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An optimal Fuzzy logic controller based MPPT controller for a PV system

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I do not forget my parents for their contribution, their support and their patience. Finally, I extend my most sincere thanks to all my loved ones and friends, who always encouraged me during the completion of this work.

Dedication

As a testimony of love and affection, I dedicate this work with pride

To my dear parents who gave me everything that I could to have an honorable career throughout my student life,

To my dear father, may God bless you and prolong your life because you are the light that illuminates my path.

I dedicate it to my dear mother, who made me want to succeed.

To my dear great sister who never stopped supporting me throughout my journey.

And to you, my dear brothers

My family and my cousin Soufyan

Which encouraged me a lot

God bless you

ملخص

إن الطلب المتزايد على الطاقة الكهربائية في المناطق النائية يستلزم البحث عن مصادر بديلة للطاقة. تبحث هذه الأطروحة في جدوى الطاقة الشمسية، وهي مصدر متجدد يتأثر في الغالب بالظروف الجوية. نقوم بإجراء دراسة شاملة للنظام الكهروضوئي (PV) ومكوناته، مع التركيز بشكل خاص على أساليب تتبع نقاط الطاقة القصوى (MPPT). تبحث دراسات المحاكاة في أداء تقنيتين MPPT السائدتين - الاضطراب والمراقبة (P&O) والمنطق الضبابي - لتحسين خرج الطاقة من خلال تتبع أقصى نقطة طاقة للنظام الكهروضوئي. علاوة على ذلك، يقدم هذا البحث منهجًا مبتكرًا من خلال دمج الخوارزميات الجينية مع طريقة المنطق المضبب لتعزيز فعاليتها وكفاءتها. تظهر الدراسات المقارنة أن استراتيجية المنطق الضبابي المحسنة تعمل بشكل أفضل، مما يسلط الضوء على فوائدها المحتملة لجعل الأنظمة الكهروضوئية أكثر كفاءة في تطبيقات الطاقة عن بعد.

الكلمات المفتاحية: النظام الكهروضوئي, المنطق الضبابي، تتبع أقصى نقطة للطاقة،المحاكاة.

Abstract

The increasing demand for electrical energy in remote locations necessitates exploration into alternative power sources. This thesis examines the viability of solar energy, a renewable source predominantly influenced by meteorological conditions. We conduct a comprehensive study of the photovoltaic (PV) system and its components, with a particular focus on Maximum Power Point Tracking (MPPT) methods. Simulation studies investigate the performance of two prevalent MPPT techniques—Perturbation and Observation (P&O) and Fuzzy Logic—to optimize power output by tracking the PV system's maximum power point. Furthermore, this research introduces an innovative approach by integrating a Genetic Algorithms (GAs) with the fuzzy logic method to enhance its effectiveness and efficiency. Comparative studies show that the optimized fuzzy logic strategy works better, which highlights its potential benefits for making photovoltaic systems more efficient in remote power applications.

Keywords: Photovoltaic systems, fuzzy logic, MPPT, simulation.

Résumé

La demande croissante d’énergie électrique dans les régions éloignées nécessite d’explorer des sources d’énergie alternatives. Cette thèse examine la viabilité de l'énergie solaire, une source renouvelable principalement influencée par les conditions météorologiques. Nous menons une étude complète du système photovoltaïque (PV) et de ses composants, avec un concentration particulier sur les méthodes de suivi du point de puissance maximale (MPPT). Les études de simulation étudient les performances de deux techniques MPPT courantes : perturbation et observation (P&O) et logique floue - pour optimiser la puissance de sortie en suivant le point de puissance maximale du système photovoltaïque. De plus, cette recherche introduit une approche innovante en intégrant un algorithme génétique (GAs) avec la méthode de logique floue pour améliorer son efficacité et son efficience. Des études comparatives montrent que la stratégie de logique floue optimisée fonctionne mieux, Ce qui met en évidence ses avantages potentiels pour rendre les systems photovoltaïques plus efficacies dans les applications d'alimentation à distance.

Mots-clés : Système photovoltaïque, logique floue, MPPT, simulation.

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General Introduction

Fossil fuels, such as coal, oil, and natural gas, account for the majority of the energy used by humans. However, due to excessive consumption, these resources are quickly depleting and pose a serious threat to the environment, primarily in the form of pollution and greenhouse gas-induced global warming. Renewable energy is one of the more promising energy options due to its abundance, lack of pollution, and global availability in varying quantities. On the one hand, the cost of conventional energies has increased, and on the other, their resources are limited.

Renewable energy sources include biomass, geothermal energy, wind, waterfalls, and tides. These are the energies of the future; while operation, they produce little to no waste or emissions that pollute the environment. A certain number of technological areas are brought together by these energies, depending on the energy source and usable energy produced.

This thesis examines the photovoltaic energy industry. The primary drawbacks of this energy, however, are its comparatively low energy efficiency and the generator's still high cost. Two approaches are taken in order to solve these issues:

- ✓ Increases energy efficiency by adopting very high-level technologies during the manufacturing of photovoltaic cells.
- ✓ Maximizes the power delivered by the generator.

The current study compares and studies two methods (optimal fuzzy logic and purturbation and observation) for optimizing the amount of electricity produced by the photovoltaic generator. Our work has been separated into three chapters in order to accomplish this goal.

The PV system, its applications, PV cells, their operation, the connection of photovoltaic cells in series and parallel, their current-voltage (I-V) characteristics, and dc/dc converters are all covered in the first chapter. An overview of mppt approaches and an optimization method (GA) is given in the second chapter. Lastly, a model based on a step-up chopper for locating a solar generator's maximum power point in the MATLAB/SIMULINK environment is provided in the third chapter. The model is simulated using both the fuzzy logic genetic algorithm and the mppt disturbances and observation (P&O) algorithms under identical meteorological conditions, and the outcomes are compared.

Chapter 1

Photovoltaics system: general discussion

Chapter 1: Photovoltaics systems: General discussion

1.1 Introduction

The sun is an almost unlimited energy source; it could cover our overall energy consumption several thousand times. This is why man has been seeking to take advantage of this important energy distributed throughout the planet for a long time. He has managed to achieve this goal using the means known as photovoltaic cells.

This chapter is dedicated to providing a comprehensive overview of PV solar energy, delving into every facet from the basic principles governing photovoltaic cells to the intricate mechanisms behind complete conversion systems. We'll explore the evolution of photovoltaic technology, tracing its roots back to the discovery of the photovoltaic effect and its subsequent advancements through decades of research and innovation. Additionally, we'll discuss the various topologies of PV solar energy systems connected with different DC-DC conversion system.

1.2 PV System

1.2.1 Brief history

Solar energy converts solar radiation into electricity which is based on the PV effect. Alexandre Edmond Becquerel discovered it in 1839 [1-2] when he found that certain materials produce an electric current when exposed to light. In 1877, two Cambridge scientists, Adams and Day, published the first report on the PV effect [1]. In 1883, Charles Fritts built a selenium solar cell with an efficiency of less than 1% [1]. In 1954, Chapin and others announced the first manufacturing of a solar element with a p-n junction and an efficiency of 6% [2-3]. Today, an efficiency of 20% can be achieved for a PV cell. Virtually all PV devices are made from semiconductor materials capable of absorbing a large portion of the solar spectrum.

1.2.2 Global electricity production by PV modules

According to the latest global status report by RENEWABLES 2019, the annual global solar photovoltaic (PV) market grew only slightly in 2018, but enough to exceed the 100 GW level for the first time. Cumulative capacity increased by around 25% to at least 505 GW [4], this compares to a global total of around 15 GW just ten years earlier (Figure 1.1). Rising demand in emerging markets and Europe, due in large part to ongoing price reductions, solar PV has become the fastest growing energy technology in the world, with markets expanding gigawatt scale in a growing number of countries. The demand for solar photovoltaic energy is spreading and expanding, becoming the most competitive option for electricity generation in a growing number of markets for residential and commercial applications and, increasingly, for utility projects public.

The following figure gives the evolution of the capacity and global annual additions of photovoltaic solar energy from 2008 to 2018, this confirms the exponential increase in the energy produced of photovoltaic nature [4].

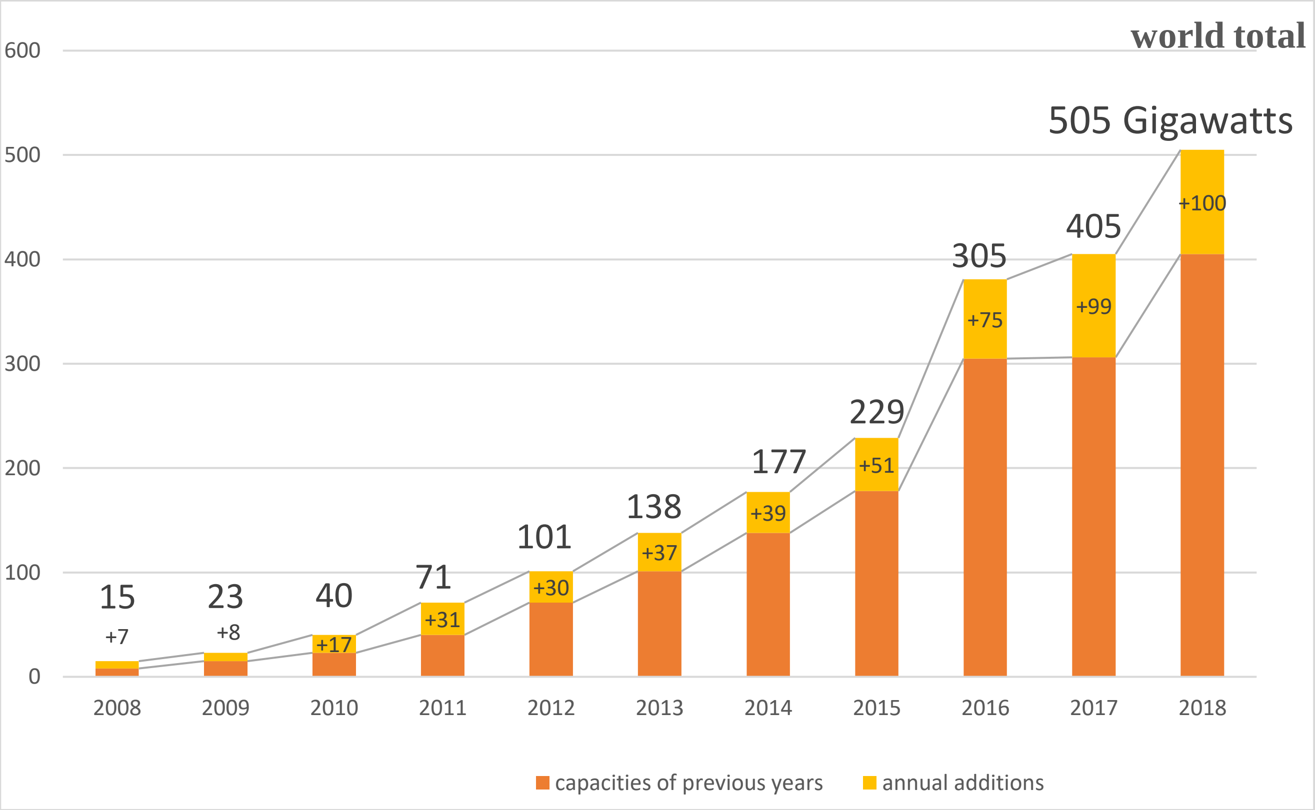


Figure 1.1 Global solar PV capacity and annual additions, 2008–2018 [4].

1.2.3 Development of photovoltaic systems in Algeria

The revision of the national energy program focuses on the development of large-scale photovoltaics. The first phase of the program was devoted to carrying out pilot projects and tests on various existing technologies. The national program for the development of renewable energies and energy efficiency aims to put into service with a renewable energy production capacity of 22,000 MW by 2030 [5] (Figure 1.2).

The second phase has just been launched by the national and international call for tenders for the Algerian project called "Atlas 1", with a total capacity of 4,050 megawatts, divided into three lots of 1,350 megawatts each in solar energy of photovoltaic type. This confirms the state's policy of investing more and more in renewable energies and in particular photovoltaic energy.

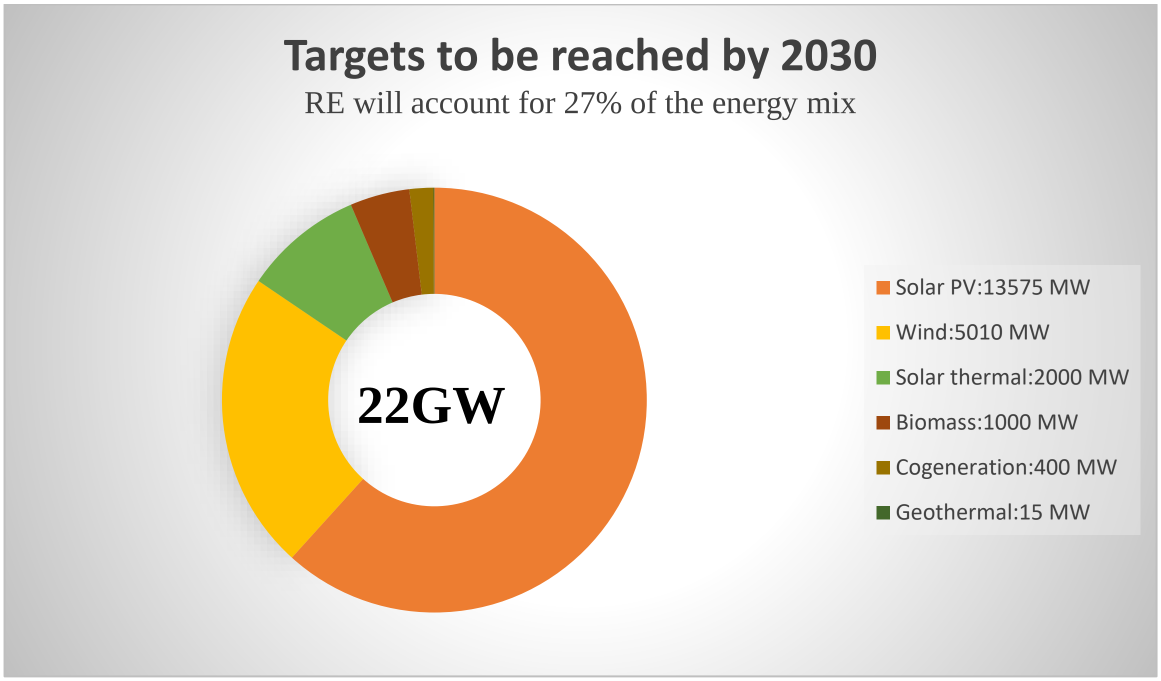


Figure 1.2 allocation of the objective of 22 GW to be achieved in 2030 [5].

1.2.4 Photovoltaic Systems

Photovoltaic (PV) modules are the basic elements of any photovoltaic system. They can be connected in series to increase their voltage and in parallel to increase their current. This set is called the PV module field [6]. The energy provided by the field can be used to charge batteries that will provide electricity when needed. It can also be used by directly connecting the modules to the load without the batteries, or by connecting them to an electrical network. It is also possible to combine the output of the PV field with other energy sources such as a generator or a wind turbine which will serve as backup, if the sunshine is not sufficient.

1.2.4.1 Types of photovoltaic systems

There are generally three types of photovoltaic systems: stand-alone systems, hybrid systems and grid-connected systems. The first two are independent of the electricity distribution system, often found in remote areas.

- **stand-alone solar systems**

An installation that operates independently of the electricity system or any other energy sources. In the majority of cases, this system is used in isolated sites. Such an installation must be capable of providing energy, including when there is no sun (at night or in bad weather). It is therefore necessary that part of the daily production of photovoltaic modules be stored in batteries [7]. This installation consists of one or more photovoltaic modules, a charge regulator, one or more batteries and possibly an inverter.

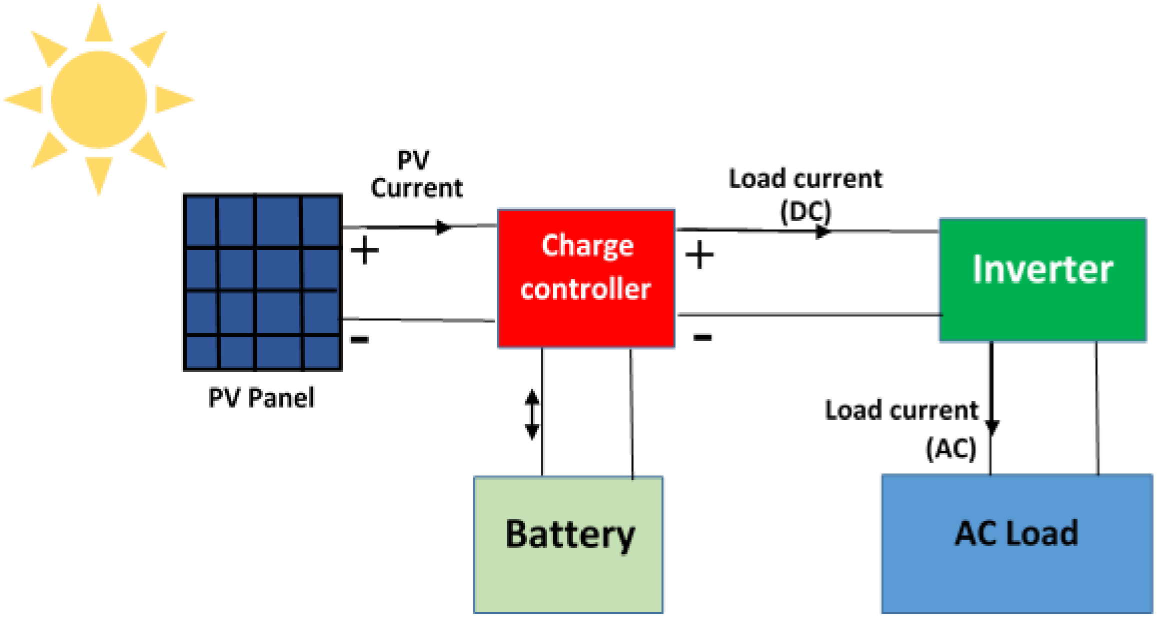


Figure 1.3 stand-alone system [8].

- **Hybrid solar systems**

Hybrid systems consist of the combination of two or more complementary technologies in order to increase the supply of energy. Energy sources as the sun and wind do not deliver constant power, and their combination can achieve more continuous electricity production over time.

Hybrid systems work such that the batteries are charged by the solar panels (during the day) and by the wind generator (when it is windy) [6-9].

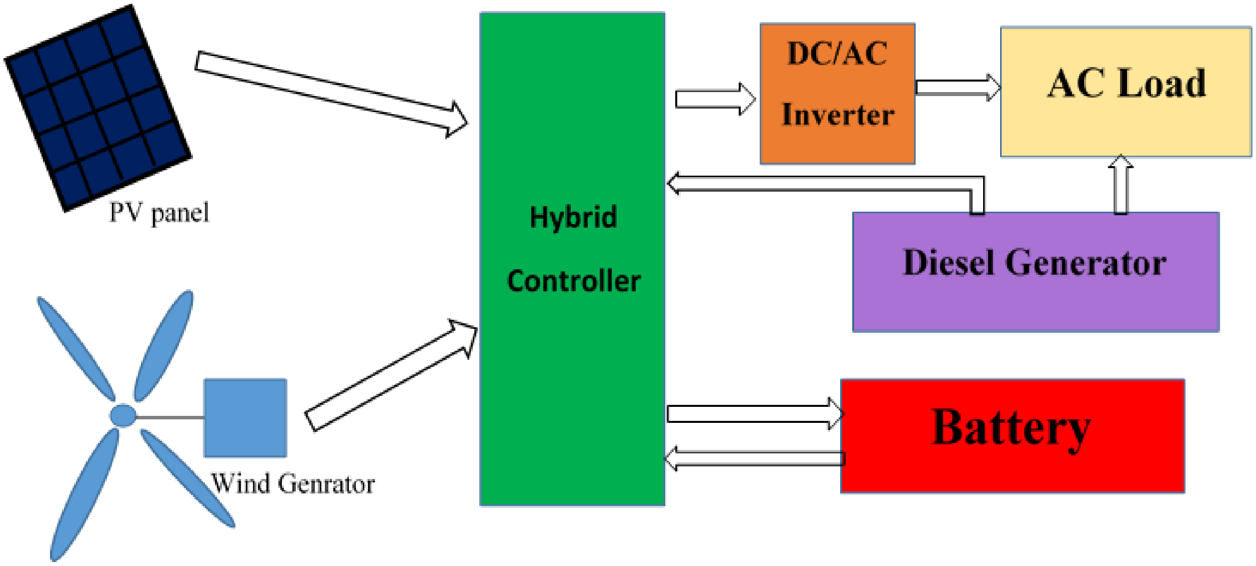


Figure 1.4 General diagram of a hybrid system for electricity production based on wind and Sun energy conversion [9].

- **Grid-tied solar systems**

Installations connected to the electricity system (or connected to a distribution center) generally constitute an optimal solution for the production of solar electricity, both in terms of energy and costs. These installations consist of interconnected photovoltaic modules, one (or more) inverter(s) connected to the electrical network [6-10]. The inverter converts the direct current generated by the photovoltaic modules and produces alternating current compliant with the electrical network. Figure 1.5 illustrates the principle of a grid-connected photovoltaic system.

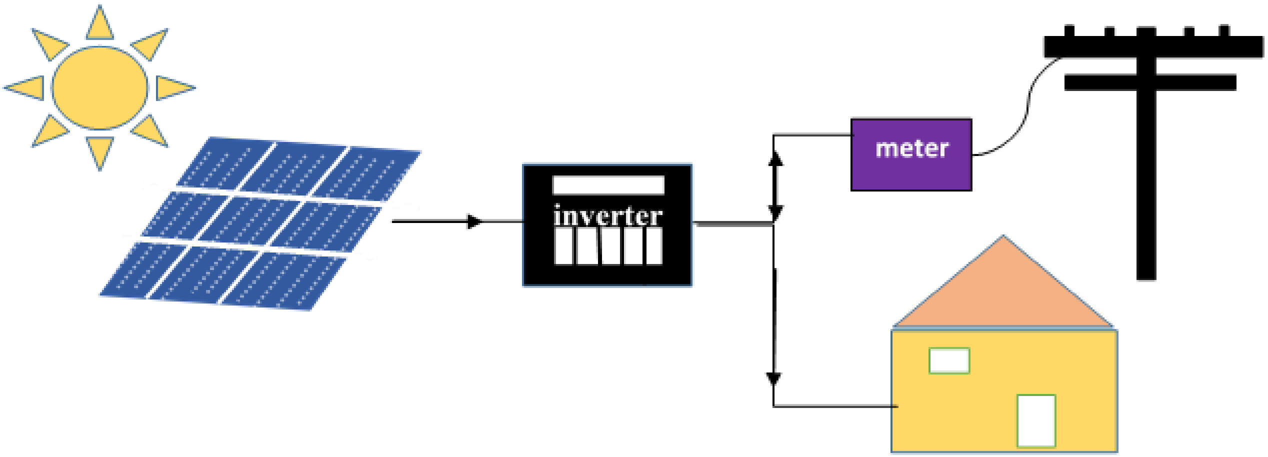


Figure 1.5 Grid-Tied Solar System [10].

1.2.4.2 Benefits and inconvenients of PV energy

Any photovoltaic energy production system has its benefits and inconvenients [6-11].

Benefits:

- Firstly, high reliability. The installation has no moving parts which makes it particularly suitable for isolated regions. This is the reason for its use on spacecraft.
- Then, the modular nature of photovoltaic panels allows simple assembly and adaptability to various energy needs. The systems can be sized for power applications ranging from milliwatt to megawatt.
- The operating cost is very low given the reduced maintenance and it requires neither fuel, nor its transport, nor highly specialized personnel.
- Photovoltaic technology has ecological qualities because the finished product is non-polluting, silent and does not cause any disturbance to the environment, except for the occupation of space for large installations

Inconvenients:

- The manufacturing of the photovoltaic module is high technology and requires high cost investments.
- The actual conversion efficiency of a module is low, of the order of 10-15%, with a theoretical limit for a cell of 28%. Photovoltaic generators are only competitive with diesel generators for low energy demands in isolated regions.

- The low efficiency of photovoltaic panels is explained by the very functioning of the cells to achieve the displacement of an electron, the energy of the radiation must be at least equal to 1ev. All incident rays having a lower energy will therefore not be transformed into electricity. Likewise, light rays whose energy is greater than 1ev will lose this energy, the rest will be dissipated in the form of heat.
- Dependent on weather conditions.
- When the storage of electrical energy in chemical form (battery) is necessary, the cost of the generator is increased.

1.2.4.3 Photovoltaic effect:

The word photovoltaic is made up of two parts: the prefix "photo", which is a derivative of the Greek word for "light" or "clarity", and the suffix "volt", relating to the electricity pioneer Alessandro VOLTA [2-12].

The photovoltaic effect is obtained by absorption of photons in a semiconductor material which then generates an electrical voltage. Photovoltaic cells produce direct current from solar radiation, which can be used to power a device or recharge a battery.

1.2.5 Photovoltaic cell:

A photovoltaic cell, or solar cell, is an electronic component which, exposed to light, produces electricity thanks to the photovoltaic effect. The electrical power obtained is proportional to the incident light power and depends on the efficiency of the cell [13]. This delivers a direct voltage and a current flows through it as soon as it is connected to an electrical load (generally an inverter, sometimes a simple electric battery).

1.2.5.1 The structure:

Silicon is currently the most used to manufacture photovoltaic cells. It is obtained by reduction from silica, the most abundant compound in the earth's crust and particularly in sand or quartz. The first stage is the production of so-called metallurgical silicon, only 98% pure [22], obtained from pieces of quartz from pebbles. Photovoltaic grade silicon must be purified to over 99.999% [22], which is achieved by transforming the silicon into a chemical compound which will be distilled and then transformed back into silicon. It is produced in the form of bars called "ingots" with a round or square section. These ingots are then sawed into thin plates 200 micrometers thick which are called wafers [22]. After a treatment to enrich in doping elements and thus obtain P or N type semiconductor silicon, the wafers are metallized: metal ribbons are inlaid on the surface and connected to electrical contacts. Once metallized, the wafers became photovoltaic cells.

1.2.5.2 Principle of photovoltaic conversion

A photovoltaic cell (photopile) is a sensor composed of semiconductor materials absorbing light energy and converting it directly into electrical energy. This conversion is called the "photovoltaic effect". The photovoltaic effect is mainly obtained by absorption of photons in a material having at least one possible transition between two energy levels (semiconductor). Energy is required to be able to transfer an electron from the valence band to the conduction band, for example, 1.1eV for crystalline silicon, and 1.7eV for amorphous silicon [14]. Absorbed photons of energy greater than this gap can create an electron hole pair, the electron in the conduction band and the hole in the valence band. To obtain a current, we separate the electron and the hole by creating an electric field in a semiconductor, a p-n diode. Zone n contains an excess of electrons, zone p an excess of holes, giving rise to an electric field separating the charges created by the photovoltaic effect [15]. A potential difference is established across the photovoltaic cell as illustrated in Figure 1.6. For silicon, we obtain a p zone by doping it with boron and an n zone by doping it with phosphorus.

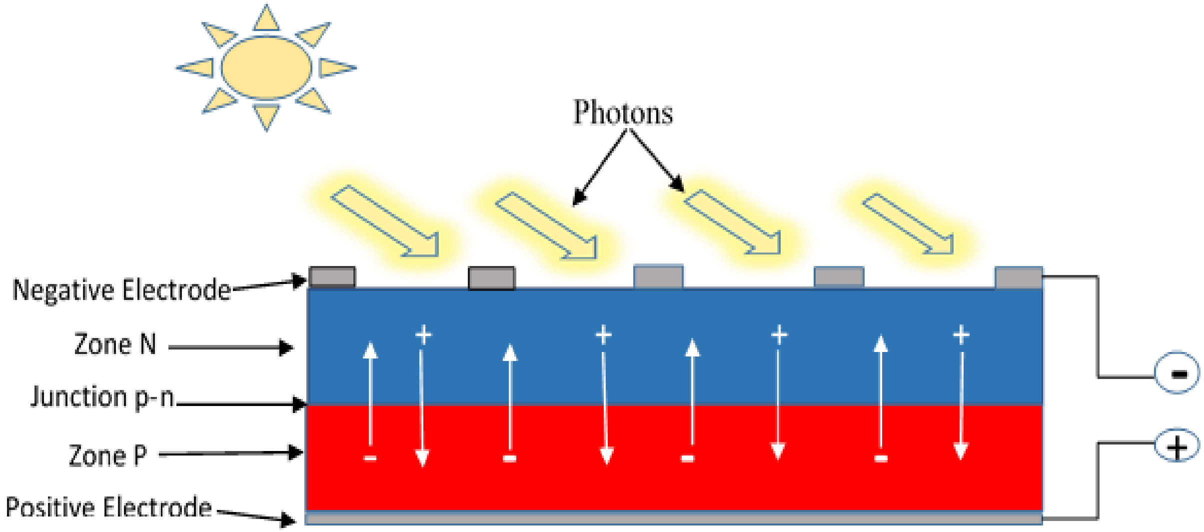


Figure 1.6 Principle of photovoltaic conversion [14].

1.2.5.3 PV Features:

The different types of solar cells: There are three main types of cells [16]:

- **Monocrystalline cells:**

The monocrystalline cell which comes closest to the theoretical model: this cell is actually composed of a single crystal divided into two layers. Monocrystalline cells make it possible to obtain high efficiencies, of the order of 15 to 22%.These cells nevertheless suffer from disadvantages:

- ✓ Laborious and difficult production method, and therefore, very expensive.
- ✓ It takes a large amount of energy to obtain a pure crystal.
- ✓ A high payback period for the energy investment (up to 7 years).

- **Polycrystalline cells:**

Polycrystalline cells are composed of an agglomerate of crystals. They also come from sawing blocks of crystals, but these blocks are cast and are therefore heterogeneous. Polycrystalline cells are:

- ✓ Lower production cost.
- ✓ Requires less energy.
- ✓ Yield of 13% and up to 20% in the lab.

- **Amorphous cells:**

Amorphous silicon appeared in 1976. Its atomic structure is disordered, crystallized, but it has an absorption coefficient higher than that of crystalline silicon. However, what it gains in absorption power, it loses in mobility of electrical charges (low conversion efficiency).

- ✓ Much lower production cost.
- ✓ Yield of only 5% per module and 14% in the laboratory.
- ✓ Works under very low illumination.

1.2.5.4 Characteristics of a Photovoltaic Cell

Take for example a KC200GT module cell. This module has the characteristics following at 1000 (*w/m²*) and 25°*C*, this PV is chosen as an application in our study.

Table 1 Characteristics of the KC200GT module [11].

Optimal power	Short circuit current	Open circuit voltage	Optimal current	Optimal tension
200 w	8.21 A	32.9 V	7.61 A	26.3 V

The following figures represent the characteristics of KC200GT module cell.

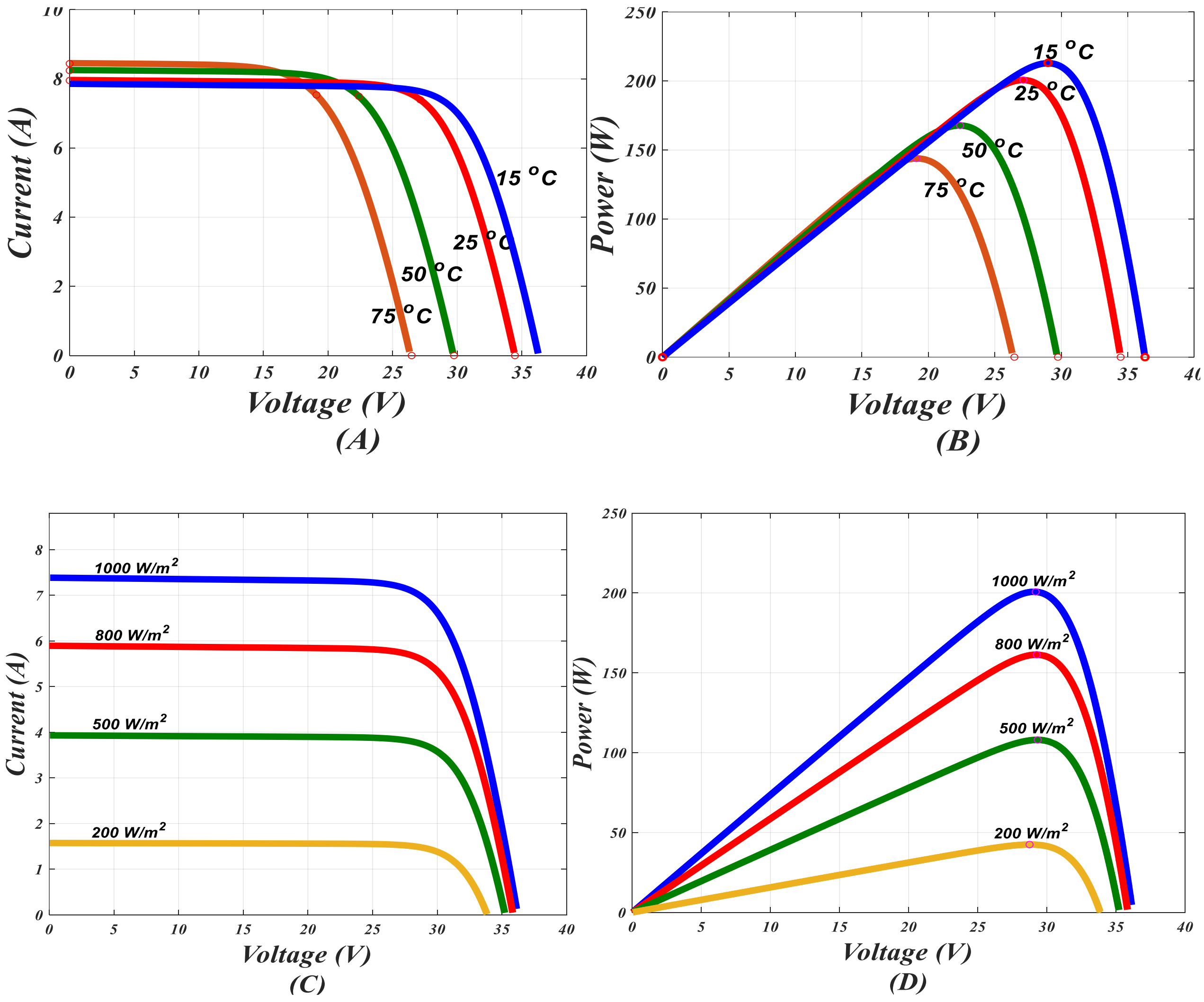


Figure 1.7 Characteristics of KC200GT module:

(A) I-V Characteristics with constant radiation (1000 W/m²) and variable temperature**,**

(C) I-V Characteristics with constant temperature (25 ºC) and variable radiation.

(B) P-V Characteristics with constant radiation (1000 W/m²) and variable temperature**,**

(D) P-V Characteristics with constant temperature (25 ºC) and variable radiation.

1.2.5.5 Group of Photovoltaic Cells

The power provided by a single solar cell is very low, several cells with similar characteristics must be electrically combined and encapsulated in plastic to form a practical GPV [20-21].

a) Association of Photovoltaic Cells in Series

In a series arrangement, the cells carry the same current and the resulting characteristic of the series arrangement is obtained by adding the voltages at a given current [20-21]. Figure 1.8 shows the resulting characteristic (I_{cs} ,V_{cs}) obtained by associating N_s identical cells in series (I_c ,V_c).

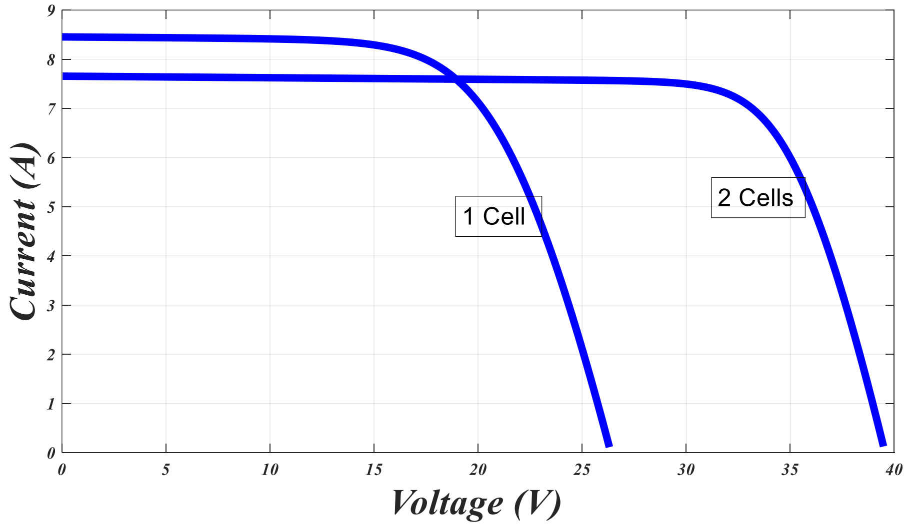


Figure 1.8 I-V characteristic of 2 photovoltaic cells (KC200GT) connected in series.

$$I_{cs} = I_c \tag{1. 1}$$

$$V_{cs} = N_s V_c \tag{1. 2}$$

b) Association of Photovoltaic Cells in Parallel

The properties of parallel grouping of cells are dual to those of series grouping. Thus, in a group of cells connected in parallel, the cells are subjected to the same voltage and the resulting characteristic of the group is obtained by adding the currents at a given voltage [20-21].

Figure 1.9 shows the resulting characteristic (I_{cp},V_{cp}) obtained by associating N_p identical cells in parallel (I_c ,V_c).

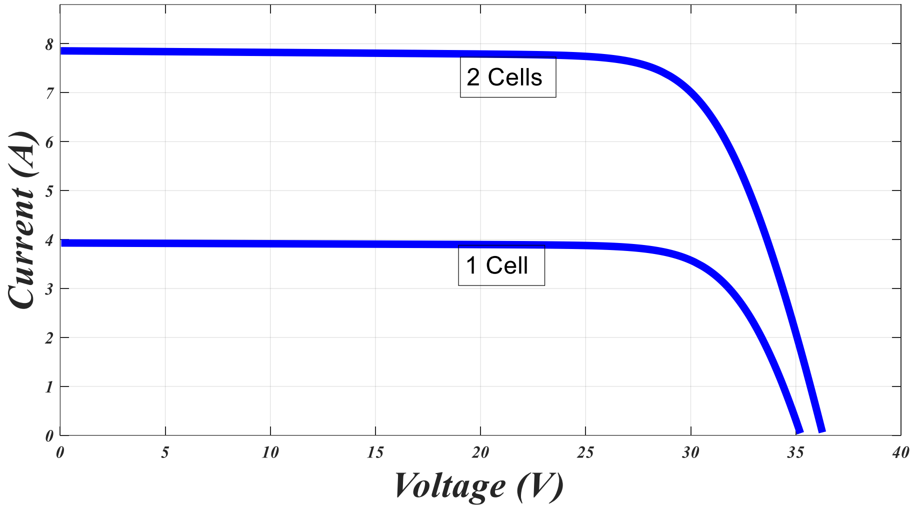


Figure 1.9 I-V characteristic of 2 photovoltaic cells (KC200GT) connected in parallel.

$$I_{cp} = N_p I_c \tag{1. 3}$$

$$V_{cp} = V_c \tag{1. 4}$$

1.2.6 Modeling of a photovoltaic cell

In order to simulate the behavior of the photovoltaic cell it is essential to develop a mathematical model from the equivalent electrical circuit. In the literature three main electrical models are widely used, an issue of physical configuration of the cell is the parameters included makes the difference between these models [17-18-19].

1.2.6.1 Simplified model

The cell will be modeled by a source of current I_{ph} in parallel with a diode. The series resistance R_s presented in Figure 1.10 is introduced as ohmic losses justifying some phenomena at the cell level.

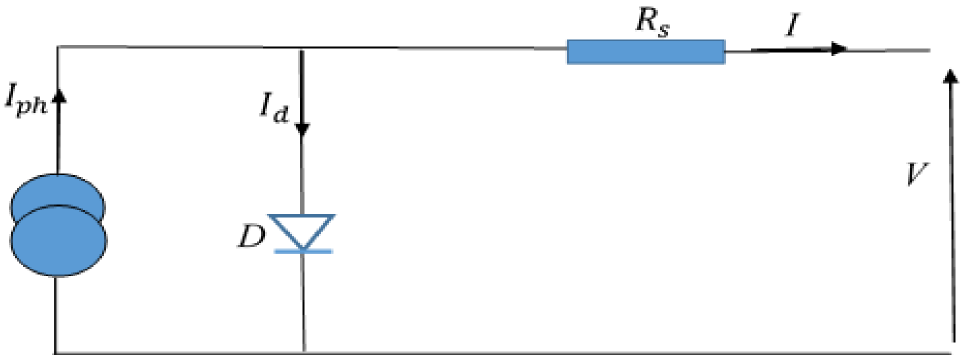


Figure 1.10 Simplified model of a PV cell [19].

This electrical model models the cell as an ideal current generator, according to the law of nodes, the current at the cell output I is given by [17-19]:

$$I = I_{ph} - I_d \tag{1.5}$$

With:

I_{ph}**:** The photocurrent which is constant for a given amount of sunlight.

I_d: The current flowing through the diode given by equation 1.6 [17-19].

$$I_d = I_s\left\{exp\left(\frac{V+R_sI}{aV_t}\right) - 1\right\} \tag{1. 6}$$

a: Ideality factor of the diode.

V_t: Thermal voltage at temperature T.

The current supplied by this model is given by:

$$I = I_{ph} - I_s\left\{exp\left(\frac{V+R_sI}{aV_t}\right) - 1\right\} \tag{1. 7}$$

1.2.6.2 Single diode model

One of the most widely used solar cell models is the one-diode model also known as the five-parameter model. This model includes a combination of a current source I_{ph}, a diode, and a shunt resistor R_{sh} and a series resistor R_s modeling the power losses. The equivalent circuit for this model is given in Figure 1.11.

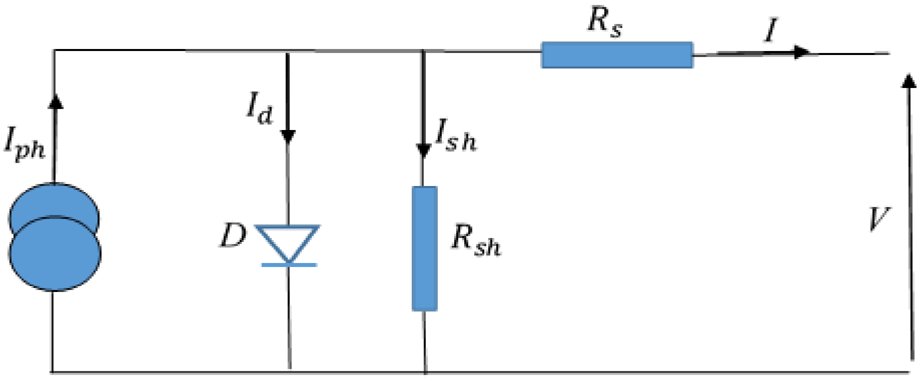


Figure 1.11 One-diode model of a PV cell [18].

The output current of the PV cell is calculated by applying Kirchhoff's law on the equivalent circuit shown in the previous figure [17-18]:

$$I_{ph} = I_d + I_{sh} + I \tag{1. 8}$$

I_{ph}: Photon current

I_d: The current flowing through the diode.

I_{sh}: The current flowing through the resistance.

I : Current generated by the photovoltaic cell.

The current in the diode is given by [17-18-19]:

$$I_d = I_0 \left\{ exp\left(\frac{V+R_s I}{aV_t}\right) - 1 \right\} \tag{1. 9}$$

The current flowing through resistor R_{sh} is given by:

$$I_{sh} = \left(\frac{V+R_s I}{R_{sh}}\right) \tag{1. 10}$$

From equation 1.8, we obtain the expression for current I:

$$I = I_{ph} - I_d - I_{sh} \tag{1. 11}$$

Replacing 1.11 in equations 1.10 and 1.9, the characteristic equation becomes [17-18]:

$$I = I_{ph} - I_0 \left\{ exp\left(\frac{V+R_s I}{aV_t}\right) - 1 \right\} - \left(\frac{V+R_s I}{R_{sh}}\right) \tag{1. 12}$$

With:

$V_t = \frac{N_s\,KT}{q}$: Thermal tension at temperature T [18].

q : Charge of the electron (1.6 *10-19 *C*).

K: Boltzmann constant (1.3854*10-23 *J/K*).

a : Ideality factor of the diode.

T: Effective temperature of the cell in degrees Kelvin [°*K*].

N_s: Number of cells in series per module.

1.2.6.3 Two-diode model

Currently the closest electrical model to a photovoltaic cell is that with two diodes (double exponential), where the cell is of course presented as an electric current generator whose behavior is equivalent to a current source with two diodes in parallel . And to take into account physical phenomena at the cell level, like the previous models, this model is supplemented by the two series R_s and parallel resistors R_{sh} as shown in the equivalent electrical diagram in Figure 1.12.

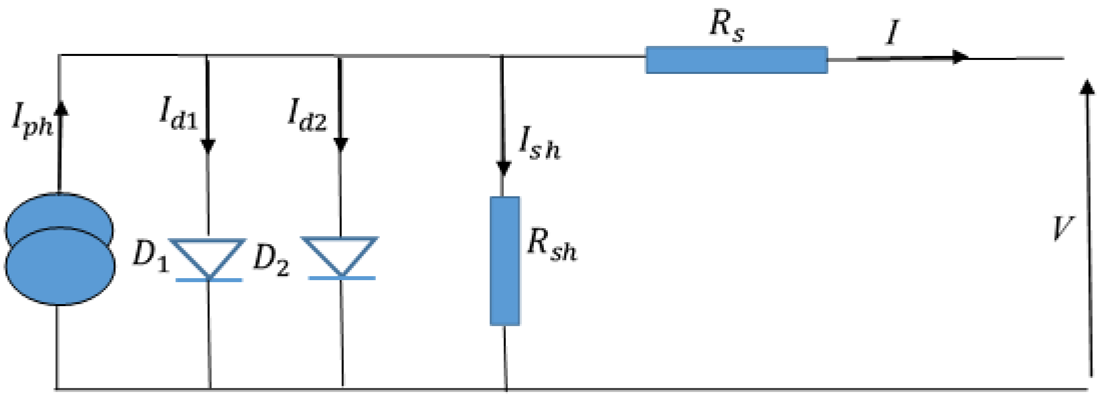


Figure 1.12 Two-diode model of a PV cell [17].

With a few steps of calculation and mathematical development, this model gives a current almost similar to the current of a real PV cell according to the relationship [17-18]:

$$I = I_{ph} - I_{d1} - I_{d2} - I_{sh} \tag{1. 13}$$

So:

$$I = I_{ph} - I_{s1}\left\{exp\left(\frac{V+R_sI}{a1V_t}\right) - 1\right\} - I_{s2}\left\{exp\left(\frac{V+R_sI}{a2V_t}\right) - 1\right\} - \left(\frac{V+R_sI}{R_{sh}}\right) \tag{1. 14}$$

a_1 And a_2: Ideality factors of diodes D_1 and D_2 respectively.

1.3 DC/DC Converters

The DC-DC converter (chopper) generally used in PV systems is either:

- Serial chopper (Buck Converter).
- Parallel chopper (Boost Converter).
- Serial-parallel chopper (Buck-Boost Converter) [23].

The choice of chopper type will depend on the batteries in which we will store the energy.

The power conversion efficiency of static converters is generally high to avoid power dissipation and to avoid excessive heating in electronic components. For this reason, all exchanged power conversion must be carried out around the energy storage components (inductor and capacitors) and switches. The power switches used depend on the level of power to be converted or controlled. MOSFETS (metal oxide field effect transistors) are usually used at relatively low power (a few kW) and IGBTS (insulated gate bipolar transistors) at higher powers. Thyristors have been generally used and accepted in the highest power levels [24].

1.3.1 Types of DC/DC Converters

1.3.1.1 Serial chopper

The series chopper is a DC/DC converter which controllable switch is in series with the power source, it allows energy to be transferred from a fixed voltage source to a current type load. The output voltage V_0 is given as a function of the voltage PV V_{pv} by [26-28]:

$$V_0 = d.V_{pv} \tag{1. 15}$$

With d is the duty cycle of the converter ($0 < d < 1$).

Then the Buck converter produces a voltage equal to or less than the input voltage.

1.3.1.2 Parallel chopper

The parallel chopper is a DC/DC converter which controllable switch is in parallel with the power source, it allows energy to be transferred from a current source (series inductance) to a voltage source type load (capacitor in parallel). The output voltage V_0 is given as a function of the input voltage V_{pv} by [25-27]:

$$V_0 = \frac{1}{1-d} V_{pv} \tag{1. 16}$$

The Boost converter produces an output voltage greater than or equal to the input voltage because d is theoretically between 0 and 1 and practically between 0.1 and 0.9.

1.3.1.3 Series-parallel chopper

The series-parallel chopper is a DC/DC converter which allows the exchange of power between a DC voltage type input source (capacitive filtering in parallel) and a DC voltage source type output load (capacitor in parallel with the resistive load). The output voltage V_0 is given as a function of the input voltage V_{pv} by [25]:

$$V_0 = \frac{d}{1-d} V_{pv} \tag{1. 17}$$

The Buck-Boost converter produces an output voltage which can be either higher (for $d > 0.5$) or lower (for $d < 0.5$) than the source voltage.

1.3.2 Modeling of DC/DC Converters

1.3.2.1 Model of the Boost converter

Considering the following hypotheses:

- all elements are ideal;
- Switching time is very small compared to the electrical time constant of the circuit, so a linear approximation can be employed.

We can thus represent the waveforms in Figure 1.13.

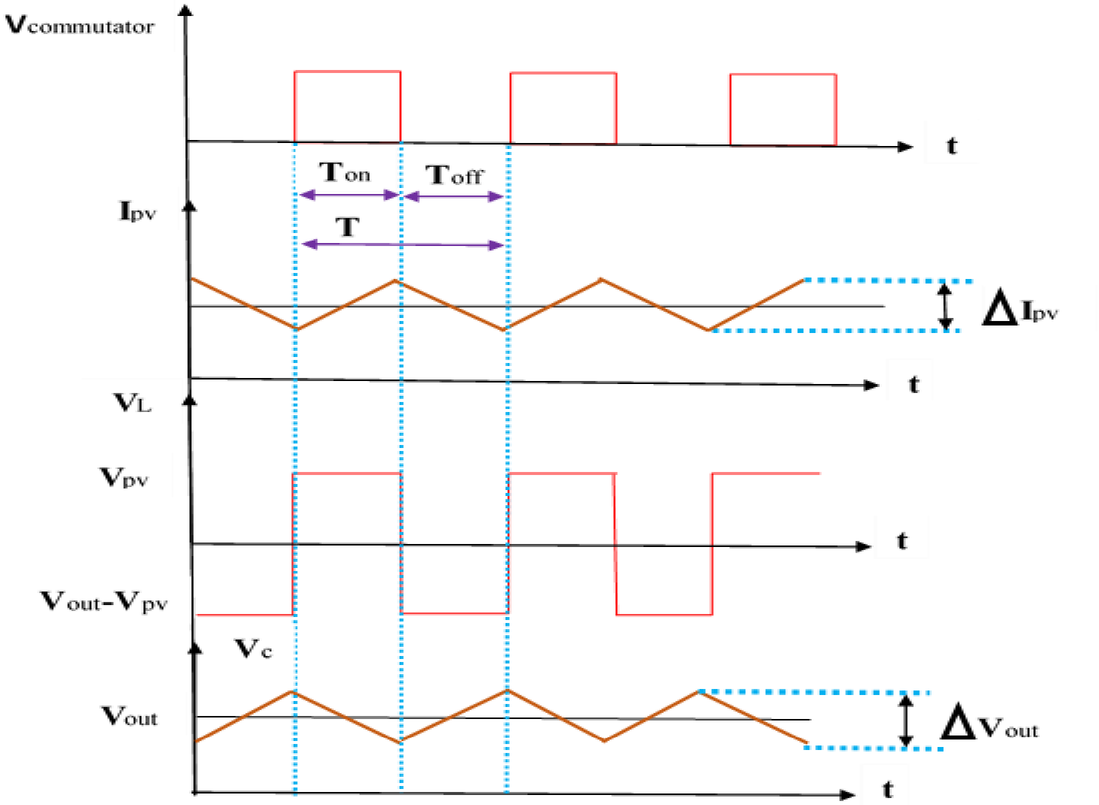


Figure 1.13 Typical boost converter waveforms [27].

✓ Output voltage equation

When the converter is in steady state, the average voltage is zero during the switching period (*T*). From where [27],

$$V_{pv}t_{on} = (V_{out} - V_{pv}) \tag{1. 18}$$

And

$$V_{out} = \frac{t_{on}+t_{off}}{t_{off}}V_{pv} \tag{1. 19}$$

Where;

$$T = t_{on} + t_{off} \tag{1. 20}$$

The report $\frac{t_{on}}{\mathrm{T}}$ is called the duty cycle (*d*).

The output voltage can be deduced [27]:

$$V_{out} = \frac{V_{pv}}{1-\mathrm{d}} \tag{1. 21}$$

With,

V_{out}: Output voltage;

V_{pv}: input voltage;

t_{on}: Time during which the switch is closed.

1.3.2.2 Model of Buck Converter

The voltage and current waveforms are shown in Figure 1.14.

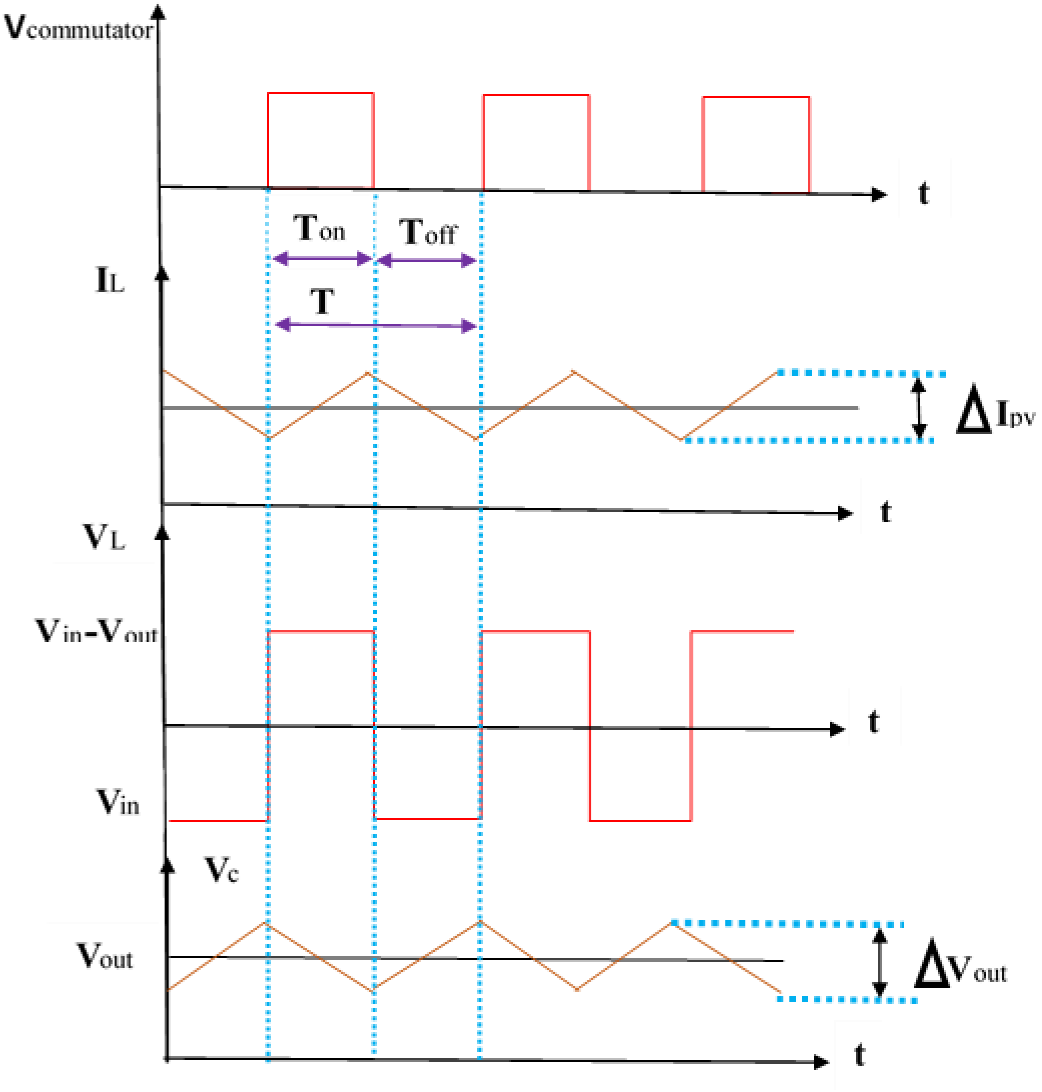


Figure 1.14 Typical buck converter waveforms [28].

- ✓ **Output voltage equation**

As in the boost converter analysis, the average voltage of the asynchronous motor is zero over the entire switching period T, so we can write [28]:

$$V_{out} = V_{in}\alpha \quad (1.\ 22)$$

The ratio of input power to output power depends on the duty cycle. Assuming the yield is η100%, then [28]:

$$V_{in}I_{in} = V_{out}I_{out} \quad (1.\ 23)$$

And, the optimal load can be obtained according to:

$$R_{charge} = \frac{V_{in}}{I_{in}} \tag{1. 24}$$

1.4 Advanced DC/DC Converters topology for PV System

The landscape of power-converter technologies has undergone significant transformation, largely influenced by advancements in power-electronics technology, especially in the realm of harnessing energy from renewable sources.

This study discusses the solar photovoltaic energy harvesting technique. The categories used to classify DC–DC converter topologies are isolated and Non-isolated kinds. The term 'isolated type' in a DC–DC converter denotes an electrical barrier positioned between the input and output sides of the device, And this barrier realize by the use of high-frequency transformers. It may be set up in either a positive or a negative configuration and it is put to work as a device for converting high voltage. Unfortunately, relative to the size of the converter the barrier on the power converter is cumbersome, and considerable power losses induced by the barrier. As a result, to circumvent the disadvantages above, a non-isolated converter is an option that may be considered. Switching out isolated kinds has been standard practice in recent years. The buck converter, boost converter and buck–boost converter are common types of DC–DC converters. Depending on the voltage-level conversion required they are appropriate for PV applications.

1.4.1 Buck converter

The buck converter decreases the DC voltage, it offers an output voltage (V_{out}) less than the input voltage (V_{in}). As shown in Figure 1.15 this converter consists of a capacitor (*C*), a switching device (*S*), a diode (*D*), and an inductor (*L*). In a switching mode power supply this converter is the basic step-down topology. To determine the output voltage of the buck converter according to the duty cycle of the switching device (D_t), the following Equation can be used:

$$D_t = \frac{V_{out}}{V_{in}} \tag{1. 25}$$

There are typically two different operating modes in the buck converter: the discontinuous conduction mode (DCM) and the continuous conduction mode (CCM). The current through the inductor will never be equal to zero because it will always be greater than zero when the buck converter operates in CCM mode. In the meantime, the current flowing through the inductor will stop entirely not long after the switching period concludes while DCM is being carried out. A different working mode has been introduced to improve the buck converter's performance.

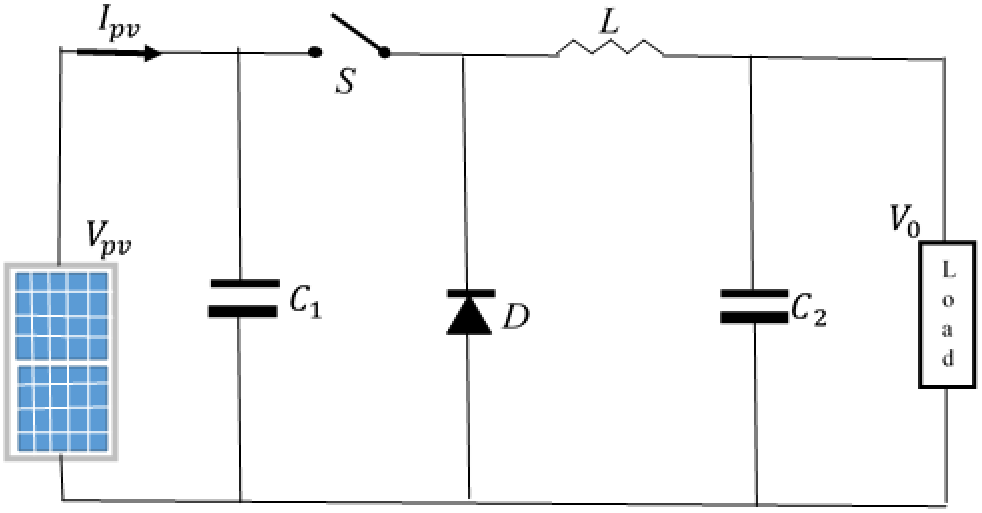


Figure 1.15 Circuit topology of Buck converter for PV applications [29].

1.4.2 Buck-Boost converter

The boost and buck-boost converters topologies circuits are comparable; as shown in Figure 1.16, the primary distinction between the two lies in the location of the switching device. The two fundamental topologies in this multilevel topology are the buck converter and the boost converter. Henceforth, it can also either raise or lower the input voltage so it is known as a step-up/down converter. To connect the voltage of the PV array to either the voltage of the DC load or the voltage of the battery it is common practice to use a buck-boost converter.

Changing the duty cycle in this way will cause a different output voltage. The converter will operate in boost mode so that the output voltage will be greater than the input voltage when the applied duty cycle exceeds 50%. The converter operates in buck mode which causes the output voltage to be less than the input voltage whenever the duty cycle is <50%; Equation (1.26) can be used to determine the output voltage of a buck-boost converter:

$$V_{out} = -V_{in}\left(\frac{D_t}{1-D_t}\right) \tag{1. 26}$$

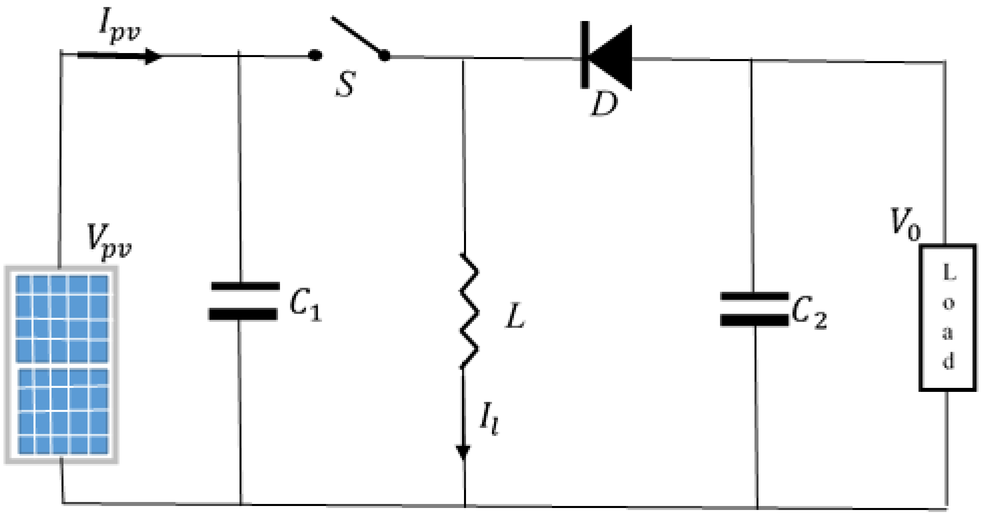


Figure 1.16 Circuit topology of buck–boost converter for PV applications [29].

1.4.3 Boost converter

the fundamental circuit of the boost-converter topology, which is depicted in Figure 1.17 consists a capacitor (*C*), diode (*D*), switching device (*S*) and inductor (*L*).The output voltage V_{out}, will be raised to be higher than the input voltage, V_{in} . This topology produces high voltages and is unsuitable for various applications but it is excellent for applications dealing with renewable energy. Equation (1.27) can be used to determine the duty cycle of the boost converter:

$$D_t = \frac{V_{out}-V_{in}}{V_{out}} \tag{1. 27}$$

With the boost converter, the Operating modes CCM and DCM are frequently utilized. Recent advancements in boost converters for solar energy harvesting systems have emphasized power-quality management, particularly in addressing issues such as load balancing, power-factor correction, harmonic elimination, and zero voltage regulation.

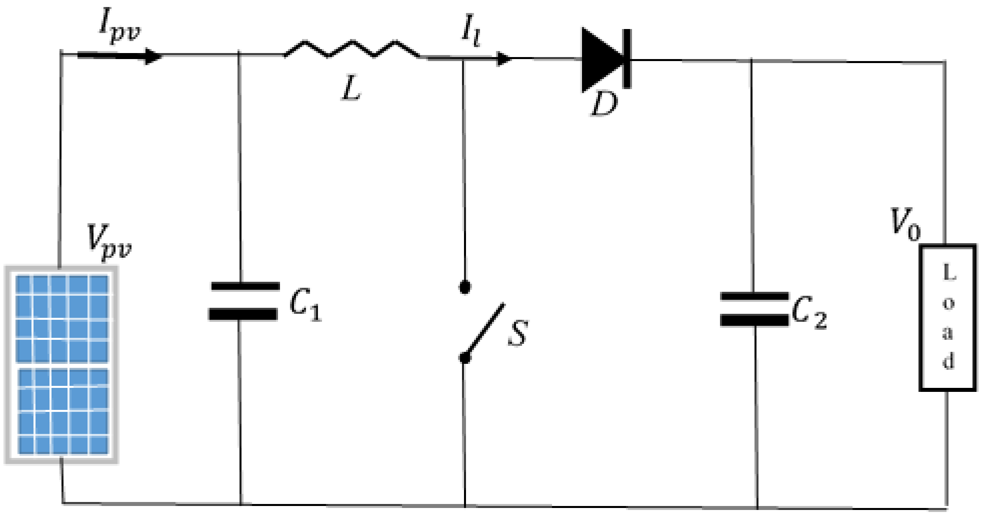


Figure 1.17 Circuit topology of Boost converter for PV applications [29].

1.4.3.1 Advantage of BOOST converter:

Despite the high efficiency of the buck converter in systems with conventional power sources, the boost converter may be more suitable for photovoltaic systems with the maximum power point tracker (MPPT) since the converter operates in direct current mode extracting as much power as possible from solar cells. Therefore the energy efficiency of the boost converter can be greater than the buck converter. The boost converter is generally used to obtain a higher output voltage, while the buck converter is used to lower the output voltage.

1.5 Conclusion

In this first chapter we presented generalities on the production systems of electrical energy which are based on the photovoltaic effect, in this context, statistics on world production were presented and the application of the PV system, then the principle of conversion, cell types and its modeling as well as the different types of converters and their modeling and topology, We have dedicated our studies to this kind of PV cells KC200GT, As a result, the most widely used to raise the output voltage of PV Systems is Boost converters and the development is still being carried out by adding more complex approaches to achieve higher performance levels. In the next chapter, we will present the MPPT techniques.

Chapter 2

MPPT Techniques

Chapter 2: MPPT Techniques

2.1 Introduction

Maximum Power Point Tracking (MPPT) is a crucial technique in the field of solar power generation. Essentially, it's a method used in photovoltaic (PV) systems to extract the maximum available power from solar panels by continuously adjusting the operating point of the panels. This optimization ensures that the panels operate at their most efficient voltage and current levels, maximizing the power output under varying environmental conditions such as changes in sunlight intensity and temperature. The principle behind MPPT is relatively simple: solar panels have a characteristic voltage at which they produce the maximum power output, known as the maximum power point (MPP). However, this MPP varies depending on factors like solar irradiance and temperature.

In this chapter we'll discuss about the MPPT, its principle, some different MPPT algorithms and the genetic algorithm.

2.2 Principle of MPPT control

The principle of MPPT is based on the use of a control algorithm to draw energy to the maximum power point by measuring the voltage and current of the PV module. This ensures that maximum energy is delivered to the output. The PPM varies with changing conditions such as illumination levels and temperature. Therefore, for a direct connection of the GPV to the load, there is little chance that the system will operate at its maximum power, so a gap results between the potential power of the generator and the power transferred to the load. However, the operating point of the system of the duty cycle of the signal controlling the semiconductor of the converter can be modified by inserting an adaptation quadrupole, a DC/DC converter boost (Boost) or step-down between the GPV and the load (Buck) depending on the applications. Thanks to adequate control to extract, at each moment, the maximum power available at the GPV terminals and transfer it to the load. It is therefore a question of using a technique for extracting the maximum power point which makes it possible to adjust the duty cycle, automatically to its optimal value regardless of weather changes or load variations that may occur at any time of operation [6-11-32].

2.3 Different MPPT control algorithms

MPPT control aims to bring the system to its optimum power and maintain it there despite parameter variations.

2.3.1 Perturbation and observation method (P&O)

The Perturbation and observation (P&O) method consists of disturbing one of the input parameters of the static converter (generally the voltageV_{pv}) and then observing the impact of this change on the system's output power. It allows the extraction of maximum power even if lighting and temperature vary.

The principle of this method is that from an initially small duty cycle, V_{pv} and I_{pv} are measured and P(k) is calculated. The value obtained is compared with the value P(k-1) calculated in the previous cycle, and depending on the comparison result, V_{pv} is adjusted either in the same direction as in the previous cycle or in an opposite direction. Thus, the power will increase, reach to the maximum, then decrease and as soon as a reduction in power is detected, the direction of the command is reversed again…etc. However, the oscillation of the system around the maximum makes it possible to follow the maximum power [33-34].

2.3.1.1 Advantages and disadvantages of P&O

- **Advantages:**
  - Simple regulatory structure
  - Reduced number of measured parameters
- **Disadvantages:**
  - Exceeding the optimal maximum point in case of rapid change in atmospheric conditions.

The following Figure 2.1 illustrates the P&O method Flowchart.

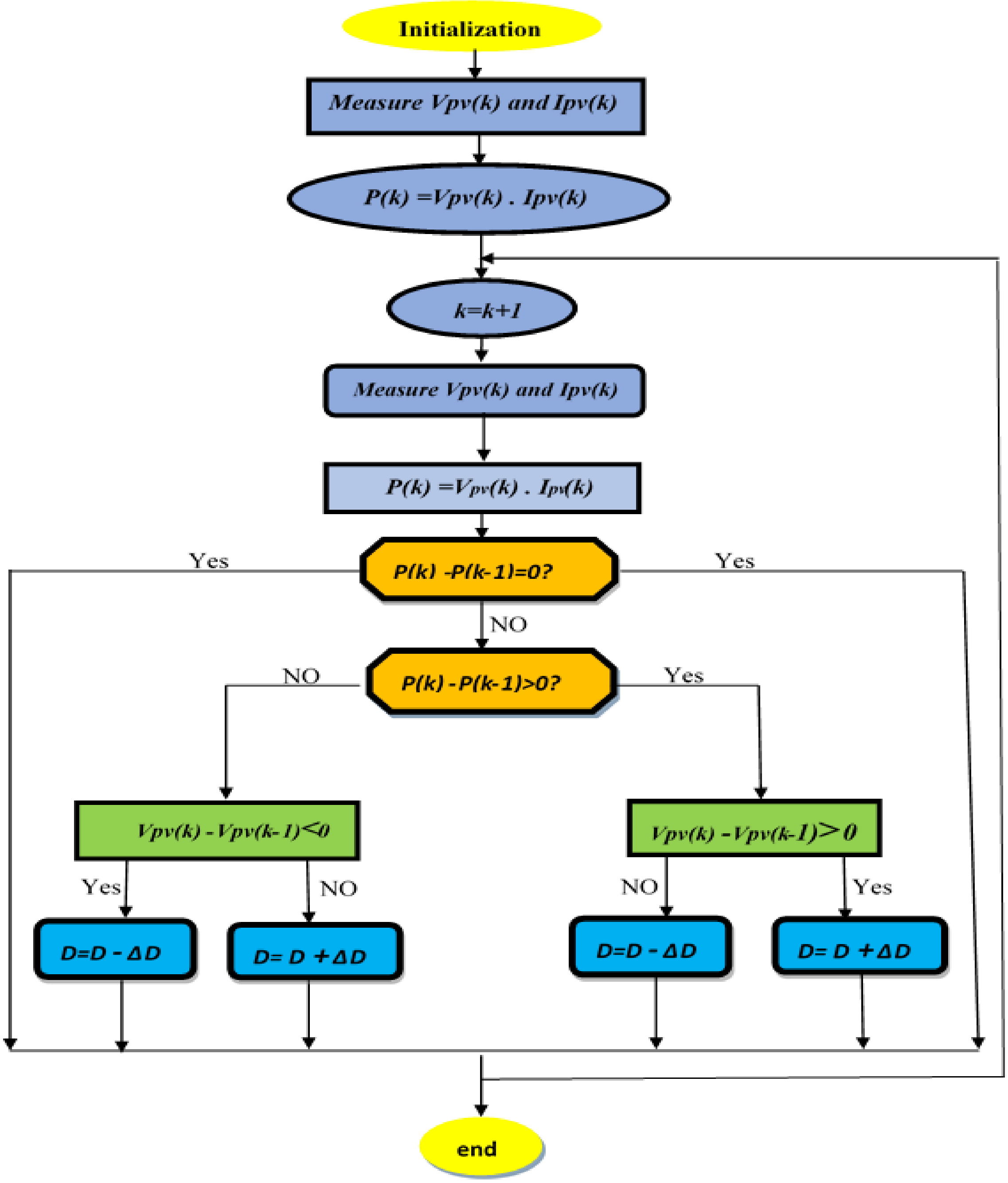


Figure 2.1 Flowchart of P&O method [33]

2.3.2 Incremental conductance method

The incremental conductance method (INC) is proposed to overcome the problems of oscillations of the P&O method and consists of establishing a relationship between the variation of the power and the voltage to find the PPM independently of the characteristics of the solar panel and the electronic components. This gives it greater reliability.

The main advantage of this algorithm is that it offers good performance even under rapid changes in atmospheric conditions. Furthermore, it achieves lower oscillation around the MPP than the P&O technique, although, when the P&O technique is optimized, the MPPT yields of the incremental conductance and the MPPT P&O algorithm are essentially the same. However, the disadvantage is that the control circuit is complex and very expensive. However, today there are many options to get it cheaply [35-36].

The conductance G is expressed by:

$$G = I/V \tag{2.1}$$

Hence, the incremental conductance is defined, as the ratio of the variation of the intensity to that of the voltage between two instants:

$$\Delta G = dI/dV \tag{2.2}$$

The power and its differential calculation are given by the relations (2.3) and (2.4), respectively:

$$P = V.I \tag{2.3}$$

$$dP = VdI + IdV \tag{2.4}$$

And, the maximum power is obtained when the condition (2.5) is verified:

$$\frac{dP}{dV} = 0 \tag{2.5}$$

Considering these last expressions, we have:

$$\left(\frac{1}{V}\right)\frac{dP}{dV} = G + \Delta G \tag{2.6}$$

This leads to the following set of equations:

$$\begin{cases} \frac{dP}{dV} < 0 \Leftrightarrow \mathrm{G} < -\Delta\mathrm{G} \\ \frac{dP}{dV} < 0 \Leftrightarrow \mathrm{G} = -\Delta\mathrm{G} \\ \frac{dP}{dV} < 0 \Leftrightarrow \mathrm{G} > -\Delta\mathrm{G} \end{cases} \tag{2.7}$$

Numerically, it is possible to calculate G and ΔG from the measurements of $I_{pv}\ (k)$, $I_{pv}\ (k-1)$, $V_{pv}(k)$, $V_{pv}(k-1)$ assuming that $dI_{pv} \approx \Delta I_{pv} = I_{pv}\ (k) - I_{pv}\ (k-1)$ and

$dV_{pv} \approx \Delta V_{pv} = V_{pv}(\mathrm{k}) - V_{pv}(\mathrm{k}-1)$; and to a lesser extent of the distance to the PPM, its direction is deduced in relation to the present operating point. In this way, the direction of convergence will always be known, which is an advantage compared to the P&O technique is presented previously, in particular when the sunshine varies quickly. However, this method poses a problem, and it can be more difficult to implement than previous methods because it involves divisions in which the denominator can be equal to zero, this is in the case where the system is actually at the PPM. In this case, the duty cycle has not been modified and therefore the voltage V remains constant ($dV_{pv} = 0$), and the incremental conductance $\Delta G = dI_{pv} / dV_{pv}$ is not then defined, we move on to observation variations in the current I_{pv} and we deduce the variations in V_{pv} to be caused to maintain the system at its PPM. The flowchart of such a command is shown in Figure 2.3.

By comparing the conductance *(G)* to the increment of the conductance *(ΔG)* we will find the maximum of the curve (Figure 2.2) by using the equations above to find the point of cancellation of the derivative of the power [35-36].

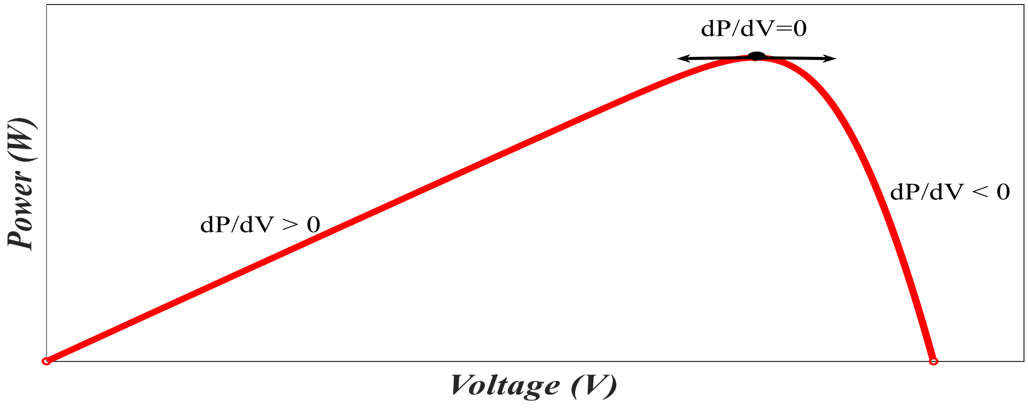


Figure 2.2 Evolution of power as a function of voltage [11].

The flowchart of the incremental conductance method is illustrated in Figure 2.3.

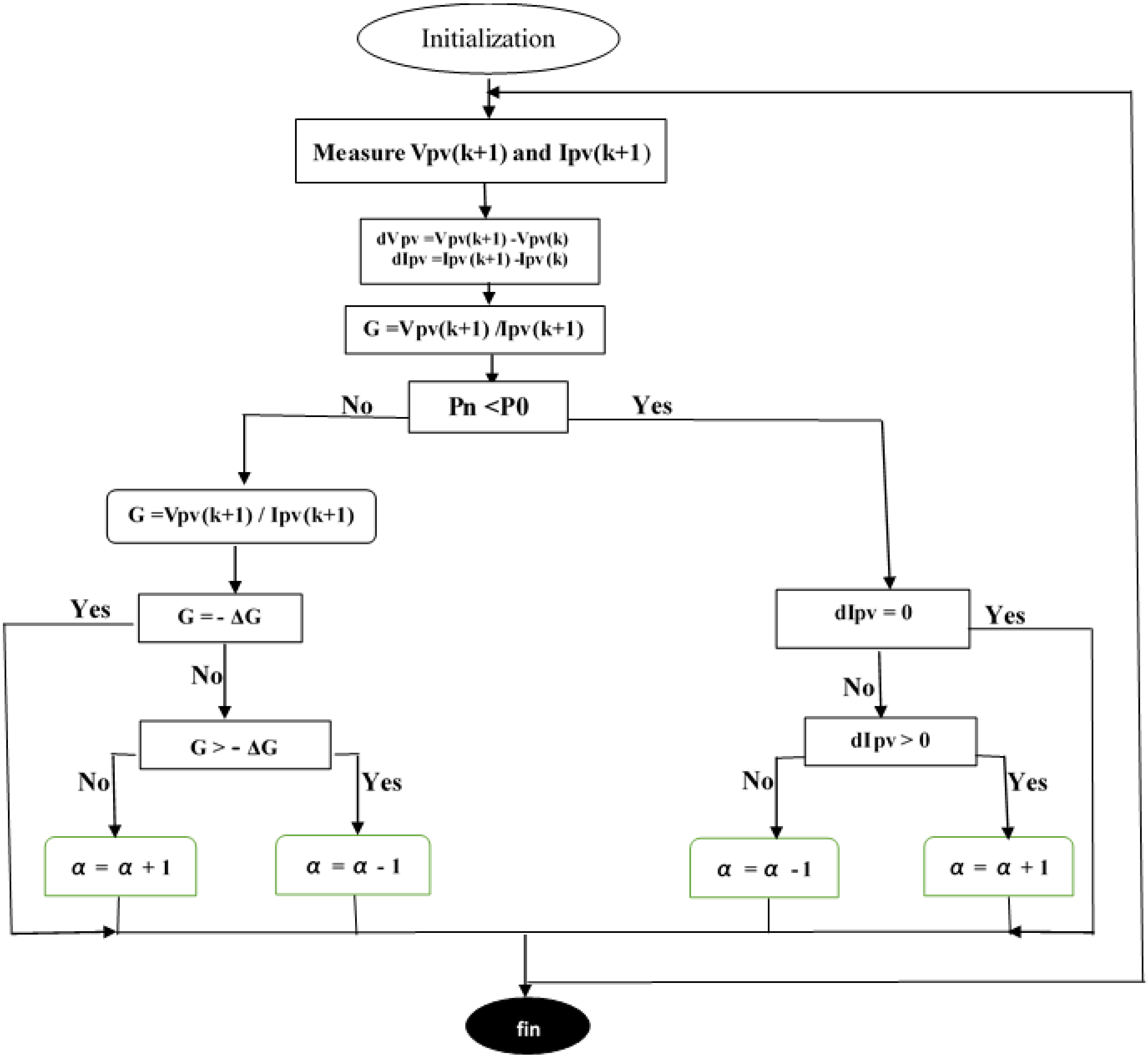


Figure 2.3 Flowchart of the INC algorithm [35].

2.3.3 Algorithm based on measuring a fraction of the voltage

This algorithm is based on the linear relationship between the open circuit voltage and the optimal voltage given by the following equation [34-37]:

$$V_{mp} = K \times V_{oc} \tag{2.8}$$

Where K is a voltage factor depending on the characteristics of the PV cell and which varies between 0.73 and 0.8.

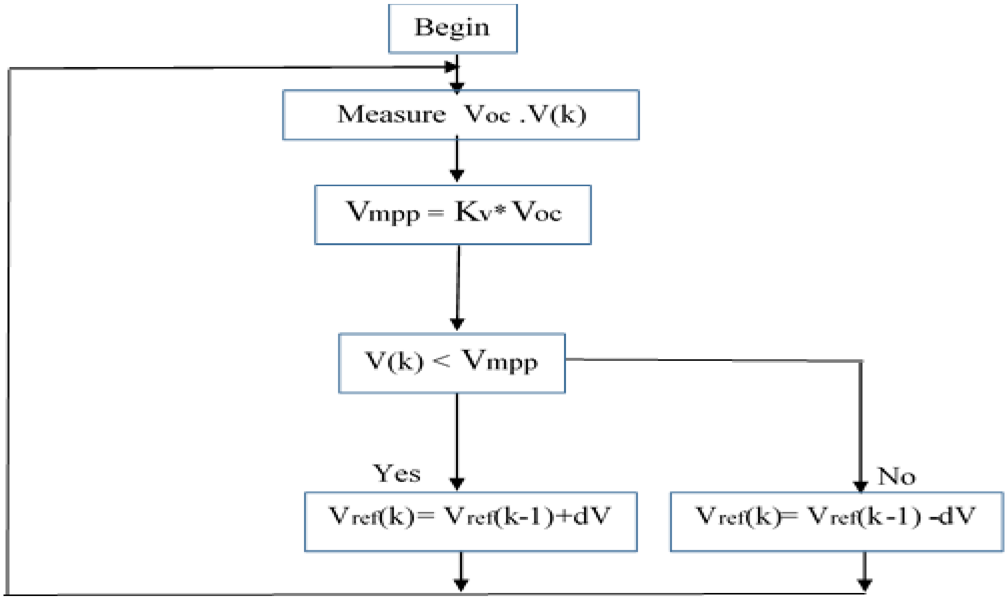


Figure 2.4 FCO Algorithm Flowchart [37].

To deduce the optimal voltage, we must measure the open circuit voltage V_{oc}. Therefore, the operating point of the panel is kept close to the optimum power point by adjusting the panel voltage to the calculated optimum voltage. The process makes it possible to act cyclically on the duty cycle to reach the optimal voltage.

2.3.4 Algorithm based on measuring a fraction of the current

This technique is based on the linear relationship between the short circuit current and the optimal current given by the following equation [34-37]:

$$I_{mp} = K \times I_{sc} \tag{2.9}$$

Where K is a voltage factor depending on the characteristics of the PV cell and which varies between 0.85 and 0.92.

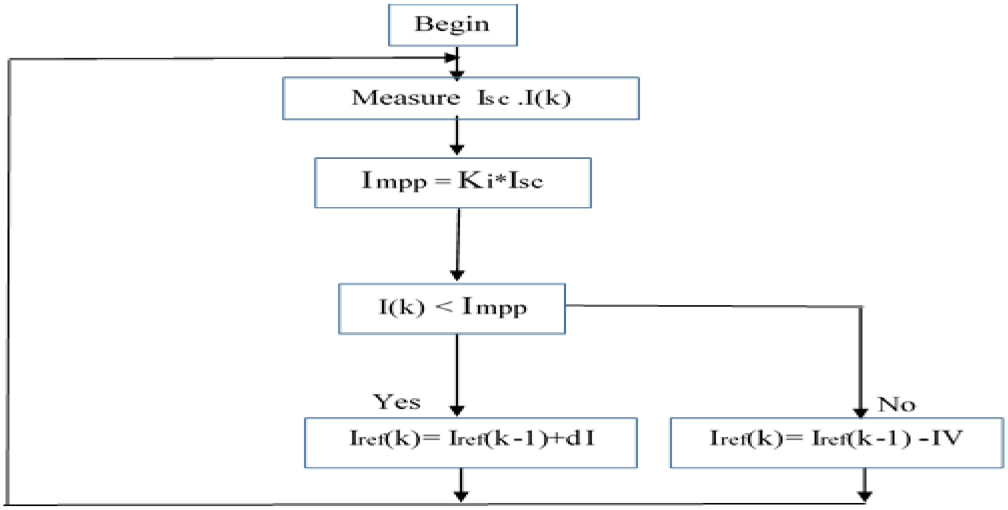


Figure 2.5 FCC Algorithm Flowchart [37].

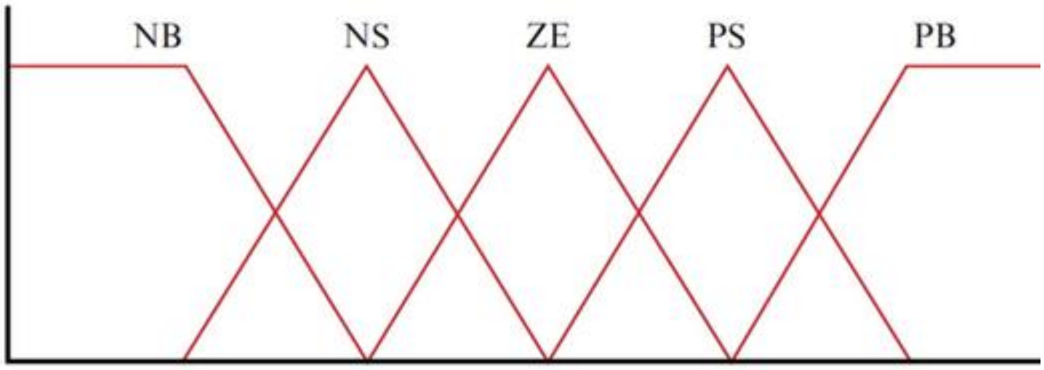
Indeed, the optimal operating point is obtained by bringing the panel current to the optimal current. Therefore, we change the duty cycle until the panel reaches the optimal value.

2.3.5 MPPT controls based on fuzzy logic

Controls based on fuzzy logic are becoming more and more popular thanks to the evolution of microcontrollers. The advantage of these techniques is that they can work with imprecise input values and do not need a high-precision mathematical model. In addition, they can deal with nonlinearities. The principle of fuzzy control is based on two input variables which are the error *ER* and the error change *ΔER* and an output variable $\Delta\alpha$ (variation of the duty cycle).The value of the output variable, which drives the static converter to find the PPM, is determined using a truth table and the evolution of the input parameters. In general, fuzzy logic control includes three stages which, in the literature, are commonly named: Fuzzification, Rule table and Defuzzification. During fuzzification, numeric input variables are converted into linguistic variables that can take the following five values [34-35-37].

- *NB*: Negative Big,
- *NS*: Negative Small,
- *ZE*: Zero,
- *PS*: Positive Small,
- *PB:* Positive Big.

As shown in the basic structure of fuzzy logic control shown in Figure 2.6.



$\boldsymbol{E, \Delta E \text{ and } \Delta d}$

Figure 2.6 Basic structure of fuzzy control [37].

The input parameters *ER* and *ΔER* are linked to the following equations [34-35-37]:

$$ER\ (n) = \frac{Ppv(n) - Ppv(n-1)}{Vpv(n) - Vpv(n-1)} \tag{2.10}$$

$$\Delta ER\ (n) = ER(n)\ -\ ER(n-1) \tag{2.11}$$

The linguistic variation assigned to $\Delta\alpha$ depends on the different combinations between ER and ΔER. At the end of the concepts given in the previous paragraphs on the MPPT command. Concerning, the MPPT command based on the principle of fuzzy logic, or has chosen the degrees of belonging of the error (ER) and the derivative of the error (ΔER) as well as that of the duty cycle (*d*). Depending on their evolutions, a truth table (Table 2) is completed.

Table 2 Truth Table

ΔE / ***E***	**NB**	**NS**	**ZE**	**PS**	**PB**
NB	PB	PB	PB	PB	PB
NS	PS	PS	PS	PS	PS
ZE	ZE	ZE	ZE	ZE	ZE
PS	NS	NS	NS	NS	NS
PB	NB	NB	NB	NB	NB

2.3.1.2 Fuzzification

Figure 2.7 illustrates the fuzzy set of the *ER* and *ΔER* inputs which Triangular memberships.

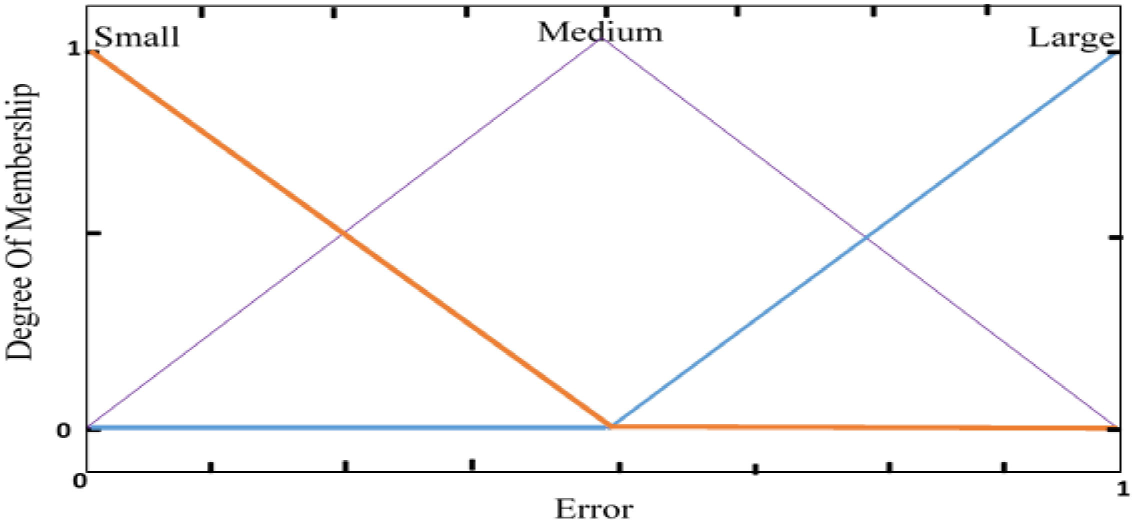


Figure 2.7 Membership function of inputs

Figure 2.8 illustrates the fuzzy set of the duty cycle output which Triangular memberships.

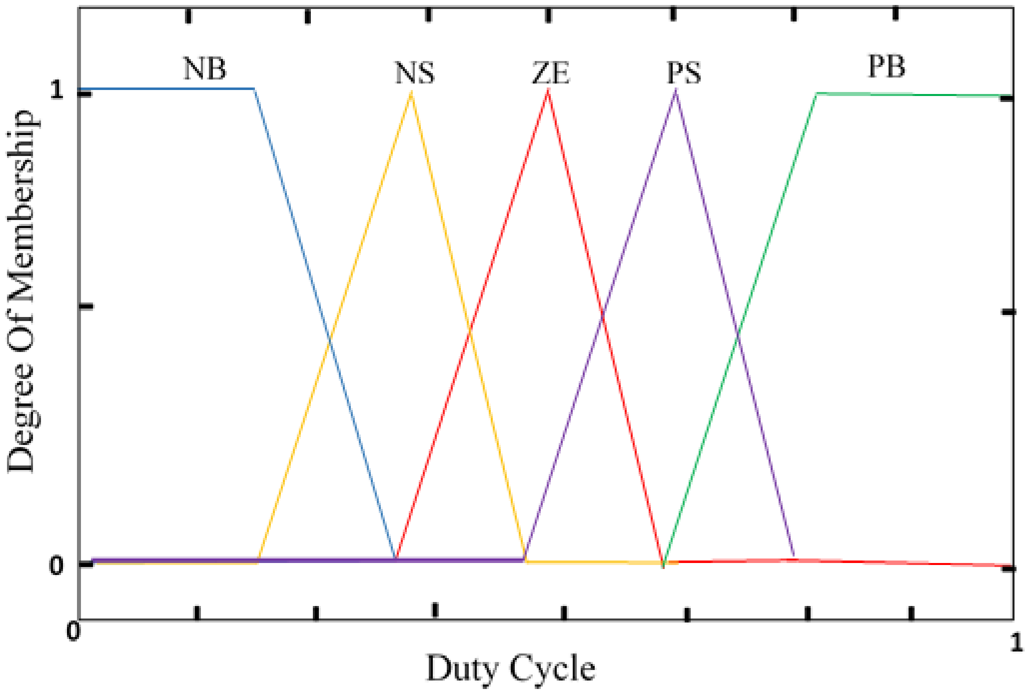


Figure 2.8 Membership function of output

2.3.1.3 Control rule base

The knowledge base defining the rules for the desired relationship is between the input and output variables in terms of the membership functions illustrated in Table 3. The control rules are evaluated by an inference mechanism, and represented as a set of:

IF *Error* is ... and *Change of Error* is ... THEN *the output will …*

Table 3. FLC rules

E **C_E**	Small	Medium	Large
Small	ZO	ZO	NS
Medium	ZO	NB	ZO
Large	ZO	NB	ZO

For example: Rule1: IF Error is ***Small*** and Change of Error is ***Small*** THEN the duty cycle is ***NS***.

Figure 2.9 shows the surface of the base rules using in FLC.

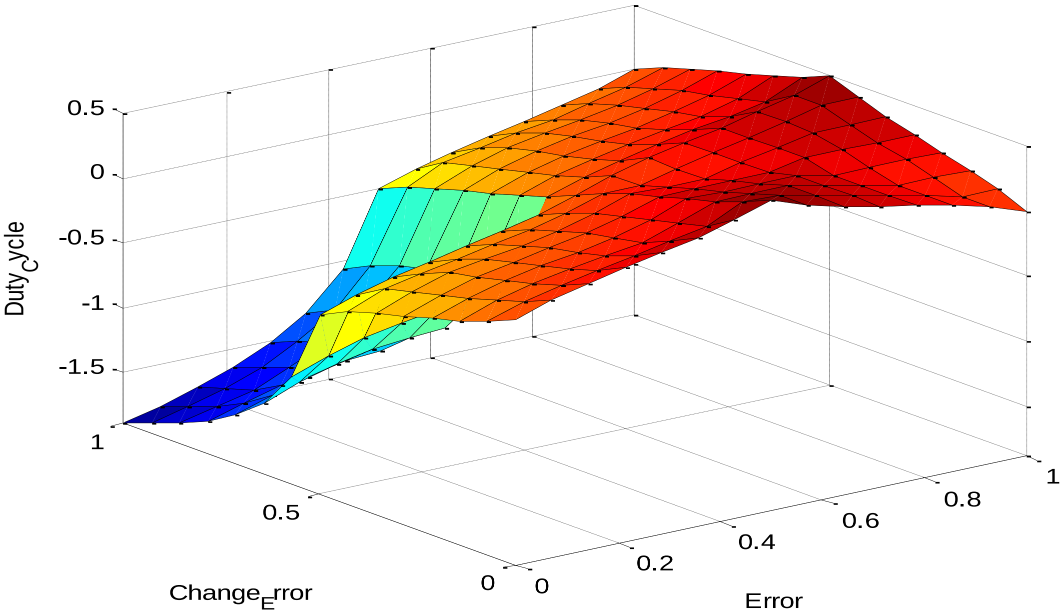


Figure 2.9 Rule surface of FLC

Figure 2.10 shows how the equations 2.10 and 2.11 are represented, to generate the Error and Change in error signals as inputs for the fuzzy logic controller.

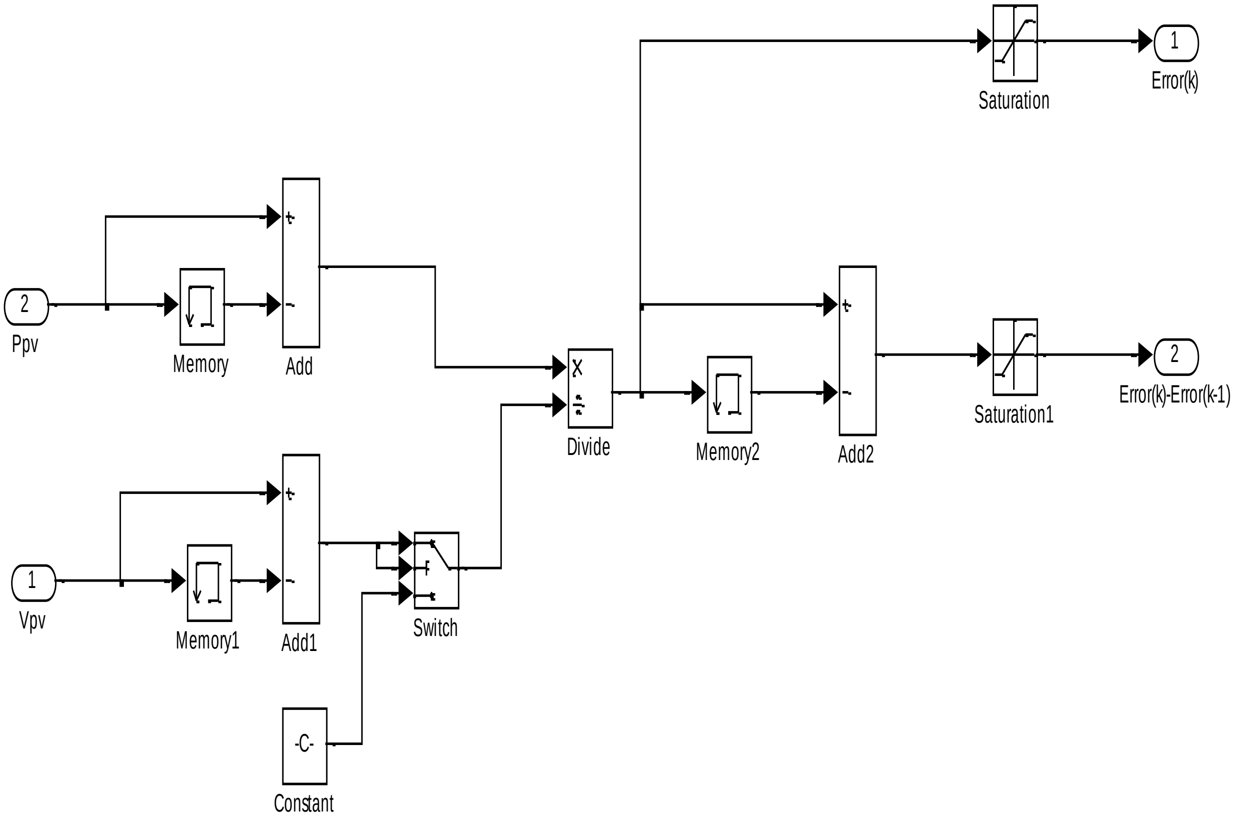


Figure 2.10 Generating the Error and Change in Error Signals

2.3.6 Proposed Fuzzy Logic Genetic Algorithm

The implementation of system PV with MPPT control based on fuzzy logic as we explained before is not optimized, when we optimize we need to integrate a method of optimization, in our study we choose the genetic algorithm, and the design of the system will be as shown in Figure 2.11

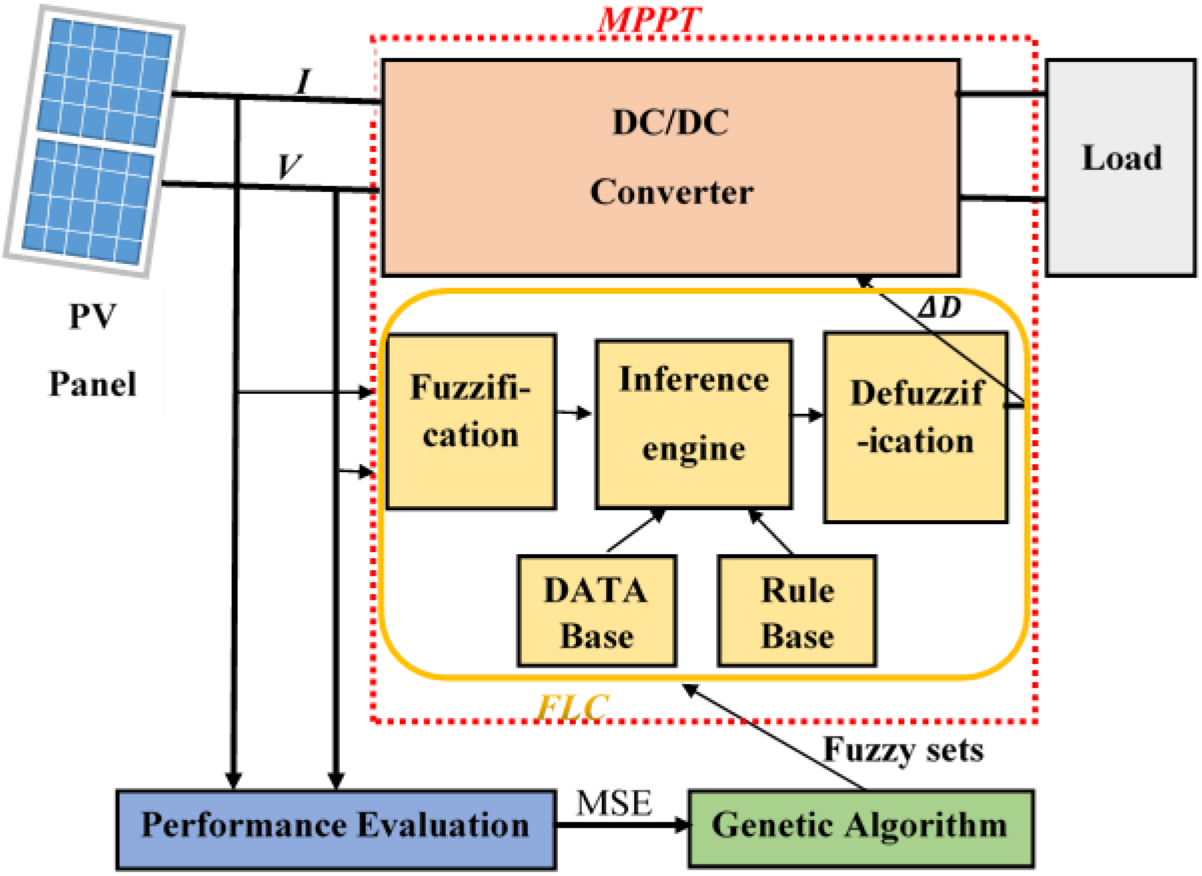


Figure 2.11 Optimized Fuzzy Logic Controller [38].

2.3.7 Genetic Algorithm

Optimization techniques involve finding the most optimal solution among various possibilities within given constraints. This process aims to determine the values of inputs that yield the most favorable output outcomes. The notion of "best" differs depending on the problem at hand, but mathematically, it often entails maximizing or minimizing one or more objective functions by adjusting the input parameters.

The search space comprises all potential solutions or values the inputs can assume. Within this space, an optimal solution is found at a point or set of points. Optimization aims to locate this optimal point or set within the search space. The genetic algorithm is an optimization technique rooted in the natural evolutionary process. It utilizes concepts of Natural Selection and Genetic Inheritance. Unlike conventional algorithms, it employs guided random search, starting with a random initial cost function and focusing the search on areas with the lowest cost. It's particularly useful for large and intricate datasets, where a pool or population of potential solutions is available. These solutions undergo recombine and mutation, like natural genetics, generating new offspring across generations. Each individual or candidate solution receives a fitness value based on its objective function, with fitter individuals having greater reproduction opportunities. This mirrors the Darwinian Theory of "Survival of the Fittest." Through this iterative process, superior individuals or solutions evolve over generations until a stopping criterion is met.

Genetic Algorithms exhibit a significant degree of randomness, yet they outperform simple random local search methods, where random solutions are attempted and the best one so far is retained. This is because Genetic Algorithms leverage historical information in addition to their inherent randomization.

The key criteria for the Genetic Algorithm (GA) approach can be summarized as follows:

- Characteristic Inheritance: Offspring should inherit beneficial characteristics from their parents.
- Completeness: Every solution must have a corresponding encoding.
- Soundness: Each code generated by genetic operators must correspond to a valid solution.
- Non-redundancy: There should be a one-to-one correspondence between codes and solutions.

The following Figure illustrates the Flowchart of the standard Genetic Algorithm.

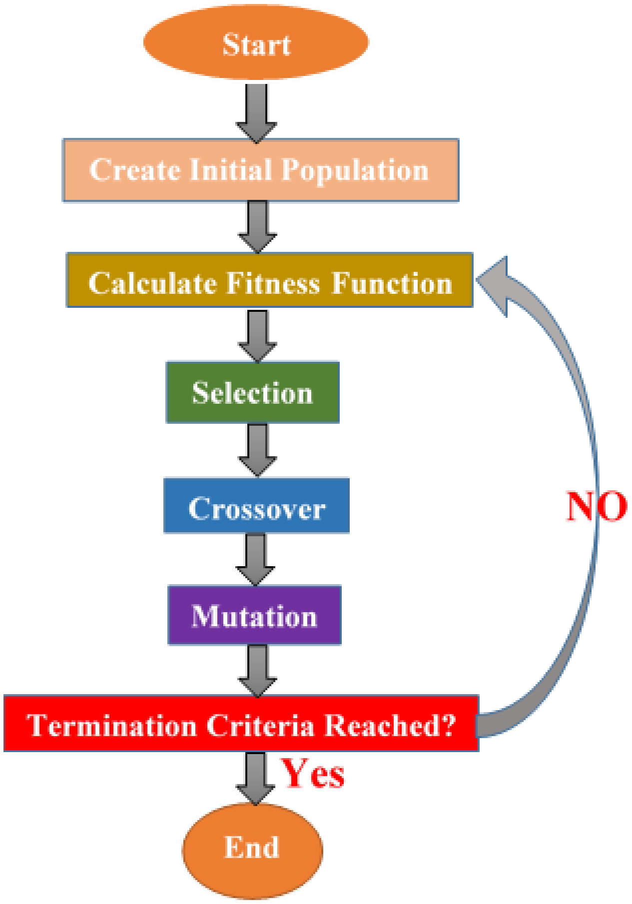


Figure 2.12 Flowchart of GAs-based MPPT [39].

- **Genetic Algorithms advantages and limitations**

Advantages:

- Is faster and more efficient as compared to the traditional methods.
- Does not require any derivative information (which may not be available for many real-world problems).
- Optimizes both continuous and discrete functions and also multi-objective problems.
- Always gets an answer to the problem, which improves over time.
- Useful when the search space is very large and there are a large number of parameters involved.
- Provides a list of “good” solutions and not just a single solution.

The limitations:

- Definition of representation for the problem
- The problem of identifying fitness function
- Cannot easily incorporate problem specific information
- Premature convergence occurs
- The problem of choosing the various parameters like the size of the population, mutation rate, cross over rate, the selection method and its strength.
- Cannot use gradients.

2.3.1.4 Genetic Algorithms Concept

Genetic Algorithms (GAs) are adaptive heuristic search algorithms within the broader category of evolutionary algorithms. They draw inspiration from natural selection and genetics to intelligently guide random search using historical data. By doing so, they navigate towards improved performance regions in the solution space. GAs are widely employed to produce high-quality solutions for both optimization and search problems.

Genetic algorithms replicate the mechanism of natural selection, where species that can adapt to environmental changes survive, reproduce, and pass on their traits to the next generation. In essence, they mirror the concept of "survival of the fittest" to solve problems. Each generation in a genetic algorithm comprises a population of individuals, where each individual represents a potential solution in the search space. These individuals are encoded as strings of characters, integers, floats, or bits, analogous to chromosomes in biological organisms.

Genetic algorithms derive their foundation from an analogy with the genetic structure and behavior of chromosomes within a population.

2.4 Conclusion

In this chapter, we presented the principle of finding the maximum power point. We have studied some MPPT controls, like Perturb and Observe algorithm, INcremental Conductance algorithm, Open Circuit Voltage fraction algorithm, Short Circuit Current fraction algorithm, and a control based on Fuzzy Logic, and we proposed a Fuzzy Logic Genetic Algorithm, then we talked about a little about Genetic Algorithm. In the next chapter we will compare between P&O algorithm and Fuzzy Logic Genetic Algorithm and present simulation results by using MATLAB/SIMULINK.

Chapter 3

Results and discussion

Chapter 3: Results and discussion

3.1 Introduction

In this chapter we'll present our considered PV system and apply two controls P&O and Fuzzy-GA to our system, and we will present the simulation results by using MATLAB/SIMULINK. The results obtained are studied by applying two controls and are implemented and compared to the system, we will start with P&O algorithm and then with fuzzy logic optimized by using Genetic Algorithm.

3.2 Model of the considered system

The proposed Fuzzy Logic Control based MPPT has been modelled and simulated using **MATLAB/Simulink**. Figure 3.1 shows our developed Simulink model. In the simulation study, the *FLC* based MPPT is simulated and under the operating condition assuming the constant temperature and constant isolation *(1000 W/m²)*. The MPPT control consists of two main parts, *FLC* and current control, as depicted in Figure 3.2. The specifications of *PV* module used in this simulation are shown in Table 1.

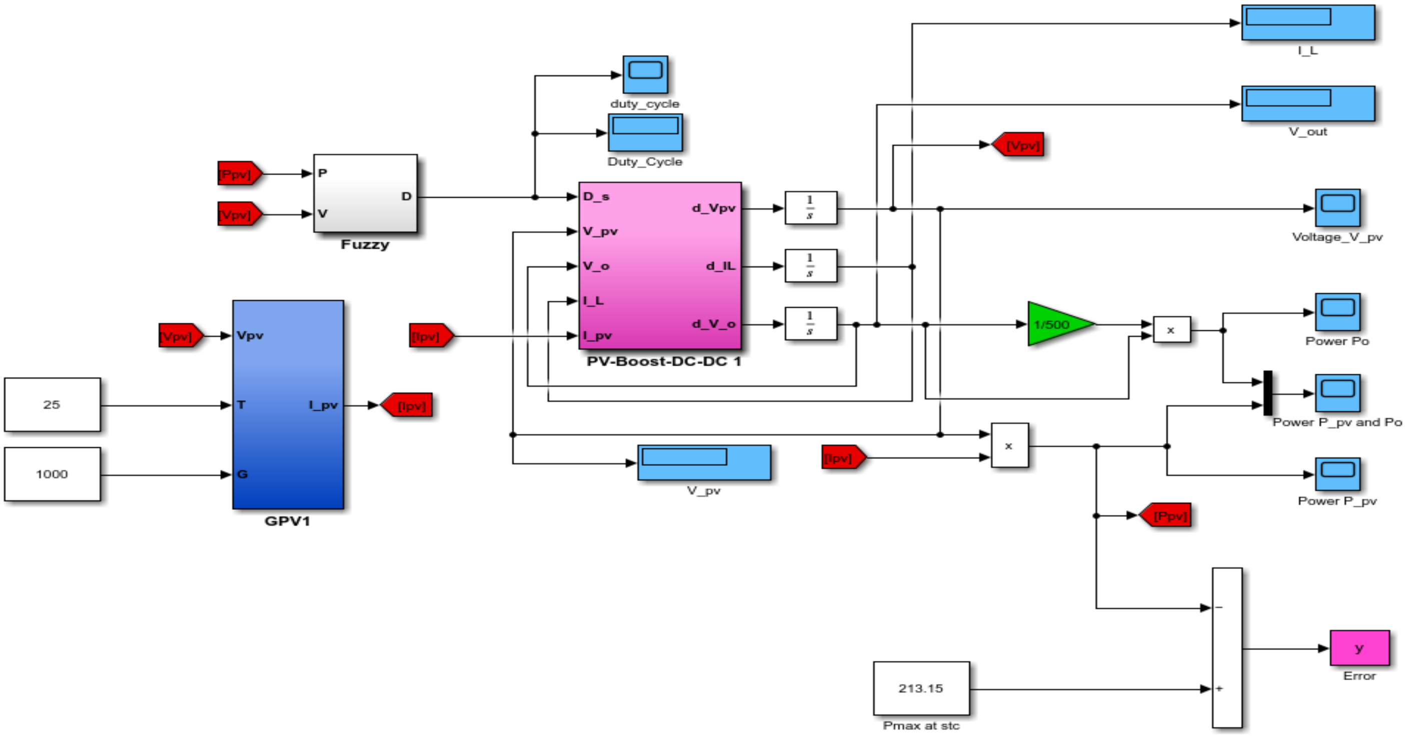


Figure 3.1 MATLAB/Simulink Model of the considered PV system

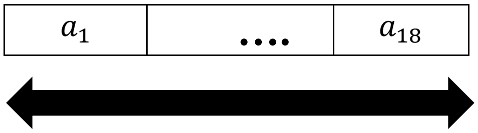
3.3 Genetic Learning Algorithm

As shown in Figure 2.11, we choose Fitness Function in the form MSE, which is given by the following equation:

$$MSE = \frac{1}{nT} \sum_{i=1}^{n} e(\mathrm{K})^2 \tag{3. 1}$$

Where: n is the total number of samples and T is the sampling time, $e(k) =$ Actual output - Calculated output is the difference between the value of the desired power output and the value of the measured power output.

Figure 3.2 the individual will consist of three parameters which are the modal values of membership functions of input and output fuzzy singletons, respecting the following constraint:



Modal values of membership and rules

Figure 3.2 Individual structure of GA

3.4 Simulation Results

We obtained the fitness function that we use to determine the values of the membership by Applying the GAs. After execution in MATLAB we obtained the fitness function as follows.

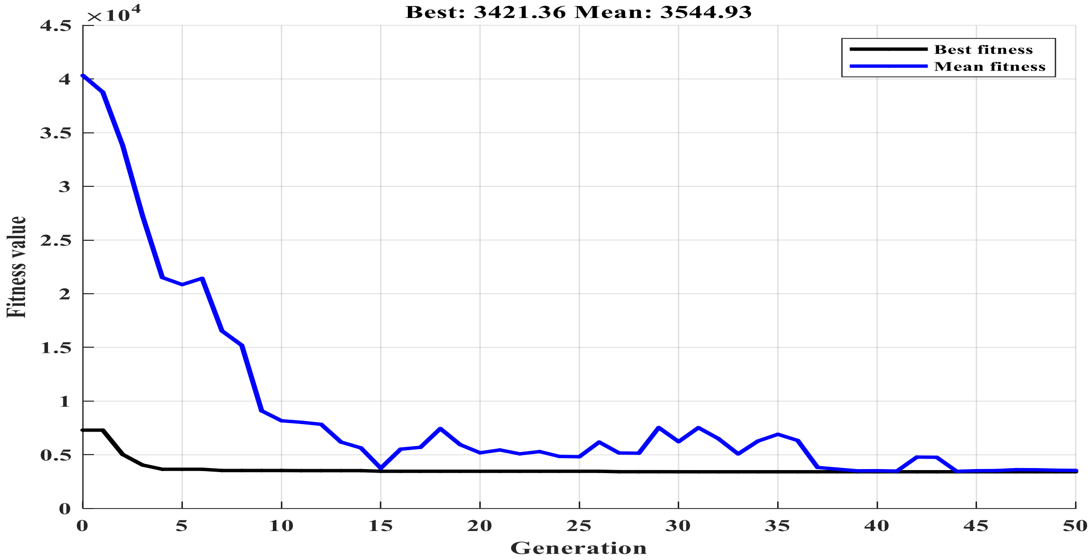


Figure 3.3 Fitness Function

Figure 3.3 shows the membership functions of inputs and output after optimization.

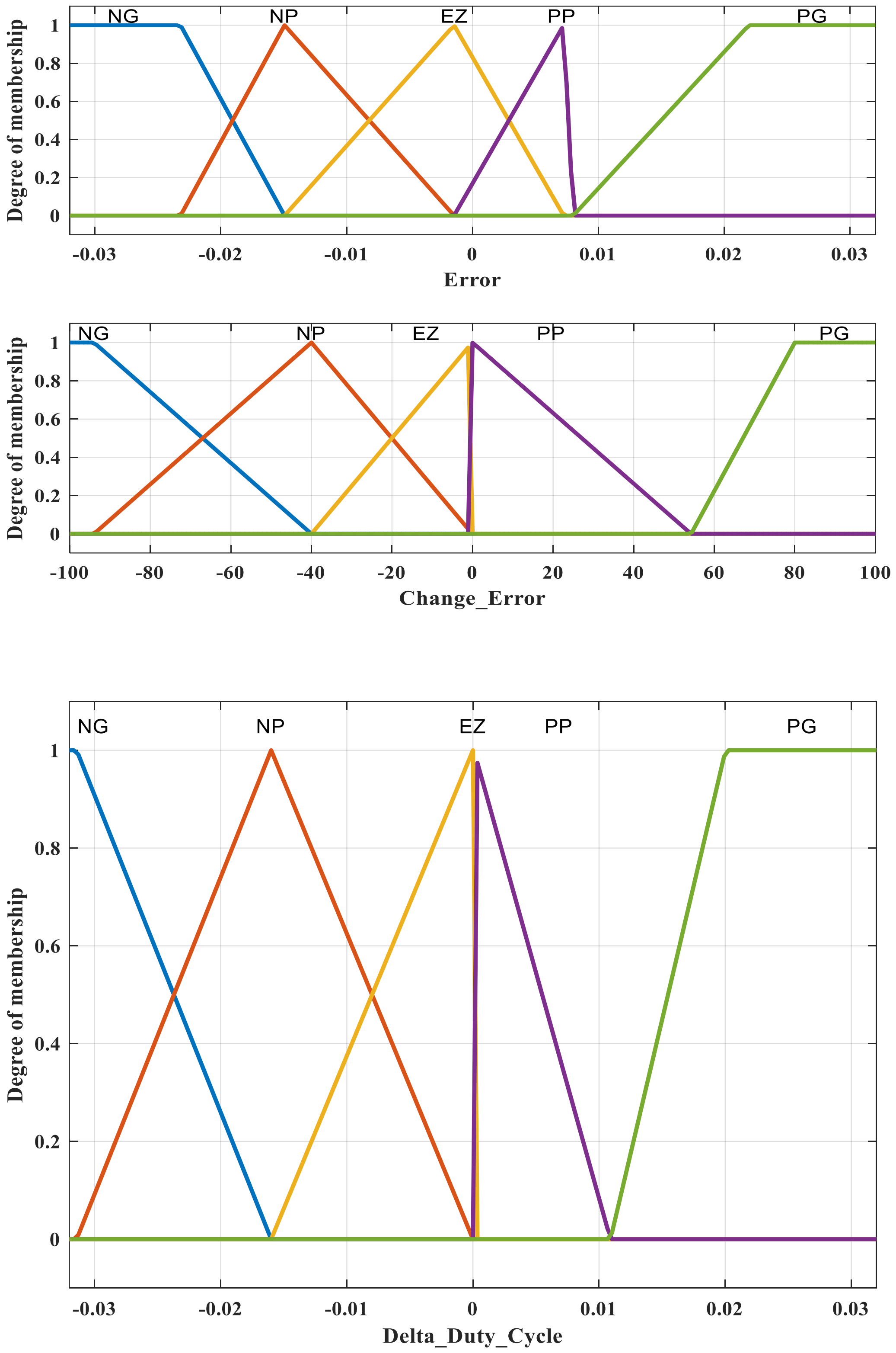


Figure 3.4 Inputs and Output after optimization

Figure 3.5 shows the surface of the base rules of Fuzzy-GA using **MATLAB/Simulink**.

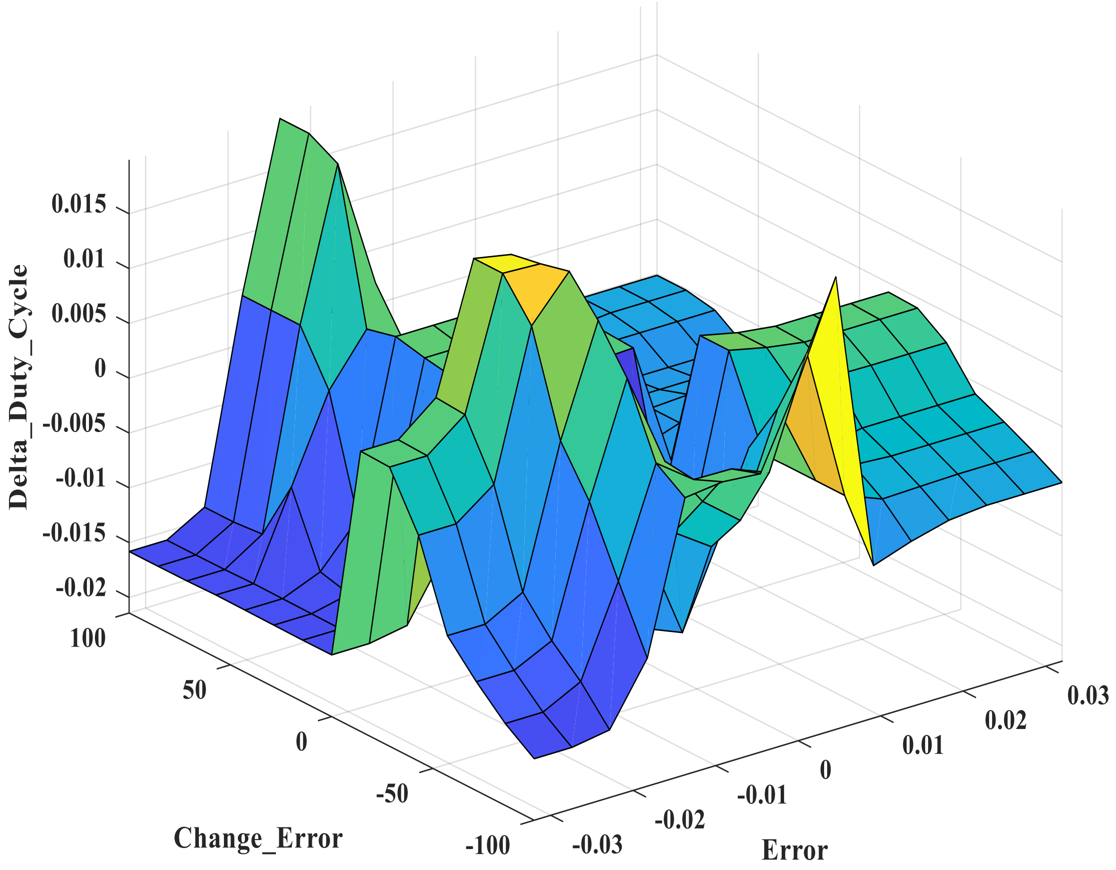


Figure 3.5 Rule surface of Fuzzy-GA

Figure 3.6 illustrates the simulation results of the system's power with different MPPT techniques P&O and Fuzzy-GA.

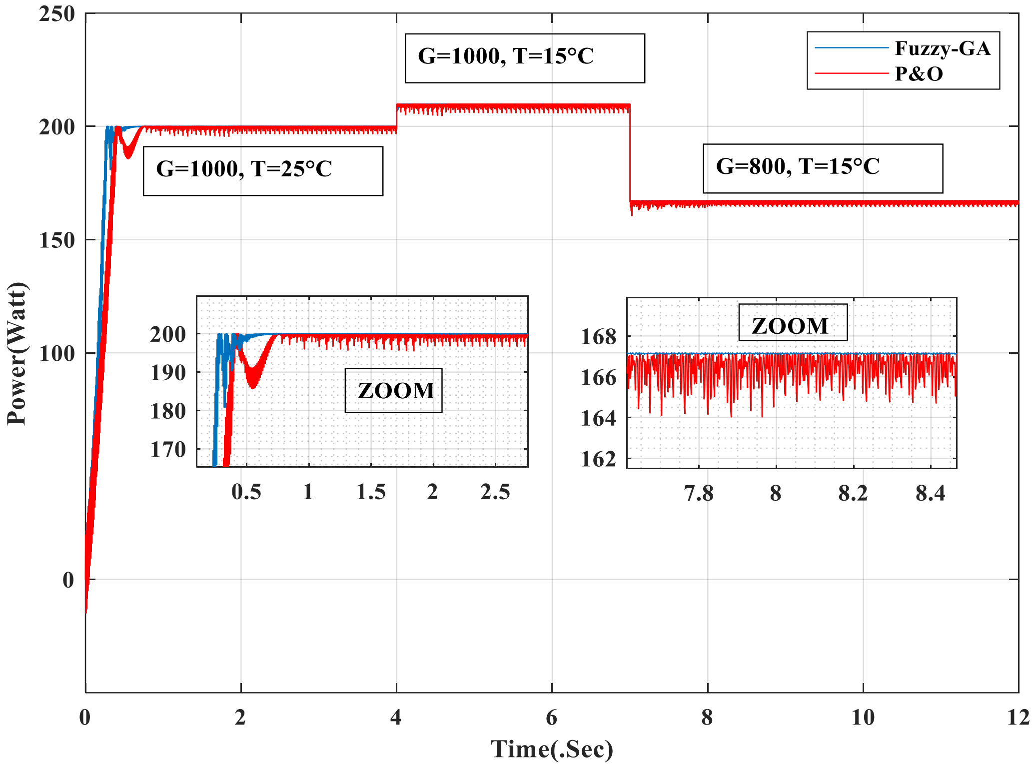


Figure 3.6 Simulation results of the Power by using P&O and Fuzzy-GA.

- **Comparison**

When comparing the P&O method's performance with Fuzzy-GA control from Figure, a thorough examination indicates notable variations in the method's efficiency, stability, and adaptability to changing environmental conditions. This is an organized analysis of the comparison:

✓ **Effectiveness:**

P&O: This technique can effectively track the maximum power point in a steady state or slowly fluctuating conditions. But because of its innate tendency to oscillate around the maximum power point, there may be power losses, especially in situations when things change quickly.

Fuzzy-GA: may modify its control strategy based on a wider range of input variables and situations, it typically exhibits superior efficiency. By reducing oscillations around the highest power point and fine-tuning its response, it can better utilize the available solar energy.

- ✓ **Reaction Time to Modifications in Environment**

  P&O: Although modifications may be made somewhat quickly, the P&O algorithm may have accuracy issues in situations that change quickly, including sporadic cloud cover, which could result in less-than-ideal power tracking.

  Fuzzy-GA: is made to manage uncertainty and variability more skillfully. Because FL is adaptable, controller settings may be changed more quickly and precisely in response to variations in temperature and sunshine, allowing for closer to optimal performance.

- ✓ **Consistency and Variability**

  P&O: Around the maximum power point, this approach is likely to produce bigger and more frequent oscillations in the power output. These oscillations may shorten the PV system's lifespan since they stress system components in addition to lowering overall efficiency.

  Fuzzy-GA: Generally speaking, it offers a power output that is considerably less oscillatory and steadier. The durability and dependability of the PV system's components are enhanced by this stability.

- ✓ **Sturdiness**

  P&O: Under complex or highly variable environmental conditions, P&O's performance can deteriorate despite its rugged simplicity and modest computational requirements.

  Fuzzy-GA: Is very resilient, especially in complicated situations. Because of its ability to dynamically modify its rules and settings, it performs better in environments with highly variable or non-linear inputs.

- ✓ **Complexity of Computation**

  P&O: Its low computational complexity makes it simple to implement with little hardware requirements, which is one of its main advantages.

  Fuzzy-GA: intricate rule-based processing approach necessitates greater processing power. In locations where conditions vary quickly, this pays off even if it could increase costs and system requirements.

3.5 Conclusion

In this chapter we present the model of our considered system and figures who illustrate the simulation results. Overall, the comparison shows that Fuzzy-GA performs better in efficiency, stability, and adaptability while P&O is better in simplicity and less computational needs. Therefore, FL is especially well suited for areas with extremely variable weather, albeit at a higher computing cost. Choosing between these approaches will rely on the PV system in question's performance needs, budget, and particular operating conditions.

General conclusion

Natural energy supplies such as uranium, gas, and oil are running out due to the industry's recent rapid growth and spread. The world's energy needs are also changing quickly. We are conducting research on renewable energies to meet our energy needs. Photovoltaic solar energy is a clean, quiet, readily available, and cost-free energy source that is one of the renewable energies capable of meeting demand. This explains why its use is greatly expanding globally. Initially, we looked into solar photovoltaic energy. We talked about the system's components. Next, we discussed methods for monitoring the maximum power point. We have created Matlab simulation programs that enable us to track the I-V and P-V properties at various temperatures and irradiances. We tested a photovoltaic system with a boost converter and MPPT controls in the Matlab simulator, first with a P&O and then with a Fuzzy-GA. We took changes in lighting, temperature, and other weather conditions into account to get a better idea of the challenges of running a photovoltaic system. The tracking time and peak power point completion accuracy for the different operating situations are good, and the results are satisfactory. The comparison reveals that Fuzzy-GA outperforms P&O.

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Annex:

KC200GT Cell:

https://www.energymatters.com.au/images/kyocera/KC200GT.pdf

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جامعة غرداية
كلية العلوم والتكنولوجيا
قسم الآلية والكهروميكانيك

إذن بالطباعة (مذكرة ماستر)

بعد الاطلاع على التصحيحات المطلوبة على محتوى المذكرة المنجزة من طرف الطلبة التالية أسماؤهم:

1. الطالب (ة) : رزاق إبراهيم
2. الطالب (ة) : /
3. الطالب (ة) : /

تخصص : طاقات متجددة في الكهروتقني

نمنح نحن الأستاذ (ة) :

الاسم واللقب	الرتبة – الجامعة الأصلية	الصفة	الامضاء
بوشلغة فاطمة	MCA - جامعة غرداية	~~مصحح (1)~~ رئيس	
بوتاقو عبد الحق	مركز بحث - طاقات	مصحح (2)	عبد الحق
محسن ثوات	أستاذ (جامعة غرداية)	مؤطر	

الإذن بطباعة النسخة النهائية لمذكرة ماستر الموسومة بعنوان

An optimal Fuzzy logic controller based MPPT controller for PV system

إمضاء رئيس القسم

العلمي عبد اللطيف
رئيس قسم الآلية
و الكهروميكانيك