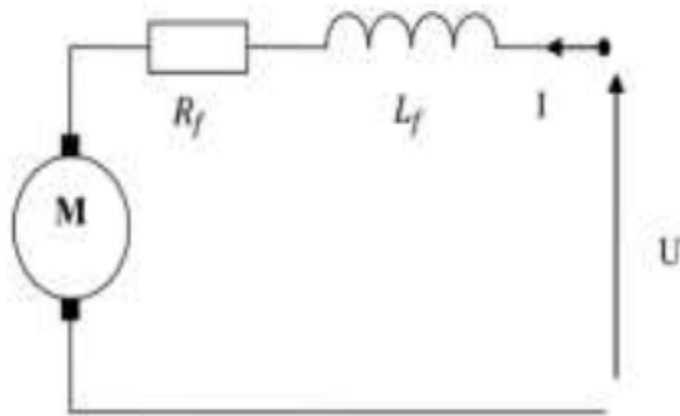


Figure (III.12): Series-excited motor [45].

#### III-4-4 compound excitation motor

It is a combination of shunt and series excitations, an additive compound (if the fluxes of the two windings add up) or subtractive (in the opposite case) can be made [45].

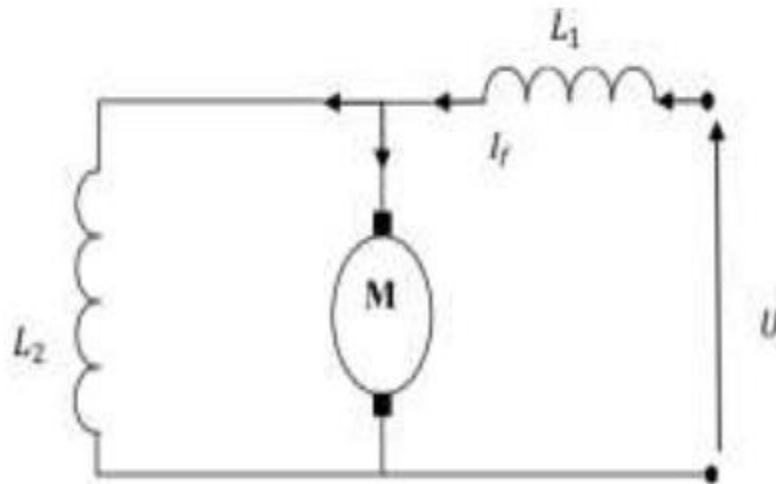


Figure (III.13): Compound excitation motor [45].

### III-5 The fundamental formulas of the direct current machine

#### III-5-1 The electromotive force

The inductor creates the magnetic flux  $\phi$  in Weber [Wb].

The rotor is made up of  $N$  conductors and rotates at the speed angular  $\Omega$  in [rad/s].

We show that the expression of the f.e.m.  $E$  is :  $E = \frac{NI\Omega}{2\pi}$

If we put  $K = \frac{N}{2\pi} S\phi$ ,

$$E = K \phi \Omega \quad (\text{III.1})$$

With:  $\phi$  in [Wb] ,  $\Omega$  in [rad/s],  $E$  : f.e.m induced in [V]

If the flow is constant, la f.e.m. induced  $E$  is proportional to the speed of rotation  $n$  either :

$$E = k n \quad [46].$$

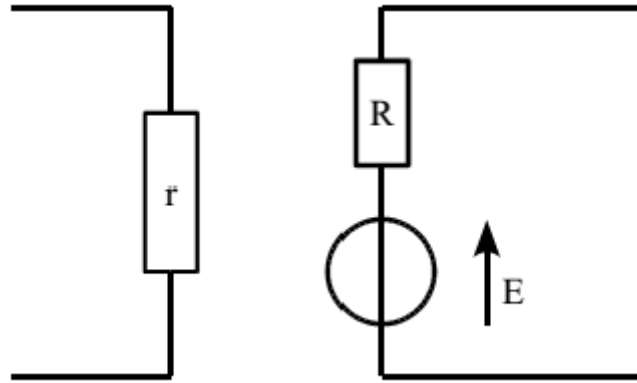


Figure (III.14): Electrical model of an MCC [46].

### III-5-2 electromagnetic power

The electromagnetic power exchanged during its rotation is expressed by the product of the electromagnetic torque  $C_{em}$  and the angular speed  $\Omega$ , according to the law of conservation of energy:

$$P_e = E I = T_{em} \Omega \quad (\text{III.2})$$

### III-5-3 Electromagnetic torque

When a current  $I$  flows in the armature, the electromagnetic power is  $P_e = E I$

The rotor rotating at speed  $\Omega$ , there is an electromagnetic torque  $T_{em}$  such that:

$$P_e = T_{em} \Omega \quad (\text{III.3})$$

We then show that the expression of the electromagnetic torque is:

$$T_{em} = K \phi I \quad (\text{III.4})$$

That is to say that the electromagnetic torque is proportional to the intensity which circulates in the armature [46].

### III-6 Different modes of DC motor speed adjustment

To vary the speed of a DC motor, we use one of the following methods:

### III-6-1 Rheostatic adjustment

To control the speed in this method, the armature resistance must be increased with a rheostat connected in series with the armature.

Through this relationship:

$$n = \frac{U - (R_a + R_{ad}) \cdot I}{K} \quad (\text{III.5})$$

For  $n = 0$ :

$$C = \frac{K \cdot U}{R_a + R_{ad}} \quad (\text{III.6})$$

With:

$R_a$ : Armature resistance (Ohm).

$R_{ad}$ : Rheostat connected to the armature terminals (Ohm).

$U$ : Supply voltage (V).

$K$ : Motor-specific constant quantity.

$I$ : Armature current (A).

$C$ : Useful engine torque (Nm).

### III-6-2 Setting by armature voltage

In the process, to increase the emf  $E$  by increasing the voltage across the armature while keeping the inductor flux constant. And from there automatically the torque is constant.

We have :

$$n = \frac{U}{K} \quad (\text{III.7})$$

With :

$U$ : Supply voltage (V).

$K$ : Constant quantity specific to the motor.

### III-6-3 Adjustment by flow

From next rotation:

$$n = \frac{U}{K \cdot \phi} \quad (\text{III.8})$$

Field flux (field flux) is reduced by reducing the field current while keeping the armature supply voltage constant. This type of operation reduces torque as speed increases.

Adjusting the voltage will only decrease the rated speed, adjusting the flux will increase the rated speed. As it is impossible to apply a voltage higher than the nominal voltage without risk, nor to use a flux higher than the nominal flux, the choice of the adjustment mode depends on the load driven by the motor.

### III-6-4 Adjustment by regulator

To guarantee a specific behavior of the variables of the DC machine, we generally use a precise method using the PID regulator, fuzzy logic or the LQR command ...,

### III-6-5 Adjustment by DC/DC converter

This method depends on the use chopper (We will discuss it next).

## III-7 DC Motor Modeling

In this part it is necessary to apply this modeling to the MCC with separated excitation.

### III-7-1 Engine equation

The electrical equation of the voltage and the armature current is written:

$$V_a = I_a R_a + L_a \frac{dI_a}{dt} + E_b \quad (\text{III.9})$$

With:

$R_a$  : Armature resistance

$L_a$  : Armature inductance

$E_b$  : f.c.e.m, is proportional to the speed of rotation of the rotor.

From equation (III.9) the motor flux and torque is constant, the f.c.e.m. developed by the machine is written:

$$E_b(t) = K_e \Omega(t) \quad (\text{III.10})$$

With :

$K_e$  : emf constant

The mechanical equation of this machine is written:

$$J \frac{d\Omega(t)}{dt} = C_m(t) - C_r(t) - f\Omega(t) \quad (\text{III.11})$$

With:

$J$  : the moment of inertia of the rotor

$\frac{d\Omega(t)}{dt}$  : Angular acceleration

$C_m(t)$  : the engine torque applied by the machine

$C_r(t)$  : the resistant couple

$f$  : viscous coefficient of friction

$\Omega(t)$  : rotational angular velocity

From the mechanical equation:

$$C_m(t) = C_r(t) \quad \text{et} \quad \Omega = Cte$$

We have the following equation:

$$C_m(t) = K_m(t) * I(t) - C_p(t) \quad (\text{III.12})$$

With :

$K_m$  : torque constant,  $K_c$ : ( $K_m K_T = K_c$ )

We replace the value of  $(t)$ , the equation (III.12) becoming:

$$J \frac{d\Omega(t)}{dt} = K_c(t) * I(t) - C_r(t) - f\Omega(t) \quad (\text{III.13})$$

### III-7-2 Model for separately excited MCC speed control as a Transfer

#### Function

We will transform the previous equations into Laplace's formula, assuming the initial conditions are zero:

$$V_a(p) = R_a * I_a(p) + (L_a * p) * I(p) + E_b(p) \quad (\text{III.14})$$

$$E_b(t) = K_e \Omega(p) \quad (\text{III.15})$$

$$Jp\Omega(p) = K_c * I(p) - C_r(p) - f\Omega(p) \quad (\text{III.16})$$

From equation (III.16):

$$\Omega(p) = \frac{K_c * I(p) - C_r(p)}{Jp + f} \quad (\text{III.17})$$

And we extract the expressions of voltage and current:

$$I(p) = \frac{Jp + f}{K_c} * \left[ \Omega(p) + \frac{C_r(p)}{Jp + f} \right] \quad (\text{III.18})$$

$$V_a(p) = \Omega(p) * \left[ \frac{((L_a * p) + R_a) * (Jp + f)}{K_c} + K_e \right] + \frac{((L_a * p) + R_a)}{K_c} * C_r(p) \quad (\text{III.19})$$

For  $C_r(t) = 0$ , SO :

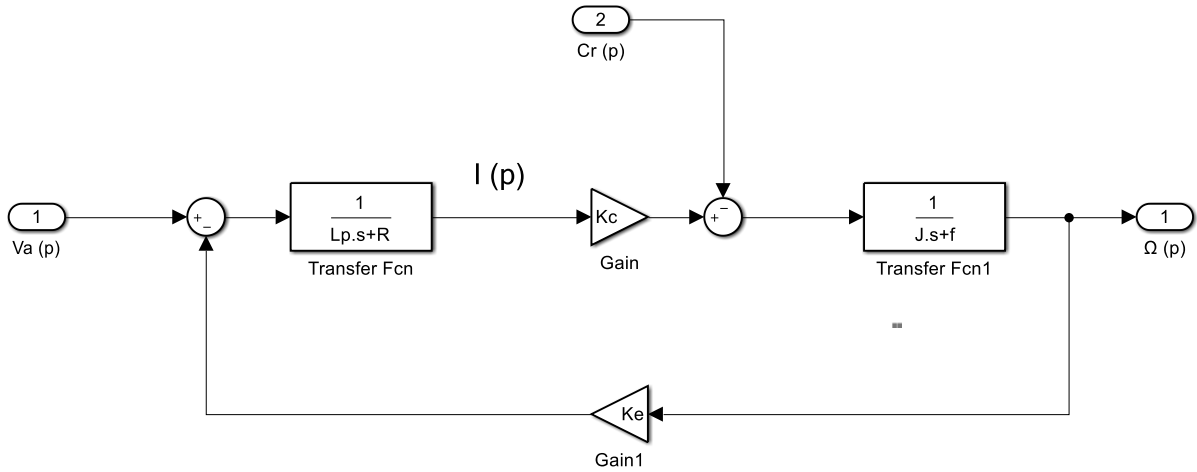
$$V_a(p) = \Omega(p) * \left[ \frac{((L_a * p) + R_a) * (Jp + f)}{K_c} + K_e \right] \quad (\text{III.20})$$

So the transfer function is:

$$H(P) = \frac{\Omega(p)}{V_a(p)} = \frac{K_c}{((L_a * p) + R_a) * (Jp + f) + (K_e * K_c)} \quad (\text{III.21})$$

### III-7-3 Construction of the block diagram

The MCC can be thought of as a feedback system. To achieve this, we must use the Laplace transform obtained, which allows us to model the engine in the form of a block diagram or a functional diagram, as shown in the following diagram:



**Figure (III.15):** Speed Open Loop MCC Motor Model Block Diagram.

### III-7-4 Simulation of Separately Excited MCC

We have simulated the model of a DC machine with separate excitation with the following parameters:

Settings	Values
Armature voltage U [V]	240
Armature resistance Ra [ $\Omega$ ]	0.6
Armature inductance La [H]	0.012
Field voltage Uex [V]	240
Inductor resistance Rex [ $\Omega$ ]	240
Inductor inductor Lex [H]	120
Moment of inertia J[kg m <sup>2</sup> ]	1
Rated speed $\Omega$ [tr/min]	2444
Rated torque Cn [Nm]	30

**Painting (III.1):** MCC Settings.

For this simulator:

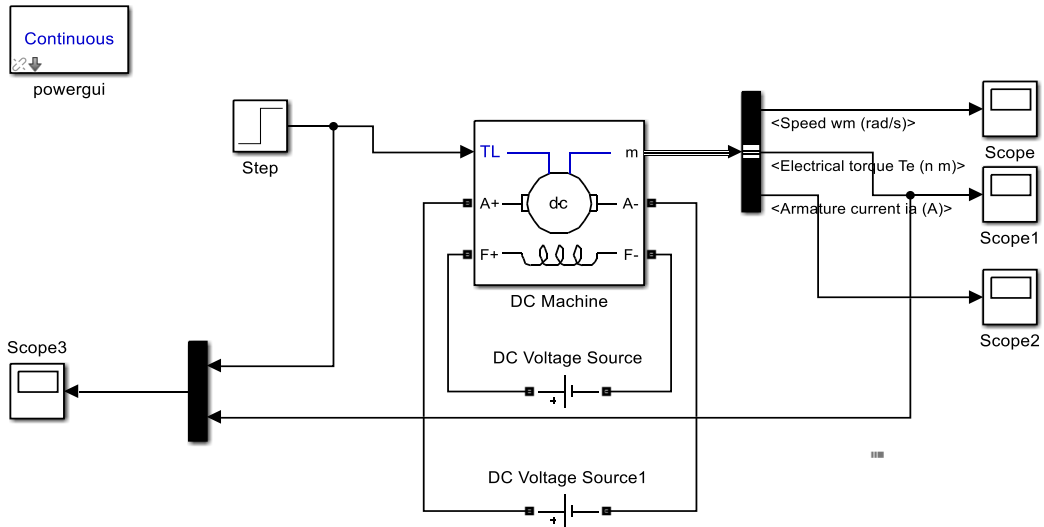
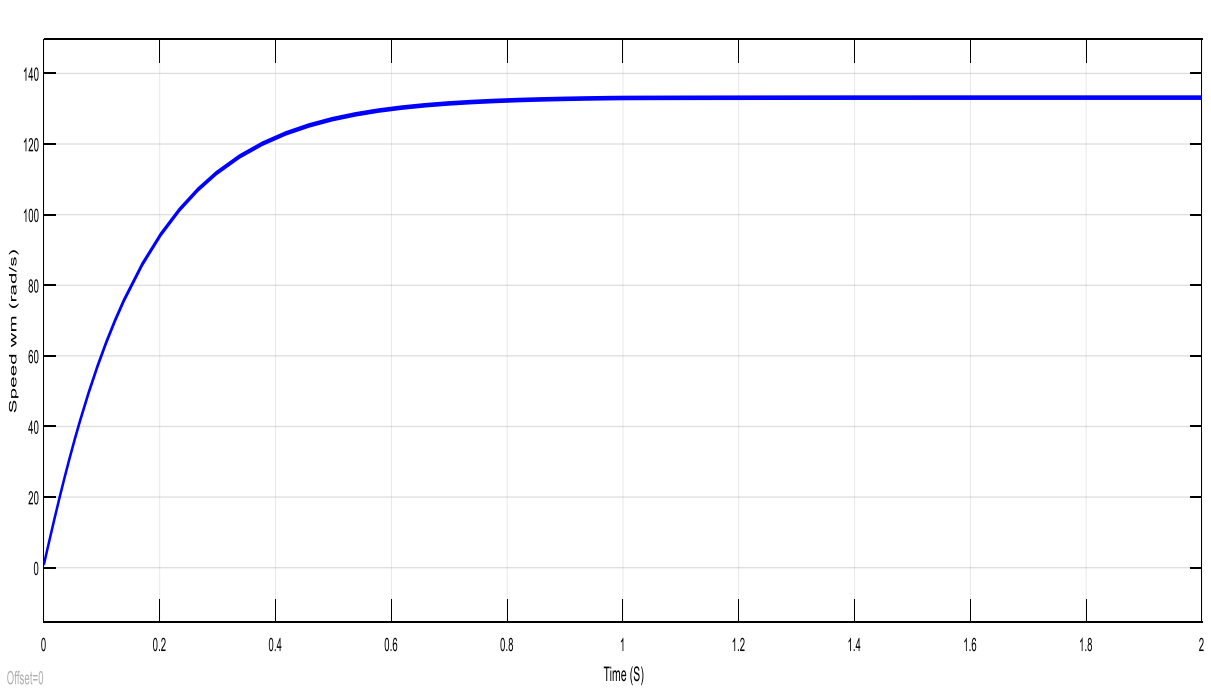
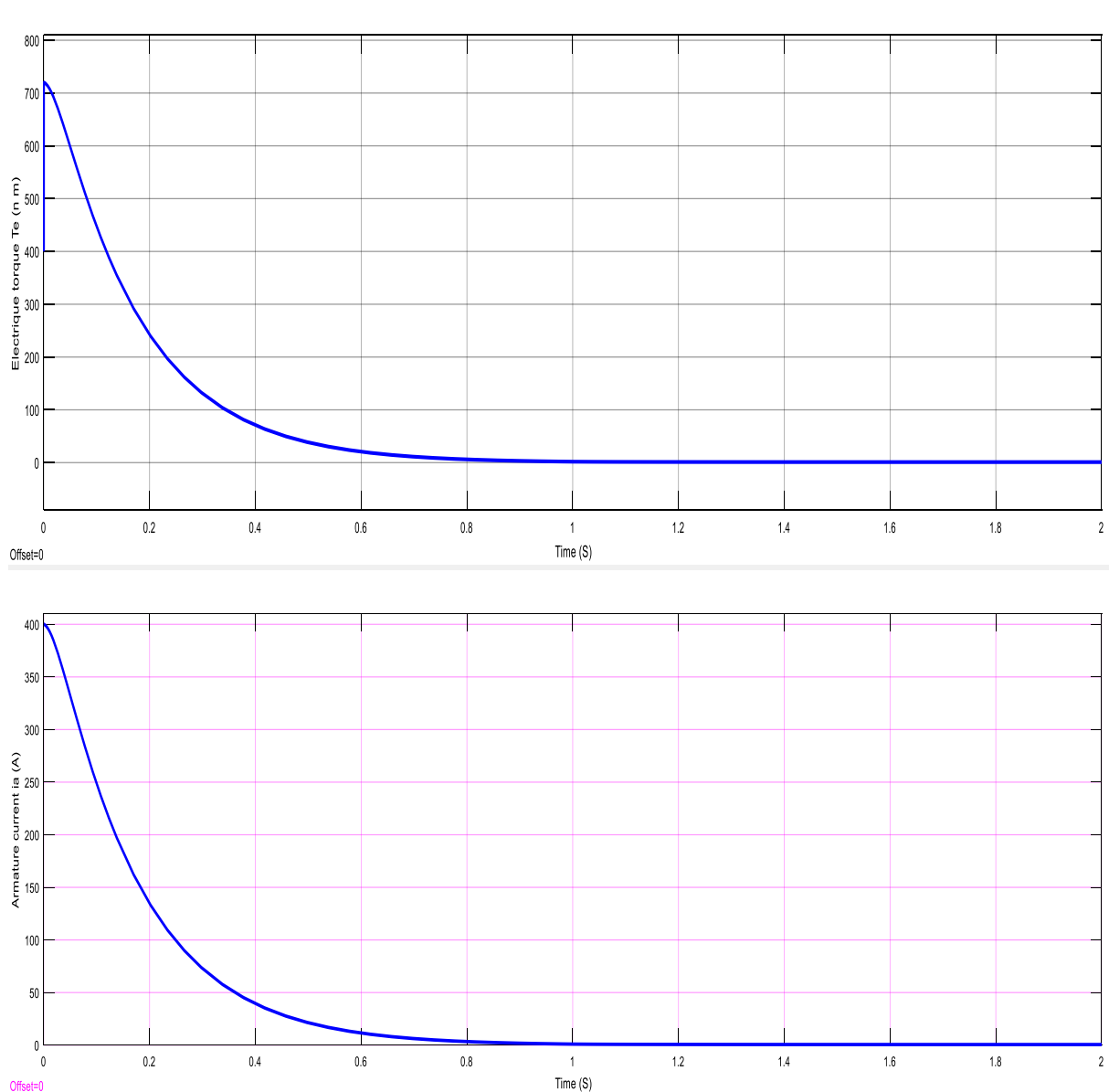


Figure (III.16): Block diagram of the separately excited MCC motor.

1) Results :





**Figure (III.17):** he torque, speed and current curves of the MCC.

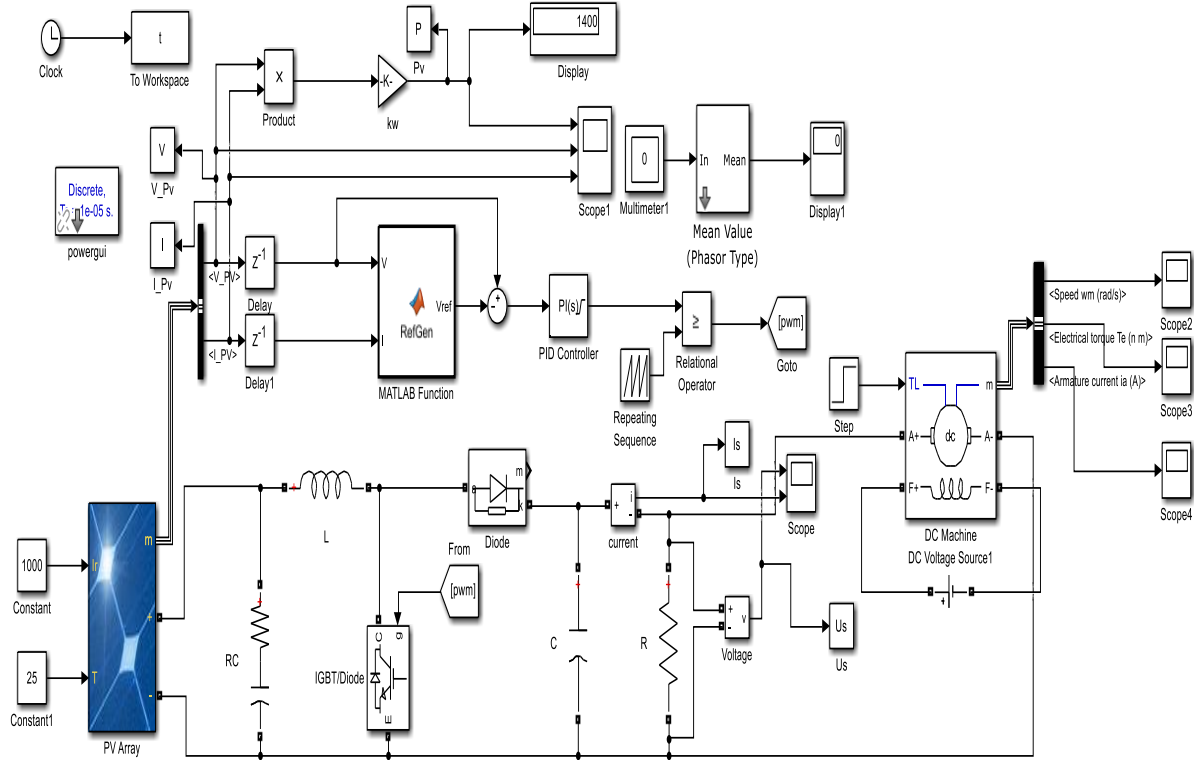
## 2) Interpretation of the results obtained

The figures in front represent the curves of current, torque and speed Different phases of operation of the DC motor. It should be noted that characteristics (current-torque-time) show a high inrush current at start-up (current and torque observed a peak of significant value equal to nearly 400 A of current and a torque of 710 N.m).

### III-8 Global simulation (GPV, converter, MPPT, MCC)

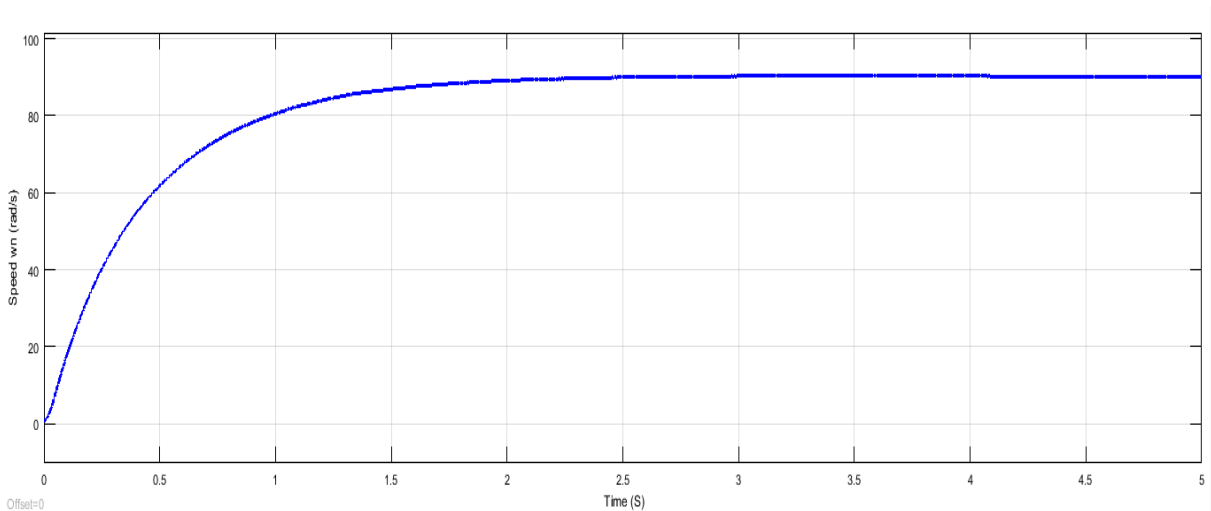
In this part it is necessary to simulate the direct current machine to connect directly to the system.

To have the necessary supply voltage and to satisfy the characteristics of the DC machine, we opted for a panel (40 Parallels and 2 Series) with a BOOST chopper.

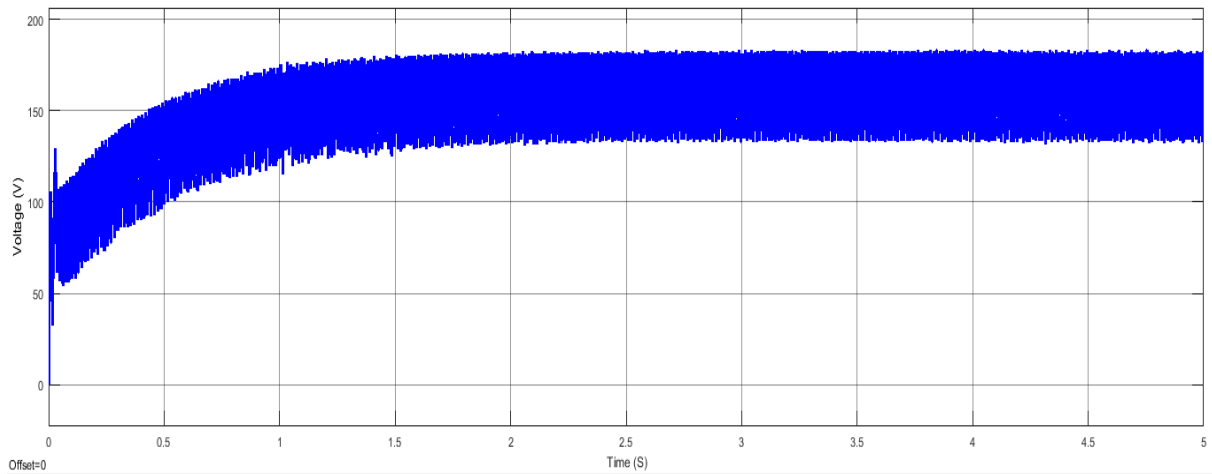


**Figure (III.18):** Block diagram of the global system (GPV, converter, MPPT, MCC).

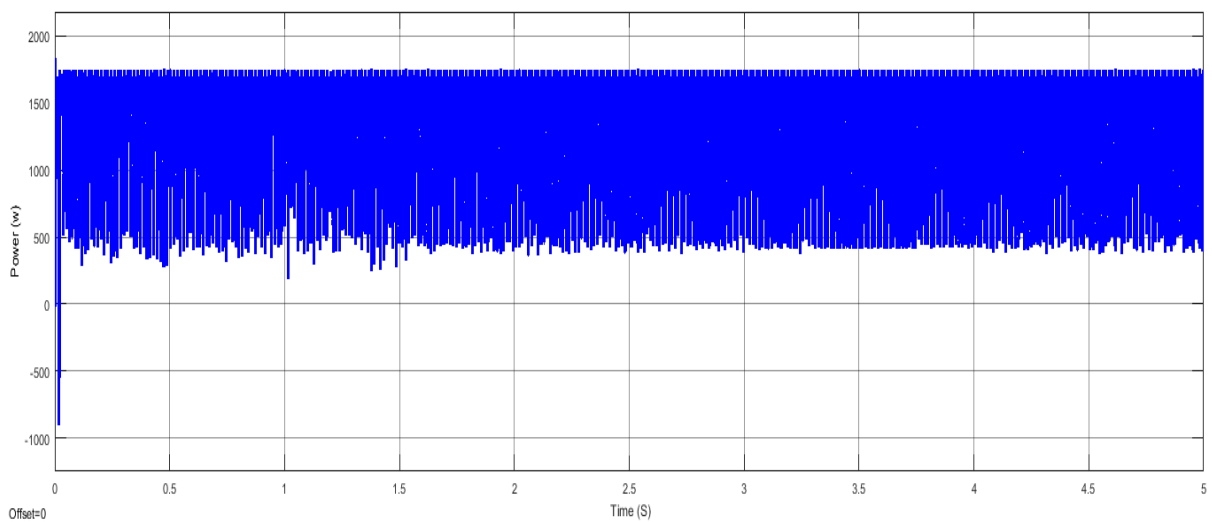
**1) Results :**



**Figure (III.19):** Speed of the MCC at time T=3 s.



**Figure (III.20):** DC-DC converter output voltage.



**Figure (III.21):** output power of the photovoltaic generator.

## 2) Interpretation of the results obtained

According to **Figure (III.19)** which represents the output speed of the motor, the speed will drop, which will change the operation of the machine (MCC). This is for the one we used a speed regulator (PI) to be able to bring the speed of the machine (MCC) back to its reference speed regardless of the load applied.

After using the photovoltaic modules, the power of the generator increases with an increase in the voltage of a converter.

## III-9 The Advantages and Disadvantages of DC Motor

The main advantage, which has made the success of DC motors, lies in their simple adaptation to the means making it possible to regulate or vary their speed, their torque et leur sens de rotation ‘ les

variable speed drives', see their direct connection to the energy source 'accumulators, batteries, etc....'.

The main problem with these machines comes from the connection between the brushes, or "carbons" and the rotary commutator. In addition it should be noted that:

- The higher the rotation speed, the more the pressure of the brushes must increase to remain in contact with the commutator, therefore the greater the friction.
- At high speeds the brushes must therefore be replaced very regularly.
- The commutator imposing contact breaks causes arcs, which quickly wear the switch and generate noise in the power supply circuit, as well as by electromagnetic radiation [47].

### **III-10 Areas of use for DC motors**

DC motors are used in [48]:

- Industry: Rolling mills, coiling (steel mills, paper mills), slitting machine (cutting of sheet metal to shorten the width of a coil), wire-drawing machine (reduction of the section of a wire by mechanical traction).
- Transport: Railway traction motors, ski lifts.
- Handling: Lifting (gantry cranes in shipbuilding or aeronautics, cranes), lifts.

DC motors are also used in areas of low power such as toys (radio-controlled cars, scale models of electric trains),

supplied with low DC voltages (<12V), DC motors are capable of developing high speeds (MFA Como Drills reference 540/1 motor can run idle at a speed of 15800rpm under 12V voltage ), these motors develop a drive torque that allows them to move loads of a respectable mass.

For powers of between a few hundred watts and a few kilowatts, DC motors equip devices for handling low loads (forklifts) and new means of individual transport (bicycles with electric assistance, electric cars).

On a daily basis, in the domestic context (universal motor in drills, circular saws, screwdrivers, etc.) and household appliances (vacuum cleaners, food processors, etc.).

**III-11 Conclusion:**

In this chapter we must talk about the different elements that constitute a DC machine and the principle of operation, and we have tested by simulation the characteristics of the MCC. Finally, we combined the MCC with (GPV with MPPT and Boost converter and PI regulator) to see how they affect the MCC (startup).



**General Conclusion**

# Conclusion

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## Conclusion

Our project focused on energy saving systems, which is an important topic in electrical engineering applications. In today's renewable energy systems, the growing interaction of technological, economic, and environmental restrictions necessitates design and control approaches.

Our objectives were to study the control laws of the boost converter in a photovoltaic chain used as a power source for a DC motor. This constitutes an interesting alternative for a better exploitation of renewable energy.

In the first Chapter, we presented General information on Photovoltaic Systems

The second chapter is dedicated to the study and the simulation of the DC-DC converter. The MPPT technique based on perturb and observe optimization was used in PV systems to maximize the output power.

In the Chapter 3, in chapter 3, we proposed a direct starting of the DC motor by a DC voltage controlled by the boost converter.

The results obtained show the feasibility of the system which can be used in several fields. Like electric traction.

Finally; we suggest as works of improvement of our work:

- experimental validation;
- use of developed and efficient control techniques ;
- use of artificial intelligence for system control and optimization.

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## **Abstract:**

A suitable power source for motors, especially in isolated areas is one of the limitations of pumping stations. This thesis focused on this sensitive issue.

Therefore, photovoltaic energy of solar origin seems to be the most attractive solution:

1. To meet the energy needs for the operation of the motors.
2. To meet the needs of isolated uses as in many regions of our country.

This work is connected with modeling a photovoltaic panel associated with an MPPT controlled DC-DC Converter, which aims to drive a DC machine.

The photovoltaic generator can operate in a wide range of output voltage and current but can only supply maximum power for specific values of current and voltage.

In fact, the  $I(V)$  characteristic of a generator depends on solar illumination and temperature.

The climate changes cause the energy cap to fluctuate.

Because of the fluctuation, one or more static controlled transformers are often interleaved between the generator and receiver allowing the maximum power point to be tracked using the disturb and monitor (P&O) method.

These commands, known as MPPT (Maximum Power Point Tracking), are linked to a DC-DC converter, which ensures coupling between the PV generator and the DC device by forcing the former to deliver its maximum power.

**Key Words:** PV generator, chopper, MPPT, P&O, DC motor.