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Title

Modelling and simulation of a photovoltaic system associated with inverter controlled by the MPPT techniques

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Thanks

First and foremost, we thank God, Almighty, for giving us the strength to survive, as well as the courage to overcome all difficulties.

A big thank you to Dr . Labiod Chouaib, Professor at the University of El Oued, my thesis director, for the trust he has given us by agreeing to be the Director of this work. We were able to appreciate his scientific skills and he knew how to make us benefit from his experience and his fruitful directives.

Our thanks also go to the members of the jury for their interest in our research.

We also extend our sincere thanks to all the teachers of the Electromechanical Engineering department who participated in our training.

Dedications

In the name of God, the Merciful and the Merciful Praise be to ALLAH the Almighty

We dedicate this modest work as a sign of respect, recognition and thanks:

To our dear parents, to our dear brothers who have helped us from near and far.

To all our family, which bears the name Fouhma, Ghania, Talbi and Ben Haoua.

To all those who have contributed to the development of this humble work and to all those who are dear to us.

Abstract :

In this work, we've done simulation model of the electric part of photovoltaic system associated with inverter controlled by MPPT. To achieve this goal, we have taken a series of steps as follows:

General study on clean energy and photovoltaic ornaments and their components and applications in various fields, especially agriculture of food security and on the other hand its importance for energy security. For this, in the second part, we studied the mathematical models of photovoltaic cells, taking into account the changes in the sun's brightness and temperature, and on the other hand, we modeled and simulated DC/DC boost converter in order to use it in the application of MPPT algorithms .

Finally, we simulated the three phase inverter for an associate with this system, because AC current is very important for energy exploitation, whether in social life, industry, or for integration with the network. After simulating all the converters, we associate them with the photovoltaic system using the maximum power P&O technique, and the results show the effectiveness of the simulations that were accomplished this work.

The DC/DC converter is very important part for the DC bus of inverter and it is developed in order to extract the maximum amount from the photovoltaic generator. O their wise, the association of inverter with of photovoltaic system gives much advantage in this system when we can be exploited for many applications as: AC load for isolated areas, use for Uninterruptible Power Supply UPS, prepared for connected to grid etc.

Keywords : Boost converter, photovoltaic system , maximum power point tracking ,three-phase inverter, perturb and observe techniques .

الملخص :

في هذا العمل ، قمنا بعمل نموذج محاكاة للجزء الكهربائي من النظام الكهروضوئي المرتبط بعاكس يتحكم فيه (MPPT) .لتحقيق هذا الهدف اتخذنا سلسلة من الخطوات مثل :

دراسة عامة عن الطاقة النظيفة و الخلايا الكهروضوئية ومكوناتها وتطبيقاتها في مختلف المجالات وخاصة الفلاحية من الامن الغذائي ومن ناحية اخرى اهميتها من اجل الامن الطاقة

من اجل هذا في الجزء الثاني قمنا بدراسة النماذج الرياضية الخاصة بالخلايا الكهرو ضوئية مع الاخذ تغيرات درجة سطوع الشمس و درجة الحرارة ومن ناحية ثانية قمنا بمحاكاة المحول الرافع للجهد من اجل استخدامه في تطبيق خوارزميات البحث عن الاستطاعة الاعظم

وفي الاخير قمنا بمحاكاة المحول العكوس وهذا لكون التيار المتناوب مهم جدا من اجل الاستغلال سواء في الحياة الاجتماعية اوالصناعة او لدمج مع الشبكة. بعد محاكاة كل المحولات قمنا بربطهم مع النظام الكهرو ضوئي باستخدام تقنية الاستطاعة العظمى P&Oوتبين النتائج مدى فعالية المحاكات التي تم انجازها في هذا العمل

الكلمات المفتاحية : محول رفع الجهد. نظام الكهروضوئي. العاكس ثلاثي الطور. تقنيات المراقبة والاضطراب .نظام الخلايا الكهروضوئية .

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General Introduction

General Introduction :

In modern societies, development level and economic wellbeing of a society are directly measured by energy generation and consumption. Energy plays an important role in the economic health of a country that is reflected by the gross national product (GNP). The per capita GNP of a country is correlate to the per capita energy consumption. There is a steady demand to increase the energy generation capacity all over the world since the global energy consumption is rising. The main reasons are the technological developments, industrial revolution and increase in population. In a modern and industrialized community, energy is used in every single human activity. Some major examples are the following [1]:

- Household applications such as heating, cooking, lighting, and air conditioning.
- Transportation—passenger cars, buses, trains, trucks, and aircrafts.
- Manufacturing heat and electricity as well as user end or industrial products.
- Irrigation and fertilizing in agricultural organizations the worldwide energy consumption has been growing steadily and rapidly right after the industrial revolution.

The worldwide growth of energy demand and the finite reserves of fossil fuel resources have led to the intensive use of renewable energy sources (RESs). Other major issues that have driven strongly the RES development are the ever-increasing impact of energy technologies on the environment and the fact that RESs have become today a mature technology. The necessity for having available sustainable energy systems for substituting gradually conventional ones requires changing the paradigm of energy supply by utilizing clean and renewable resources of energy. Among renewable, solar energy characterizes as a clean, pollution free and inexhaustible energy source, which is also abundantly available anywhere in the world. These factors have contributed to make solar energy the fastest growing renewable technology in the world [1]. At present, photovoltaic (PV) generation is playing a crucial role as a solar-based RES application because of unique benefits such as absence of fuel cost, high reliability, simplicity of allocation, low maintenance and lack of noise and wear because of the absence of moving parts. In addition to these factors are the decreasing cost of PV panels, the growing efficiency of solar PV cells, manufacturing-technology improvements and economies of scale [2]

Energy production is a challenge of great importance for the years to come. Indeed, the energy needs of industrialized societies are constantly increasing. By elsewhere, developing countries will need more and more energy to carry out their development. Nowadays, a large part of the world's production of energy is supplied from fossil sources. The consumption of these sources gives rise to greenhouse gas emissions and therefore an increase in pollution. The danger additional is that excessive consumption of the stock of natural resources reduces reserves this type of energy in ways that are dangerous for future generations. By renewable energy, we mean energy from the sun, wind, heat soil, water or biomass. Unlike fossil fuels, Renewable energies are energies with unlimited resources. Renewable energies group together a certain number of technological sectors according to the source of energy recovered and the useful energy obtained.

This project aimed to modeling and simulation of a photovoltaic system associated with inverter controlled by the MPPT techniques, this work presented in three parts as follow:

The purpose of this project is the modeling and simulation of a photovoltaic system associated with inverter controlled by the MPPT techniques, this work presented in three parts as follows:

The first chapter is divided into three parts, the first part deals with renewable energy resources and solar radiation generally speaking. The second part identifies the photovoltaic elements and their applications, and in the last part of this chapter, general study on the photovoltaic system to know the components and materials used for the manufacture and their application.

The second chapter presents characteristics of photovoltaic panel, as well as working principle of MPPT and their different algorithms. Hence, the DC/DC boost converter will be modeled to be used as a tool to achieve the MPPT in the solar panel. Several MPPT techniques in literature, but in this chapter, P&O algorithm and Conductance increment algorithm were presented, and then modeling and simulation of converted DC/DC Boost were developed to be used as tools to implement MPPT in Simulink in the next chapter

In the last chapter of our project, the modeling of the three-phase inverter and the boost DC/DC converter has been developed, then the association of the boost converter with the inverter will be carried out after voltage control by PWM techniques. Next, we will associate the photovoltaic system with the MPPT using the converted DC/DC boost. Otherwise, the MPPT of the photovoltaic system is connected to the inverter where it regulates the power of the solar panel and to the inverter where it regulates the power of the solar panel and is converted from DC to AC by the inverter, in the last part of this chapter, we have simulated an MPPT system with solar PV panel connected to DC/AC inverter.

Chapter I:

General study on photovoltaic system

I.1 Introduction

Energy production is a challenge of great importance for the years to come. In Indeed, the energy needs of industrialized societies are constantly increasing. By elsewhere, developing countries will need more and more energy to carry out their development. Nowadays, a large part of the world's production of energy is supplied from fossil sources. The consumption of these sources gives rise to greenhouse gas emissions and therefore an increase in pollution. The danger additional is that excessive consumption of the stock of natural resources reduces stores this type of energy in a dangerous way for future generations [3].

In this chapter, general study on the photovoltaic system to know the components and materials used for the manufacture and their application in the social or industrial life.

I.2 Renewable energy resources

These sources and technologies include solar and wind power, hydropower and mini-hydropower, tidal power, biomass energy (including biofuels) and geothermal energy [4].

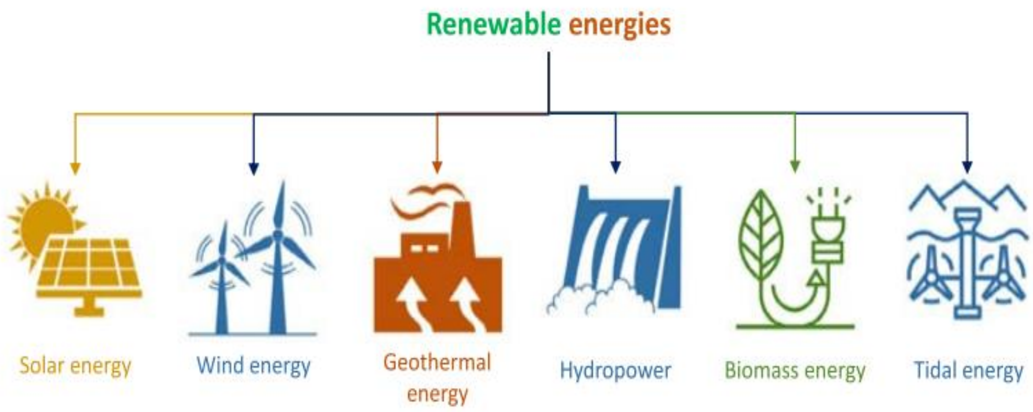

Figure I.1: Different types of renewable energies

I.2.1 Definition of renewable energy resources

Renewable sources are often associated with green energy and clean energy, but there are some subtle differences between these three energy types. Where renewable sources are those that are recyclable, clean energy are those that do not release pollutants like carbon dioxide, and green energy is that which comes from natural sources. While there is often cross-over between these energy types, not all types of renewable energy are actually fully clean or green. For example, some hydroelectric sources can actually damage natural habitats and cause deforestation [5].

I.2.1.1 The development of renewable energy

Although renewable energy is often seen as a solution for the future of our power needs, we have been harnessing the natural power of nature for centuries. Windmills and water wheels were used to power granaries, while the sun has been used to create fire for heat and light.

However, humans became increasingly dependent on the use of fossil fuels including coal and natural gas. The widespread use of these types of energy has been shown to have had a detrimental impact on the planet, with increasing global temperatures, an increase in extreme weather events and the loss of natural habitats as a result.

Recent advances in capture and storage, along with the global drive towards Net Zero, has created an expansion in renewable and green energy production. These advances range from small-scale production, such as the placing of solar panels on a home, to large-scale facilities like offshore wind farms [6].

I.2.2. Types range of renewable sources

There area range of renewable sources that have been developed, with each offering their own advantages and challenges depending on factors such as geographical location, requirements for use and even the time of year [7].

I.2.2.1 Solar Power

Solar energy is one of the growing renewable energy sources, which is plentiful and has the greatest availability among other energy sources. The amount of solar energy supplied from the sun to the earth is capable of satisfying the total energy requirements of the earth for 1 year. Furthermore, solar energy does not produce pollutants or harmful by-products; it is free of emissions. Solar energy is applicable to many fields such as vehicular, residential, space, and naval applications [8].

Figure I.2: Solar energy

I.2.2.2 Wind Power

Wind is one of the largest potential energy sources available, the available energy is capable of meeting the current global energy requirements. But We have obstacles because energy transmission is relatively difficult and expensive and yet it is good renewable energy [9].

Figure I.3: Wind Power

I.2.2.3 Hydroelectric Power

The hydroelectric power is not an effective solution, since most of the potential sites are already in use or they are not feasible to be exploited due to environmental and economic concerns. In addition, the life span of hydroelectric power plants is limited, due to soil erosion and accumulation. Because of these concerns, the world has been building smaller hydro power units called as micro hydro since they can be a part of distributed generation, opening up many locations for power generation and they have less or negligible environmental effects on the other hand, hydroelectric power plants have no emissions since no fuel is burnt. Hence, hydropower is a clean energy source in comparison with fossil-fuel-based energy [10].

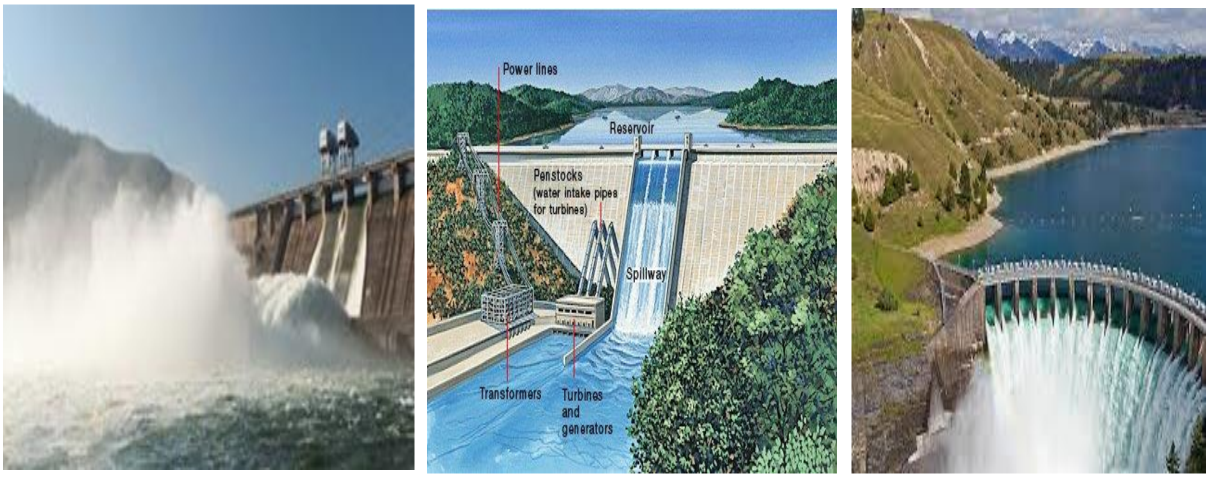

Figure I.4: Hydroelectric Power

I.2.2.4 Biomass Energy

Biomass is a fuel that is also called bio fuel, and the bioenergy is the energy enclosed in the biomass. Renewable energy is any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use. It is obtained from the continuing or repetitive flows of energy occurring in the natural environment and includes low carbon emission technologies such as solar energy, hydropower, wind, tidal and wave power and ocean thermal energy, and renewable fuels such as biomass [11].

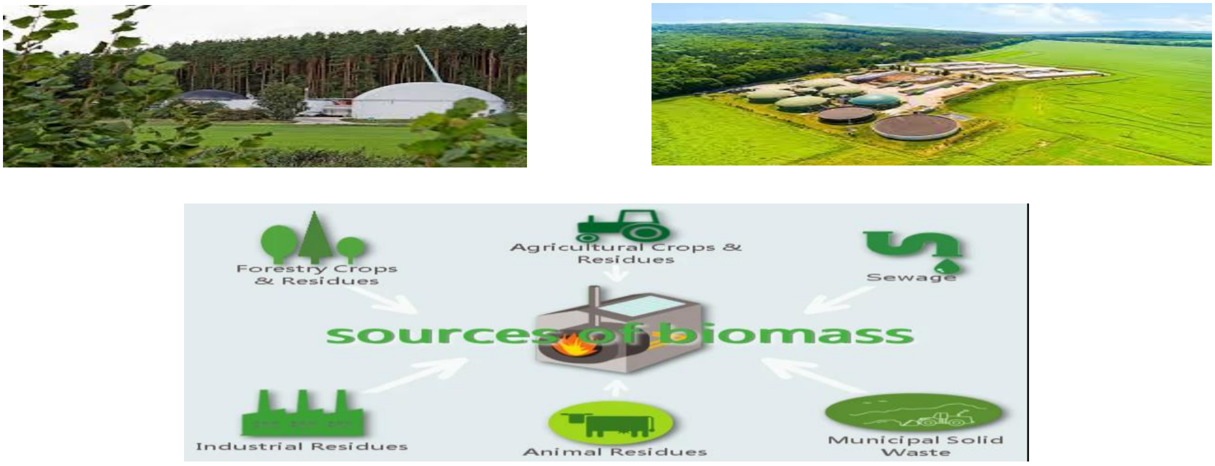

Figure I.5: Biomass Energy

I.2.2.5 Geothermal

Geothermal energy is the thermal energy that is stored in the inner layers of the Earth composed of rocks and fluids. The temperature of the inner layers of the Earth gets hotter as the depth increases. In deeper layers, it is even extremely hotter due to the hot molten rock called magma. Geothermal energy can be utilized by several methods and it can be used as direct heat for electric power generation [12].

Figure I.6: Geothermal

I.2.2.6 Ocean Power

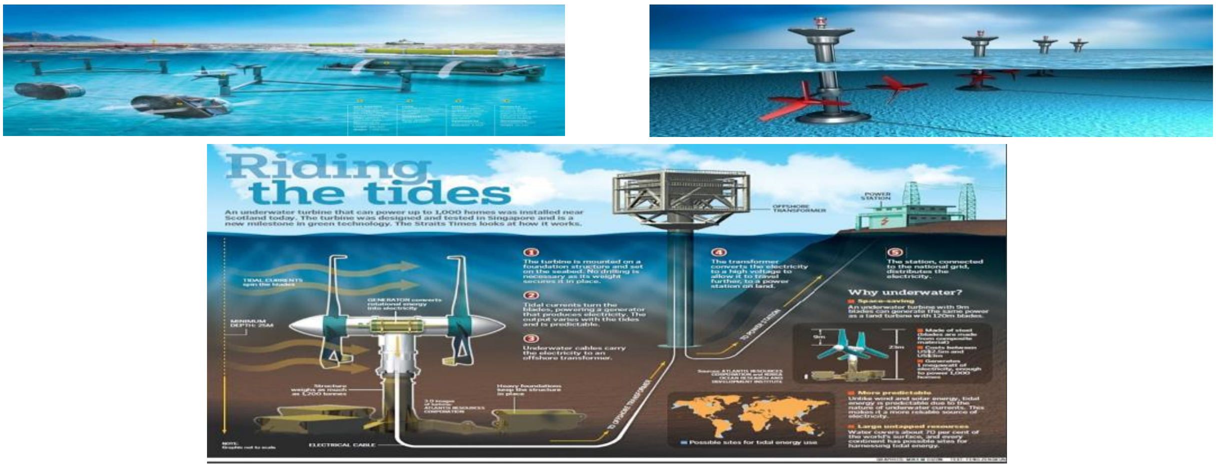

Figure I.7: Ocean Power

Energy of ocean can be categorized in three major methods ocean wave power, ocean tidal power, and ocean thermal power. All of these three methods can be installed as onshore or offshore applications. Wave energy harvesting is a concept that the kinetic energy of waves of the deep water or waves hitting the shores is captured and converted to electric energy [13].

Renewable energy is any form of energy from solar, geophysical or biological sources that is replenished by natural processes at a rate that equals or exceeds its rate of use. It is obtained from the continuing or repetitive flows of energy occurring in the natural environment and includes low carbon emission technologies such as solar energy, hydropower, wind, tidal and wave power and ocean thermal energy, and renewable fuels such as biomass.

I.3 Solar radiation

This section reviews the fundamentals of electromagnetic and black-body radiation that are required to understand the nature of the Sun and of the solar radiation that reaches Earth. It also defines some important concepts that are useful for practical applications of solar radiation.

I.3.1 The source of solar energy

The Sun, our closest star, is a spherical gaseous self-gravitating body consisting mainly of hydrogen. It is located at the center of the solar system, on average 1.5 × 1011 m from Earth. At the inner core of the Sun, the gravitational force creates a pressure which generates nuclear fusion that turns hydrogen into helium. In this process a portion of the mass is converted into an abundant amount of electromagnetic radiation, which makes the Sun the dominant source of radiative energy in the solar system. The Sun has a complex physical structure and consists of several regions, from the dense inner core to the outer atmospherically layer, the corona. Both the corona and the core are very hot, in the order of 106 − 107 K, while the intermediate regions that transport and emit energy as outgoing radiation are cooler (although hot by earthly standards).

Energy from fusion reactions in the Sun's interior is transported through successive convection, radiation, absorption, emission and irradiation to the Sun's equivalent of a surface, the photosphere, which absorbs and emits a continuous spectrum of radiation. The photosphere is the source of most visible radiation reaching Earth. It has a surface temperature, or, more correctly, an effective black-body temperature of 5777 K (this is the temperature of a black-body radiating the same amount of energy as the Sun). Although it consists of several absorbing and emitting layers and has a considerable temperature gradient across its radius, the Sun closely resembles the ideal concept of a black-body, the properties of which will be explored in the next section [14].

I.4. Description of the photovoltaic elements

To understand the photovoltaic effect, some basic theory about semiconductors and their use as photovoltaic energy conversion devices needs to be given as well as information on p-n junctions. These are explained in the following sections. As is well known, atoms consists of the nucleus and electrons that orbit the nucleus. According to quantum mechanics, electrons of an isolated atom can have only specific discrete or quantized energy levels. In elements that have electrons in multiple orbitals, the innermost electrons have the minimum (maximum negative) energy and therefore require a large amount of energy to overcome the attraction of the nucleus and become free. When atoms are brought close together, the electronic energy of individual atoms is altered and the energy levels are grouped in energy bands. In some energy bands, electrons are allowed to exist, and in other bands electrons are forbidden. The electrons at the outermost shell are the only ones that interact with other atoms. This is the highest normally filled band, which corresponds to the ground state of the valence electrons in an atom and is called the valence band. The electrons in the valence band are loosely attached to the nucleus of the atom and, therefore, may attach more easily to a neighboring atom, giving that atom a negative charge and leaving the original atom as a positive charged ion. Some electrons in the valence band may possess a lot of energy, which enables them to jump into a higher band. These electrons are responsible for the conduction of electricity and heat, and this band is called the conduction band. The difference in the energy of an electron in the valence band and the innermost shell of the conduction band is called the band gap. A schematic representation of the energy band diagrams of three types of materials is shown in Figure I.8. Materials whose valence gap is full and whose conduction band is empty have very high band gaps and are called insulators because no current can be carried by electrons in the filled band and the energy gap is so large that, under ordinary circumstances, a valence electron cannot accept energy, since the empty states in the conduction band are inaccessible to it. The band gap in these materials is greater than 3eV [15].

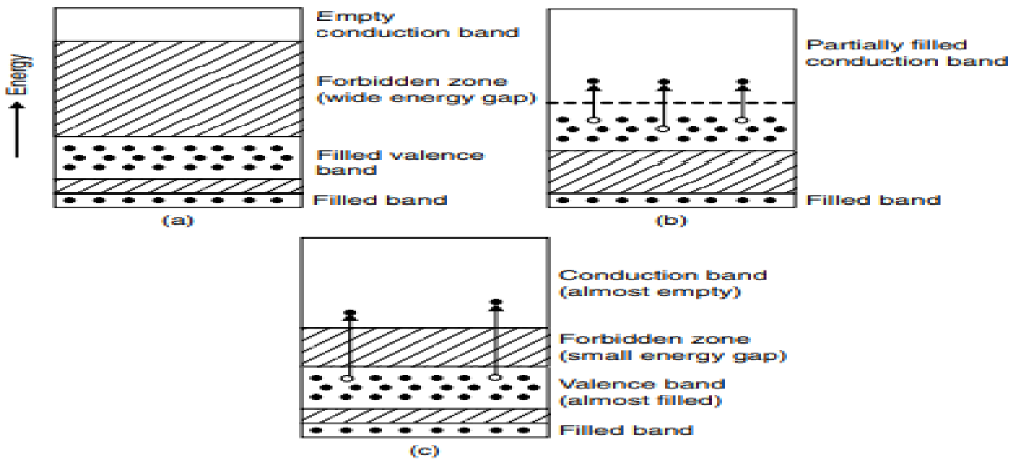

Figure I.8: schematic diagrams of energy bands for typical materials. (a) insulator. (b) conductor (metal). (c) **semiconductor**.

I.4.1. Junction p-n

Silicon (Si) belongs to group 4 of the periodic table of elements. In semiconductors, if the material that is doped has more electrons in the valence gap than the semiconductor, the doped material is called an *n-type semiconductor*. The n-type semiconductor is electronically neutral but has excess electrons, which are available for conduction. This is obtained when Si atoms are replaced with periodic table group 5 elements, such as arsenic (As) or antimony

(Sb), and in so doing, form electrons that can move around the crystal. If these excess electrons are removed, the atoms will be left with positive charges. In semiconductors, if the material that is doped has fewer electrons in the valence gap than the semiconductor, the doped material is called a *p-type semiconductor*. The p-type semiconductor is electronically neutral but it has positive holes (missing electrons) in its structure, which can accommodate excess electrons. This type of material is obtained when Si atoms are replaced with periodic table group 3 elements, such as gallium (Ga) or indium (In), and in so doing, form positive particles, called *holes*, that can move around the crystal through diffusion or drift. If additional electrons could fall the holes, the impurity atoms would ft more uniformly in the structure formed by the main semiconductor atoms, but the atoms would be negatively charged.

Both types of semiconductors are shown schematically in Figure I.8. Both n- and p-type semiconductors allow the electrons and holes to move more easily in the semiconductors. For silicon, the energy needed to get an electron across a p-n junction is 1.11eV. This is different for each semiconductor material. What is described in the previous paragraph occurs when the p- and n-type semiconductors are joined together, i.e., form a junction, as shown in Figure I.9.

As can be seen, when the two materials are joined, the excess electrons from the n-type jump to fall the holes in the p-type, and the holes from the p-type

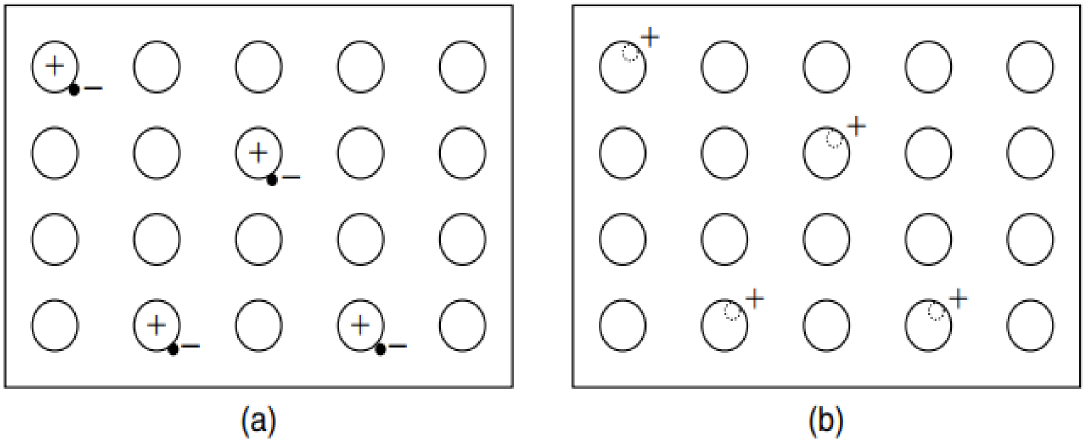

Figure I.9: Schematic diagrams of n- and p-type semiconductors. (a) n-type, with excess electrons. (b) p-type, with excess positive holes.

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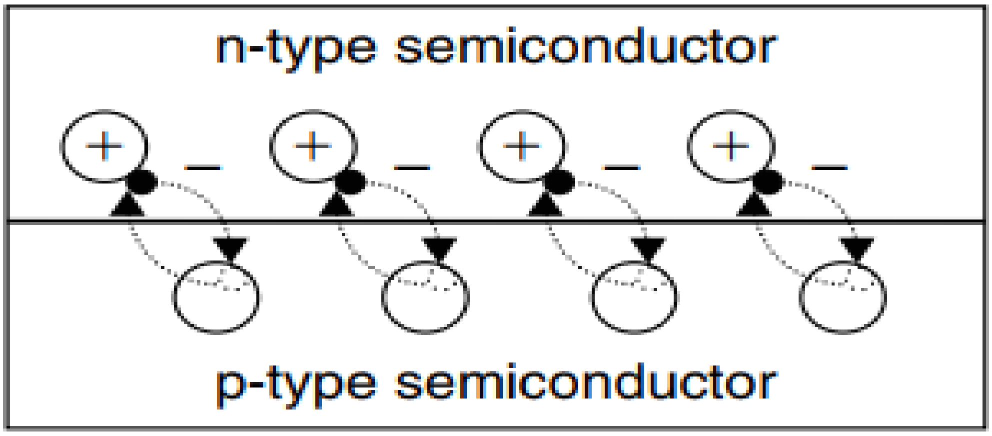


Figure I.10: Schematic diagram of a p-n .

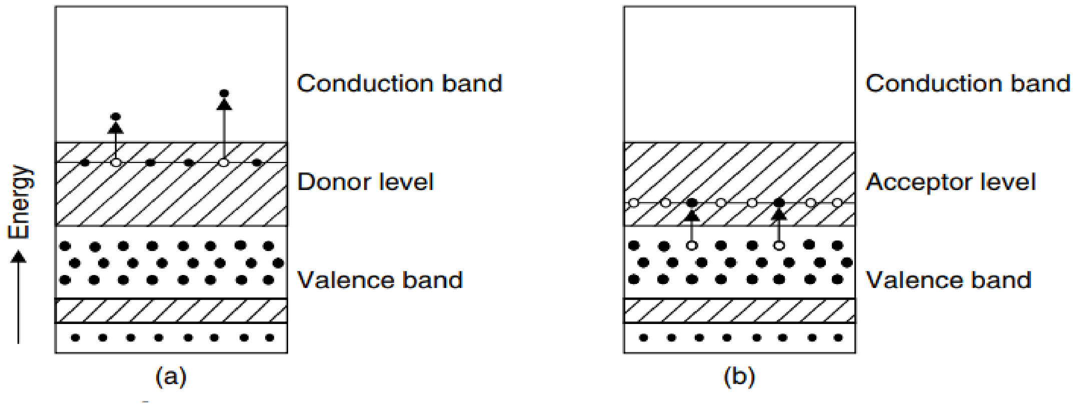


Figure I.11: Energy band diagrams of n- and p-type semiconductors. (a) n-type semiconductor. (b) p-type semiconductor..

Diffuse to the n-type side, leaving the n side of the junction positively charged and the p side negatively charged. The negative charges of the p side restrict the movements of additional electrons from the n side; however, the movement of additional electrons from the p side is easier because of the positive charges at the junction on the n side. Therefore, the p-n junction behaves like a diode. A schematic diagram of the energy bands of the n- and p-type semiconductors is shown in Figure I.9. In the n-type semiconductor, because the doped impurity donates additional electrons for the conduction of current, it is called the donor and its energy level is called the donor level. The n-type energy band diagram is shown in Figure I.9a, and as can be seen, the donor level is located within the forbidden band. In the p-type semiconductor, the doped impurity accepts additional electrons; therefore, it is called the acceptor and its energy level is called the acceptor level. Its energy band diagram is shown in Figure I.9b, and as can be seen, the acceptor level is located in the forbidden band.

I.5 Applications

Thanks to the assistance and solutions provided by photovoltaic cells in the field of power generation, and since it is renewable energy nonpolluting and has no emissions, it has become its application in several fields

I.5.1. Applications of solar PV systems (On-farm):

The agricultural sector is certainly the only provider of human food with a projected global population increase of 25% in the next 20 year the demand for food and energy is expected to be significantly raised as a consequence. Most agricultural activities are directly or indirectly powered by fossil fuels that cause greenhouse gas (GHG) emissions, leading to climate change as a consequence of global warming. In this regard, sustainable alternative energy resources are required to reduce growing concerns about the environmental impacts of nonrenewable fuels. Photovoltaic (PV) systems offer a promising solution to run agricultural activities in a sustainable manner. It has been reported that PV technology is among the fastest-growing energy technologies [16]. Solar PV systems can be employed to either supply electricity or both heat and electricity (through the use of PVT systems) to supply the energy demands of various agricultural activities. Solar farm application systems have the following items:

I.5.2 Agro_photovoltaic (APV):

The idea of agrophotovoltaic (APV) was first proposed by Goetzberger and Zastrow [17] in 1982. It revolves around the coproduction of solar PV energy and agricultural products on the same field. Nowadays, this technique is also known as an agrivoltaic system. The proposed idea included the installation of PV panels 2m above the ground to enlarge the space between them, avoiding excessive crop shading Scientists.

Figure I.12: (A) APV system installed in Italy, and (B) APV facility installed above the potato farm (RESOLA project), Heggelbach, Germany

I.5.3 Aquavoltaics:

FV (Floatovoltaics) installation on the surface of an aquaculture system forms a cooling mechanism for PV modules, enhancing the power conversion efficiency (PCE) between 5% and 22% depending on the deployment method. FVs can also perform as fish aggregation techniques which suggest a controlling framework for the behavior of fishes by protecting them, and presumably improve the yield [18]. Kim et al. [19] proposed the concept of a floating PV system for harvesting salt and electricity at the same salt farm for the first time

Figure I.13: (A) The FV system installed on an irrigation pond, Niente winery, California's Napa Valley region, (B) The FV system installed on a sandpit lake in Zwolle, the Netherlands, and (C) The FV system installed at Tengeh Reservoir in Tuas, Singapore.

I.5.4 Solar-powered desalination systems

Solar energy is known as the most abundant renewable energy source. It has intensively been developed because of both governmental support policies and remarkable improvements in the technological aspects of utilization and the development of renewable energies [20]. Solar energy is an abundant and ecofriendly source of renewable energy with the most promising potential to drive desalination plants.

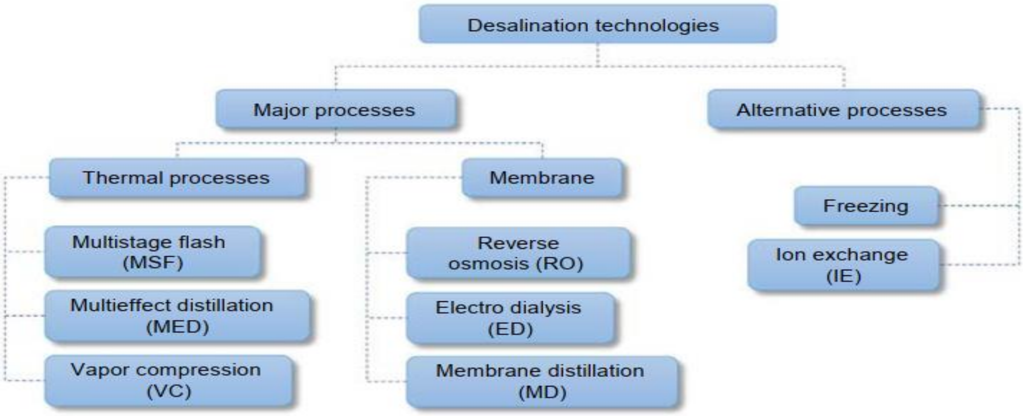


Figure I.14 : Classification of the most mature desalination technologies

I.6 Applications of solar PV systems in agriculture

Numerous researchers have studied various applications of solar PV systems in agricultural practices broadly categorized as conventional and modern activities.

I.6.1 PV-powered solar water pumping systems

PV-powered solar water pumping systems are among the most promising solar-powered farm applications, especially at remote locations with no reliable access to grid electricity and cost-effective diesel fuel. These systems are eco-environment with low maintenance and without any fuel costs.

I.6.2 PV-powered desalination systems

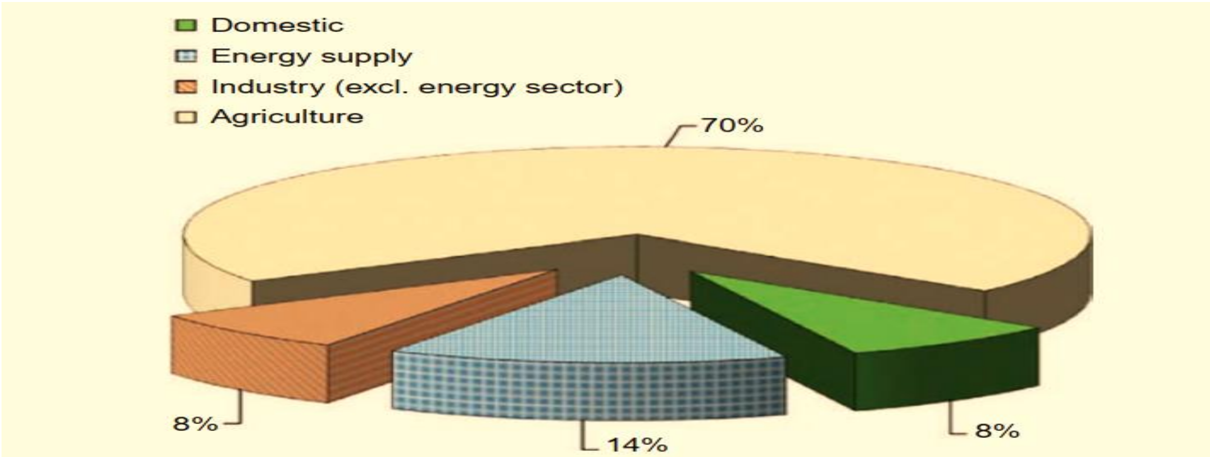


Figure I.15: Global use of freshwater in different sections

Desalination is beneficial to the agricultural industry because it offers an alternative to brackish water for irrigation, decreasing the adverse effects of the direct use of salt water on crop growth and yield due to the negative impacts of salinity on soil properties. Desalination can also remarkably reduce civil works and labor requirements [21]. Due to the accelerated achievements in solar energy technologies (both PV and thermal), there is a strong tendency to integrate solar systems with desalination plants with the goal of improving energy efficiency.

I.7. Solar-powered dryers

Solar drying is one of the most promising technologies among various solar energy applications. Drying can be defined as a mechanism to remove products' moisture involving both heat and mass transfer. Solar drying offers an alternative method for drying agricultural products in a clean and sanitary environment that can reduce crop losses, energy consumption, and drying time in addition to improving the quality of the final products [22]. The basic principle of a solar dryer is shown in Fig I.16.

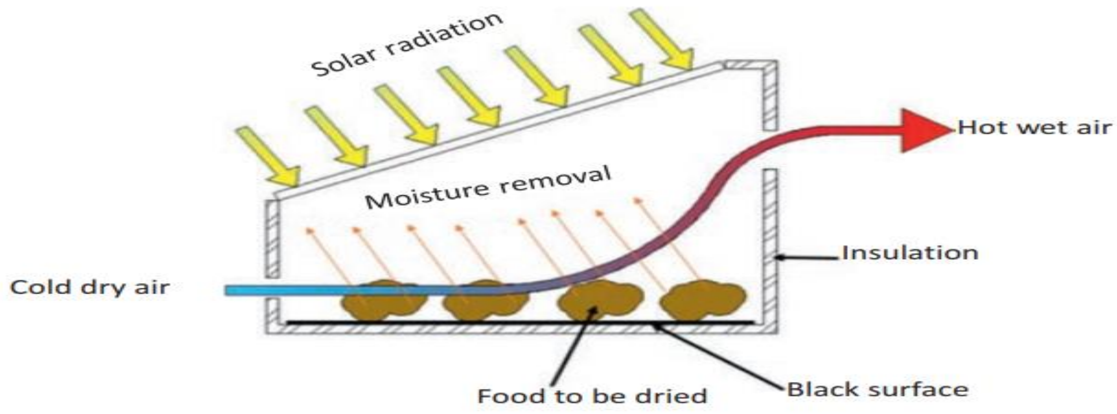


Figure I.16: Working principle of a simple solar dryer

I.7.1 PV-powered solar greenhouses

Greenhouses are one of the most integral centralized elements of modern agricultural systems. They are used to protect crops from harsh weather conditions outside while also offering contamination prevention and pest protection. Additionally, greenhouses bring the possibility of growing specified types of crops such as fruits, vegetables, flowers, herbs, etc., throughout the year [23]. The integration of PV systems with greenhouses has recently received remarkable attention because they have great potential to address the main challenges embedded with the greenhouse sector, including the limitation in arable land availability and the obligation for mitigating GHG emissions.

Until now, integrations of a wide range of various PV module technologies with greenhouses have been studied by researchers, including the integration of them with PV modules [24], PVT modules [25], and concentrating PVT (CPVT) modules [26].

Figure I.17: (A) Solar PV panels mounted as a part of the roofs in commercial greenhouses implemented at Prides Corner Farms, and (B) The PV systems installed close to the greenhouses in Hongxingqiao Town, Changxing County, in east China's Zhejiang Province

I.8. Solar-powered crop protection systems

I.8.1 Solar-powered fencing

One of the favorable techniques due to its practicality is the use of solar-powered prohibitive fencing to the farms to protect them from animals and trespassers [27]. This low-cost technology is based on nonlethal electric shocks, in which the object experiences high-voltage low-current shocks supplied in a pulsating pattern. Solar PV technology is usually implemented in this protective system to provide the main power, especially in remote regions where power network access is limited at the farm location. As shown in Fig I.18, electricity is generated from solar energy via the PV cells and charges the battery. The battery unit stores electric power for operations at night or cloudy days. The converter unit (energizer) is the heart of the system, and produces a different range of voltage pulses depending on the type of animal, fence length, vegetation load, and power source.

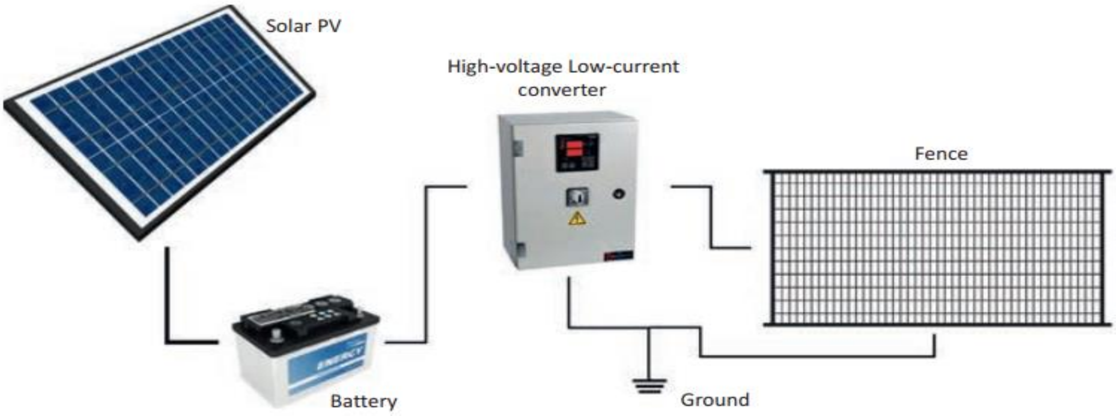


Figure I.18: Schematic view of PV-powered fencing used in farms, adapted from.

I.8.2 Solar-powered bird repelled:

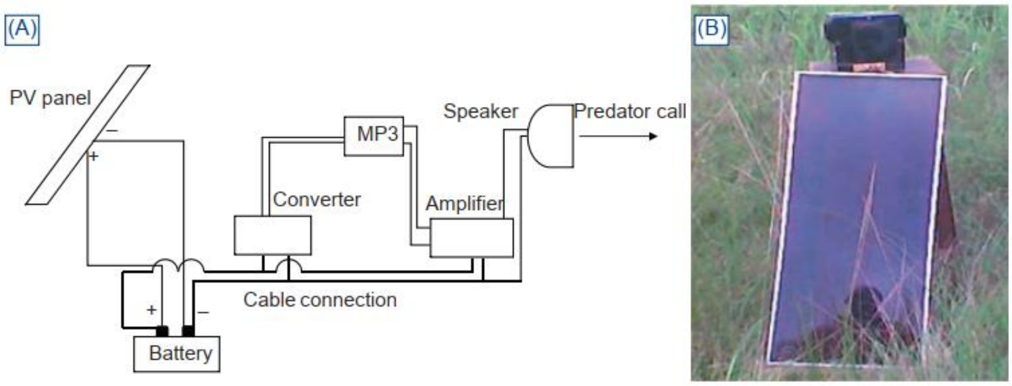


Figure I.19: Solar-powered bird repeller device: (A) Schematic view of an audible model, and (B) photo of an ultrasonic type.

In situations where birds cause significant crop damage, this species becomes detrimental to human beings and must be hampered before any catastrophic crop losses. Different techniques have been tested throughout history to control birds, especially in farms where old methods included scarecrows, hawk kites, colored lights, lasers, flashes, chemicals, etc. [28]. However, recent studies suggest new techniques that implement sounds to make birds uncomfortable and avoid the environment. Therefore, solar-powered bird repellent devices are designed to take advantage of available solar energy to power an electric device that makes distress calls through a speaker and irritates birds to keep farms safe.

I.8.3 Solar-powered light trap:

The growing concern over the extreme use of pesticides for many crops drives public opinion toward other integrated pest-management techniques. The application of solar light traps has become a promising method with significant outcomes in pest control. In addition to remarkable portability, this device promotes smooth operation in any field location and can be used for a vast variety of pests [29]. In a typical design, UV LED bulbs are used as the illumination source to attract insects showing sensitivity to the UV wavelength. Solar panels coupled with a battery unit are mainly incorporated to provide supply power with storage ability for at least 8h.

Figure I.20: Solar-powered light traps: (A) The model (with funnel) used in the Brinjal field, and (B) the model (with electric wire mesh) implemented in a coconut

The main conclusions of the current chapter on the usage of PV technologies in agriculture are summarized below:

- The application of PV technologies in agricultural farms is quite diverse and has tremendous potential for mitigating carbon emissions and bringing further profitability to the business.
- The development of several hybrid technologies brings further innovation and flexibility in the on-farm use of PV technologies, especially PVT systems for dairy farms, water heating, drying, greenhouses, and desalination systems.

• More cost-efficient solutions with cheaper energy storage options are required to further improve the uptake of PV technologies. This should be possible with a unified legislative, political, social, and economic will for a sustainable future.

I.9. Photovoltaic generator

I.9.1 Photovoltaic cells

There are several types of cells which are differentiated by the materials used in their manufacture. Apart from the price, the choice of a type of cell has little importance for the user, the main difference will be the surface which, at equal power, may vary from simple to double [30].

The basic element, used in the construction of PV cells, is in most cases the silicon. This technology constitutes more than 85% of the world market today, including 29% for monocrystalline silicon and 51% for multi-crystalline silicon. Depending on the manufacturing process, will obtain more or less efficient solar cells, in amorphous, polycrystalline or mono form crystalline. Other materials can be used: Gallium Arsenide (GaAs), Cadmium Telluride (CdTe), Indium Gallium Phosphide (InGaP), and Cu (InGa)Se2. The choice among these different technologies depends on price and energy efficiency. Some returns on various existing solar cells are presented below [31]:

- Monocrystalline cells are part of the first generation of solar cells. They have a excellent yield rate of 24.7% in the laboratory (record obtained in 1999). Sun Power sells a cell of the same nature with a good yield which can reach 24.2%.
  However, their production technique is laborious and difficult, and therefore, very expensive. It's necessary large amount of energy to obtain pure crystal.
- Polycrystalline cells have a lower production cost, and using a process less energy-intensive, with a yield of 11 to 15% (19.8% in the laboratory).
  Amorphous cells have a much lower production cost, but unfortunately witha low yield of 5 to 8% (13% in the laboratory). This technology makes it possible to use very thin layers of silicon of only 0.3 to 1.0 micromillimeters (500 ÿ mm for thetwo other types). Amorphous panels need about twice as much areato generate the same amount of energy, and seem to degrade faster. However,they have the advantage of reacting better to scattered light and fluorescent light and of being more efficient at high temperatures.
- Monocrystalline composite cells (AsGa) with an efficiency of 18 to 20% (27.5% in laboratory).

Polycrystalline composite cells (CdS, CdTe, CulnGaSe2, etc.) have an efficiency of8% (16% in the laboratory).

- Amorphous Photovoltaic Modules :Amorphous photovoltaic modules have a much lower production cost, but unfortunately their efficiency is only 6 to 8% currently. This technology allows the use of very thin layers of silicon which are applied to glass, flexible plastic or metal, by a vacuum vaporization process. The efficiency of these panels is lower than that of polycrystalline or monocrystalline technologies. Amorphous silicon, on the other hand, allows the low-cost production of largearea panels with little raw material.

I.9.2 Assembly of PV cells

The photovoltaic cell has an area of approximately 150 cm², generates 2.3 Watt-peak under approximately a voltage of 0.5 Volt [32]. This low power is insufficient for the most domestic or industrial photovoltaic applications. In order to provide the external receiver a high voltage and power, several photovoltaic cells must be connected to each other, to constitute what is called: "a module". Modules can be assembled in series and/or in parallel to form panels (Figure I.21), they even interconnected to make a photovoltaic field.

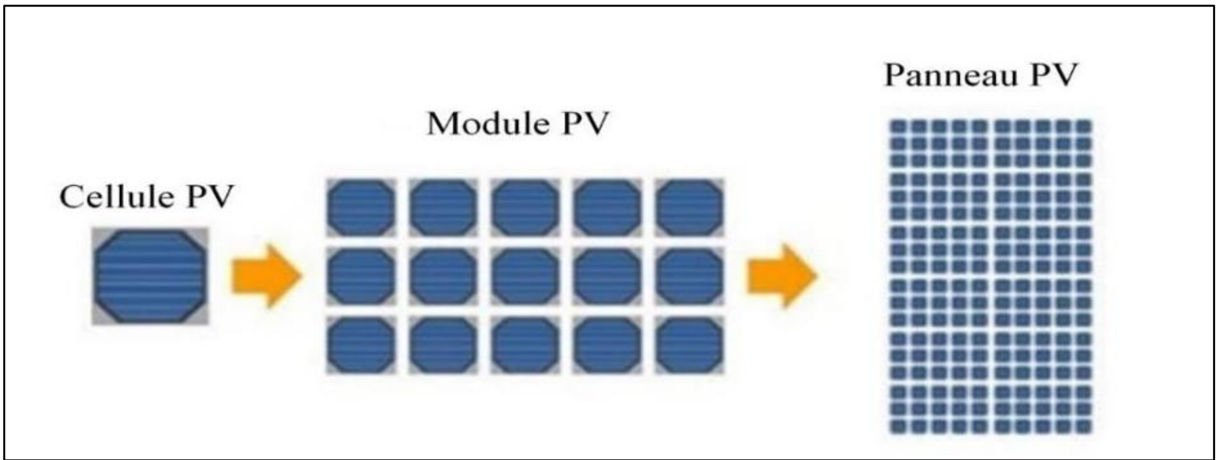


Figure I.21: Constitution of a photovoltaic generator.

I.9.3 Protection of solar panels

To go from a module to a panel, it is necessary to add protection diodes (Figure I.22). For show the usefulness of protection diodes, there are two types of PV cell assembly:

parallel and series. In a parallel array, the cells are subjected to the same voltage and the currents add up. Under unfavorable conditions (non-uniform illumination and circuit open), a weak cell can be traversed in reverse by the current generated by the other cells and thus dissipate significant power and be destroyed. To avoid this problem, add a diode in series which prevents any reverse current.

On the other hand, in a series grouping, the current is constant and the voltages are added. In certain conditions of non-uniform illumination and operation close to short-circuit, a cell can be subjected to the voltage of the other cells applied in reverse and thus operate in receiver by dissipating a significant power and be destroyed if the thermal stress is too strong or if the avalanche voltage is exceeded. To avoid this effect, a diode must be put in parallel, across the terminals of an elementary assembly of 30 to 40 silicon cells at most.

Spontaneous triggering of this parallel diode, as soon as a reverse voltage appears across the terminals of the group limits the latter to the voltage of the diode and thus the dissipated energy [33].

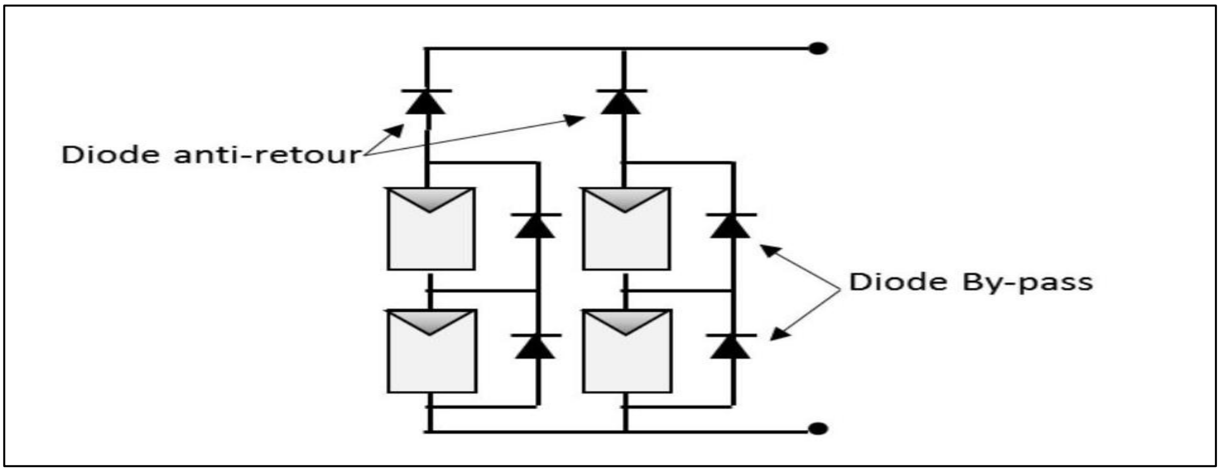


Figure I.22: Module protection diodes

I.10 Conclusion

This chapter contains all the details of renewable energy sources, solar radiation, and a description of photovoltaic elements and their applications in various fields.

Through this study, we show the importance of solar energy for food security through its applications in agriculture and water desalination, as well as energy security through the adoption of clean and sustainable energy.

On the other hand, we describe many types of photovoltaic cells, their components, and how to collect and protect solar panels

Chapter II:

Power converters for PV system

II.1. Introduction

The raw DC voltage from the solar panels is converted to a regulated DC voltage using a boost converter and a large capacitor (converter), and then the DC output is converted to AC using an inverter bridge (inverter). The ratio between the load current and the short circuit current of the photovoltaic array at the point of maximum power is approximately constant for different levels of saturation (light) and this property is used in the design of a simple point tracking controller of maximum power (MPPT).

In this chapter, the DC/DC boost converter will be modelled to be used as the tools to achieve the MPPT in the solar panel. Several MPPT techniques in literature, but in this chapter, P&O algorithm and Conductance increment algorithm were presented, then modelling and simulation of converted DC/DC Boost were developed to be used as tools to implement MPPT in Simulink in the next chapter.

II.2 Characteristics of photovoltaic panel

A solar cell is a fundamental device for conversion of photon energy into pollution-free electricity if this device is connected in series and parallel fashion than PV module is formed. Further to build PV arrays these modules are coupled in series and parallel arrangement which are responsible to generate clean and green electricity. A single solar cell can be represented as a component of an electrical circuit. It contains a p–n junction called as a diode, a photocurrent generator represented a generation of current from light and two resistors, one is arranged in series and another one is in parallel which described the Joule effect and recombination losses. Then this combination is called as a single diode solar cell model. For modelling of a solar PV module same methodology is adopted as described for a solar cell. The simplified circuit model of a solar panel is illustrated in Figure II.1.

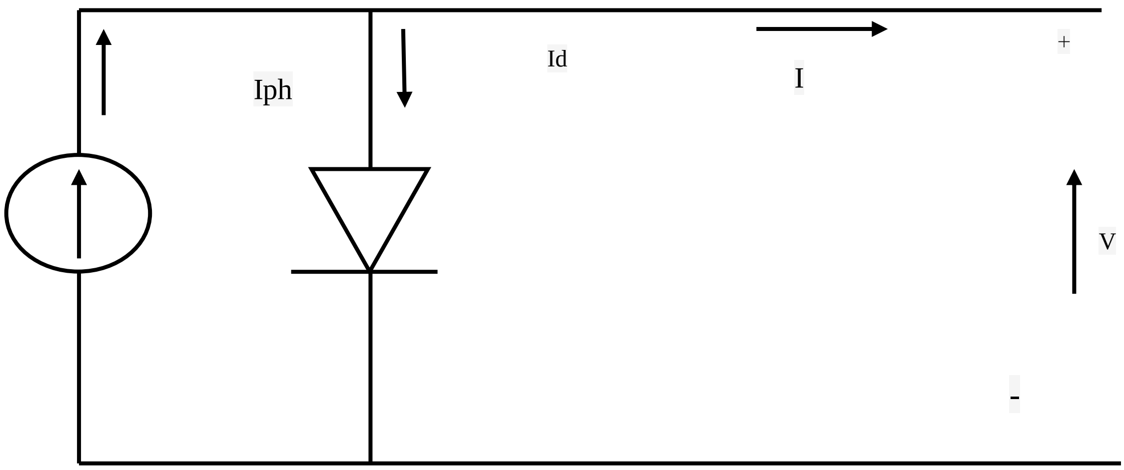


Figure II.1: Simplified equivalent circuit of PV panel.

In ideal case solar cell provides a very good approximation to photon generated current which is directly proportional to illumination intensity and irradiance. There are some parameters which are not taken into consideration in ideal case model and that actually affect the output of a PV device in real or practical cases In the next subsection here presents the single diode modified model for the real case. 3.2. Mathematical model of a PV cell (real/practical cell case) A more realistic circuit model of solar PV cell is illustrated in Figure II.4. This is also identified as real single diode model with series resistance (R_s) and parallel resistance (R_p). Ideally R_s and R_p are ignored but in reality it is not possible to overlook these resistances, because efficiency of the PV solar cell is affected by these parameters So the appropriate model is represented in Figure II.2.

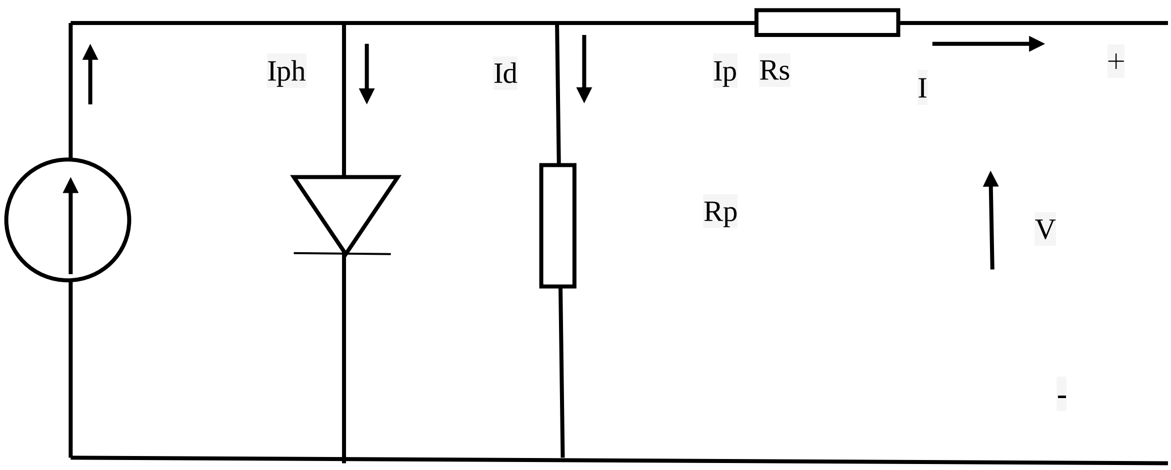


Figure II.2: Equivalent circuit of real model for PV panel

As shown in Figure**,(**1**)**, the solar PV device can be represented as an ideal solar cell with a current so urce (Iph) parallel to the diode, and the output current of an ideal solar cell is defined in Eq (1).

$$I = Iph - Id \qquad \text{II.(1)}$$

The essential mathematical equation that defines the I–V properties of the PV solar cell, known as Shockley's diode current equation, is derived from semiconductor theory in Eq. (2).

$$Id = Is\left[\exp\left(\frac{qVoc}{NsKATo}\right) - 1\right] \qquad \text{II.(2)}$$

The output current I of an ideal solar cell is produced by plugging the value of the Id into Eq. (1) and (3).

$$I = Iph - Is\left[\exp\left(\frac{qVoc}{NsKATo}\right) - 1\right] \qquad \text{II.(3)}$$

When a high number of PV modules are used in a solar photovoltaic system, the influence of R_p becomes apparent. As a result, R_s is taken into account, and R_p is assumed to be limitless.The diode current Eq. (2) is then changed to Eq. (3). (4).

$$Id = Is\ \left[\exp\ \left(\frac{q(V + IRs)}{NsKATo}\right) - 1\right] \qquad II.(4)$$

$$I = Iph - Is\ \left[\exp - \left(\frac{(q(V + IRs)}{NsKATo}\right)\ 1\right] \qquad II.(5)$$

Considering PV cells that are connected in a series–parallel configuration Eq. (5) can be changed if the output current I is computed**.**and is shown as follows in Eq. (6).

$$I = Np *Iph - Np * Is\left[\exp\ \left(\frac{q(V + IRs)}{NsKATo}\right) - 1\right] \qquad II.(6)$$

$$Iph = [Isc + Ki(To - Tr)] *\frac{G}{Gref} \qquad II.(7)$$

There are various parameters that need to be determined for PV cell modelling using the above-mentioned equations. modelling, which is dependent on the PV module model used Bellini and colleagues (Bellini et al., 2009). This model necessitates that we follows in Eq (8) and(9).

$$Irs = Isc/\left[\exp\left(\frac{qVoc}{NsKATo}\right) - 1\right] \qquad II.(8)$$

$$Is = Irs\ [\ To/Tr]3\exp\left[\left(\frac{qEg}{AK}\right)\left(\frac{1}{Tr} - \frac{1}{To}\right)\right] \qquad II.(9)$$

Results of characteristics of a photovoltaic system:

Figure II.3: Create a temperature conversion model for use in the field. Temperature is an input parameter in solar PV systems in degrees Celsius; however the temperature used in mathematical formulas for PV modeling is in Kelvin, thus all temperature data must be in Kelvin.

To be calculated in Kelvin, as shown in Figure II.5 and to serve as modelling of solar PV as a subsystem

Figure II.4: Develop a product model during the PV Module's mathematical modelling, as explained, the N_sKAT_o in Eqs. (3) to (8) is shown in the previous section.

The operating temperature is measured in Kelvin. As a result, a product model is required. Simulink is used to calculate and use the value of NsKATo. In the final PV model as a subsystem. The product model is shown in Figure II.6. PV photocurrent model.

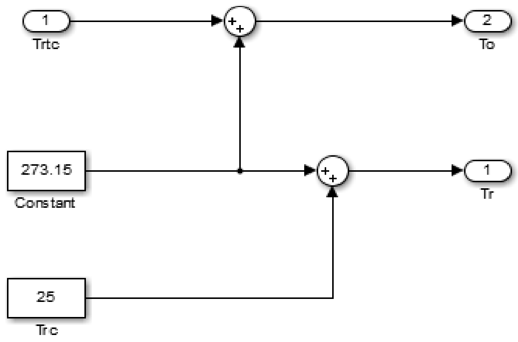


Figure II.3 : Operating Temperature conversion model

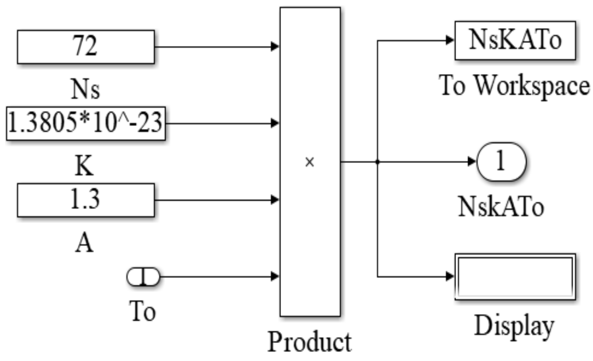


Figure II.4: Product model of NsKATo

Figure II.5:

PV photocurrent model PV photocurrent modeling is built utilizing Simulink's Eq. (7) as a subsystem in solar PV modeling. The photocurrent is affected by the sun irradiation and behaves linearly. The operating temperature. The detailed implementation of I_{ph} in the Simulink environment, including subsystems and environmental effects. As input parameters, solar irradiance (G) and temperature (To) are used. as seen in Figure II.5.

Figure II.6: PV reverse saturation current mode the reverse saturation current model is shown in Figure.II.6 In the Simulink environment, use Eq. (8). Additionally, data about the manufacturing process the model is created using sheet parameters.

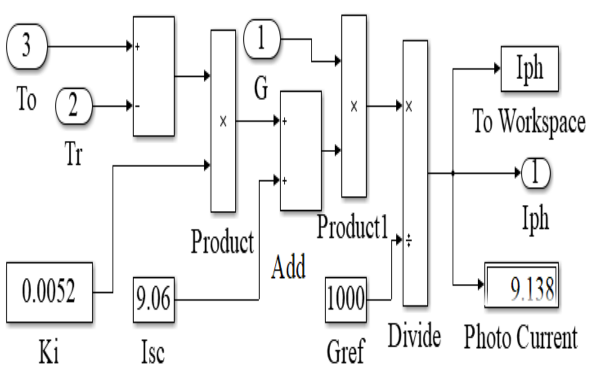


Figure II.5: Photo_current model

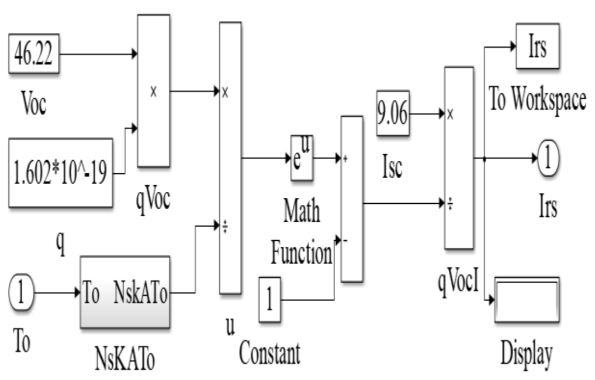


Figure II.6: Reverse saturation current model

Figure II.7**:**

PV saturation current model Eq. (9) depicts the saturation current (Is), which fluctuates with cell temper ature, and the Simulink environment is used to create a model for it.

The energy bandgap, electron charge, reference temperature, and operating temperature of the module ar e used as inputs, together with the reverse saturation current subsystem model illustrated in Figure 6. The saturation current is calculated using the simulation model illustrated in Figure II.9.

Figure II.8:

Current PV output model In Simulink, the output current supplied by Eq(6)is created as shown in Figure .8. This Simulink model can be used to explore the output current in relation to the voltage, which is aff ected by irradiance and temperature.

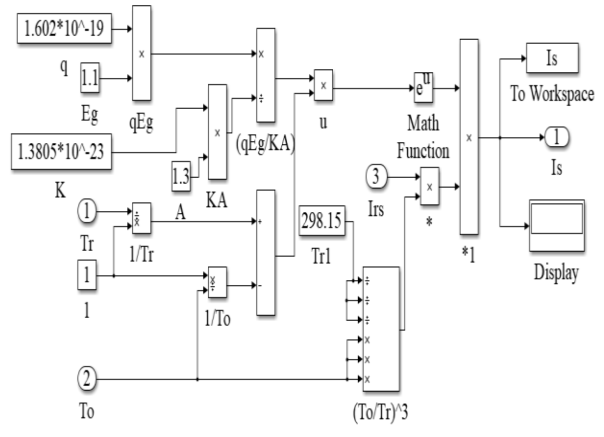


Figure II.7: saturation curent model

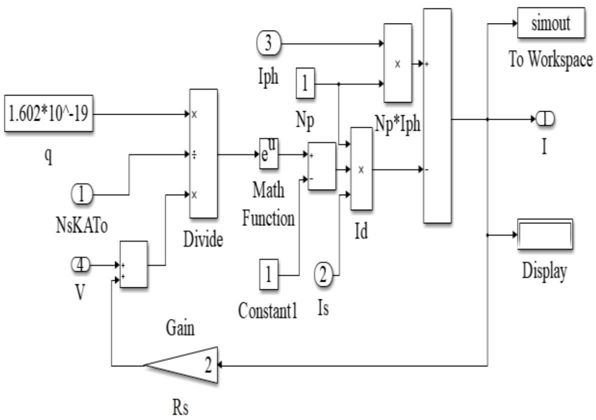


Figure II.8: PV output current model

Figure II.9: Linked model as illustrated in Figure II.9, the complete subsystem model produced in the Simulink environment from step 1 to step 6 was linked together and established a linked model.

Figure II.10

Final PV module model the final PV solar module model is constructed in the Simulink environment as shown in Figure II.10, with input parameters of irradiance G and temperature T and output values of current I and voltage V

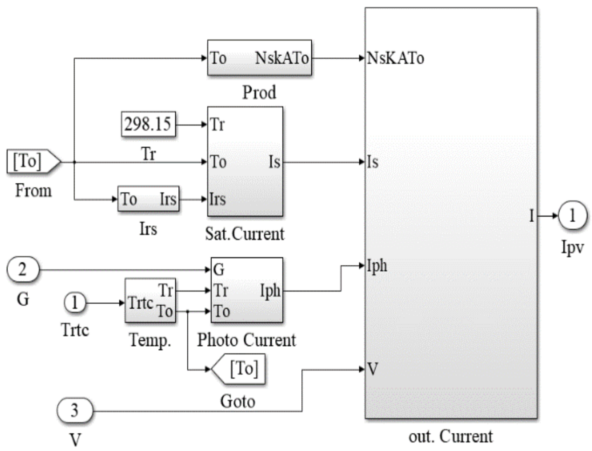


Figure II.9: Linked model of subsystems

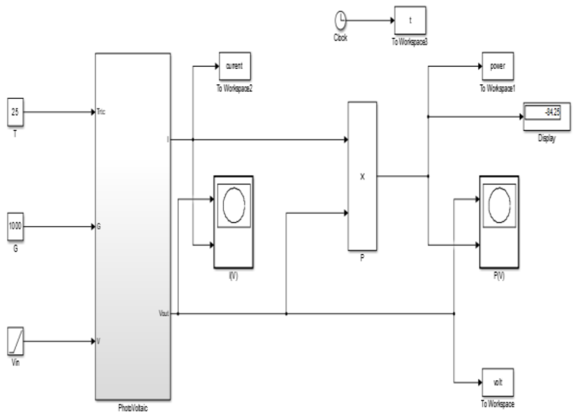


Figure II.10: PV module modelling in MATLAB/Simulink

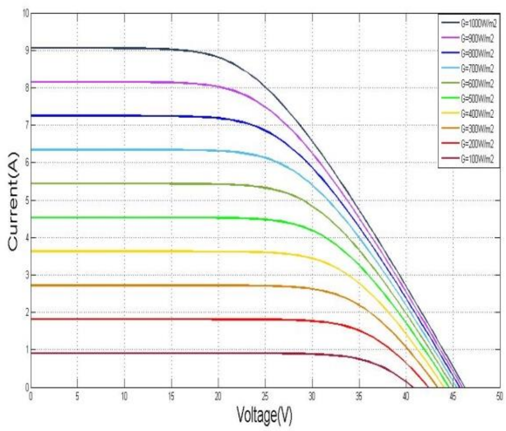


Figure II.11: I_V characteristics, varying irradiance at constant temperature

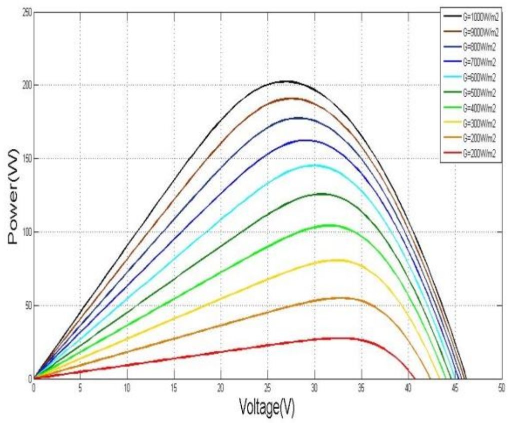


Figure II.12: P_V characteristics , varying irradiance at constant temperature

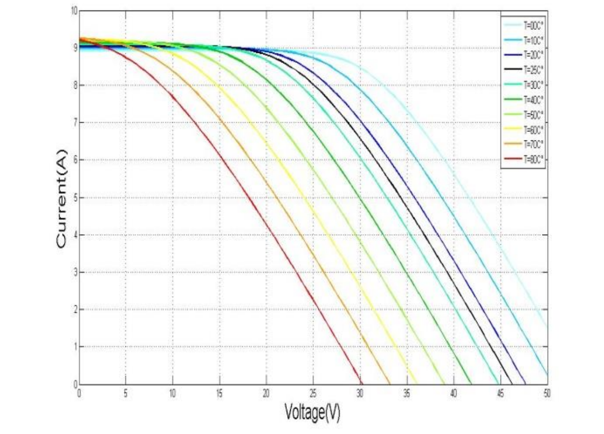


Figure II.13: I_V characteristics, varying temperature at constant solar radiation

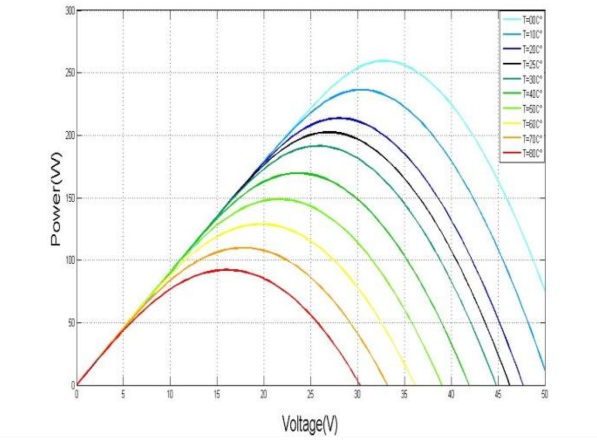


Figure II.14: P_V characteristics, varying temperature at constant solar radiation

The behaviour of the PV module is very sensitive to variations in irradiance (G), and temperature (T) because these variations have a significant effect on the power supplied by the module.

Figure II.11 shows that for a constant temperature of 25°C, the current I_{PV} and the voltage vary according to the voltage V_{PV} for different values of illumination and there are several curves P(V) which correspond to the Points of Maximum Power MPP (V_{mp}, I_{mp}). According to Figure II.12. a voltage of open circuit also current short circuit I_{sc} varies proportionally to the illumination[34].

Figure II.13 shows that if the illumination is constant (1000 W/m2) and the temperature increases, the voltage V_{oc} decreases but the current I_{sc} may a little vary. So, the operation of the PV module depends essentially on the environmental conditions to which it is subjected. [35]. To this end, these factors must be taken into consideration to correctly size the PV generator which will make it possible to obtain the desired power [34].

Irradiance effects on PV solar module the effect on solar PV model I–V and P–V characteristics curves are depicted in Figure II.11 and Figure II.12 by varying the intensity of irradiance from 100 W/m2to 1000 W/m2at constant temperature of 25 o C.

It is observed that current remains constant with rising voltage up to 30 V after which it decreases. Moreover, the current increases while rising the irradiance intensity. This demonstrates that irradiance has a substantial effect on short circuit current, at the same time open circuit voltage is quite low as shown in Figure II.11. The maximum power evidence exists on power performance curves.

We notice from this figure and when the temperature changes from 0 to 80 o C that as the temperature increases, the power[W] decreases with the change in [V].

II.3- MPPT techniques of Photovoltaic solar:

The charge regulator is made up of a high-efficiency switching DC/DC converter which performs three functions: Detection of the maximum power of the photovoltaic field as long as the battery is not charged. - DC/DC conversion. - Regulation of the output voltage according to the charging phase (Bulk, Absorption and Floating). To know The DC/DC converter is used as a voltage step-down device. This means that the MPP voltage of the photovoltaic generator must always be higher than the battery voltage. The solar field is connected to the input of the regulator and the battery to its output. When the battery voltage is lower than the regulation voltage, the regulator operates the photovoltaic generator at maximum power Pmpp and transfers this power to the output. By design, the MPPT regulator allows a production gain of 5 to 30% compared to a PWM regulator. This gain will increasing winter and during periods of low sunlight. The MPPT charge controller allows greater flexibility in the choice of panels. Indeed, all types of photovoltaic module can be used as long as one remains within the voltage (V) and current (A) tolerances of the regulator [36].

Maximum power point tracking (MPPT) is an algorithm implemented in photovoltaic (PV) inverters to continuously adjust the observed impedance on the solar array so that it continues to operate at its peak power point (all most) under varying conditions, such as with changes in solar irradiance, temperature and load. Engineers developing inverters implement MPPT algorithms to maximize the power generated by PV systems. The algorithms control the voltage to ensure the system operates at its "maximum power point" (or peak voltage) on a voltage/power curve, as shown below. MPPT algorithms are usually encountered in controllers for PV systems. The algorithms take into account factors such as variations in irradiance (sunlight) and temperature to ensure that the PV system consistently generates maximum power.

II.3.1.Disturbance and Observe (P&O):

The principle of P&O type MPPT commands consists in disturbing the voltage of a low amplitude around its initial value and to analyse the behaviour of the resulting power variation Thus, as shown in (see Figure II.16), one can deduce that if a positive increment of the voltage generates an increase in power, this means that the operating point is to the left of the PPM [37]. If, on the contrary, the power decreases, this implies that the system has exceeded the PPM a similar reasoning can be made as the voltage decreases. From these various analyzes on the consequences of a voltage variation on the characteristic),t is then easy to locate the operating point with respect to the PPM, and to make the latter converge towards the maximum power through a control order.

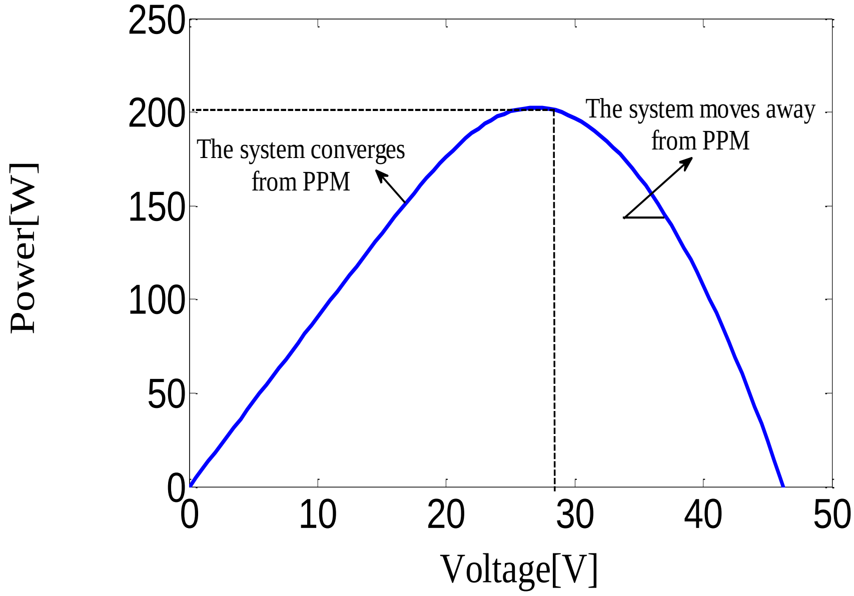


Figure II.15: Diagram of convergence towards the PPM by P&O

This algorithm perturbs the operating voltage to ensure maximum power. Even though there are many advanced and more optimized variants of this algorithm, below is a basic MPPT P&O algorithm.

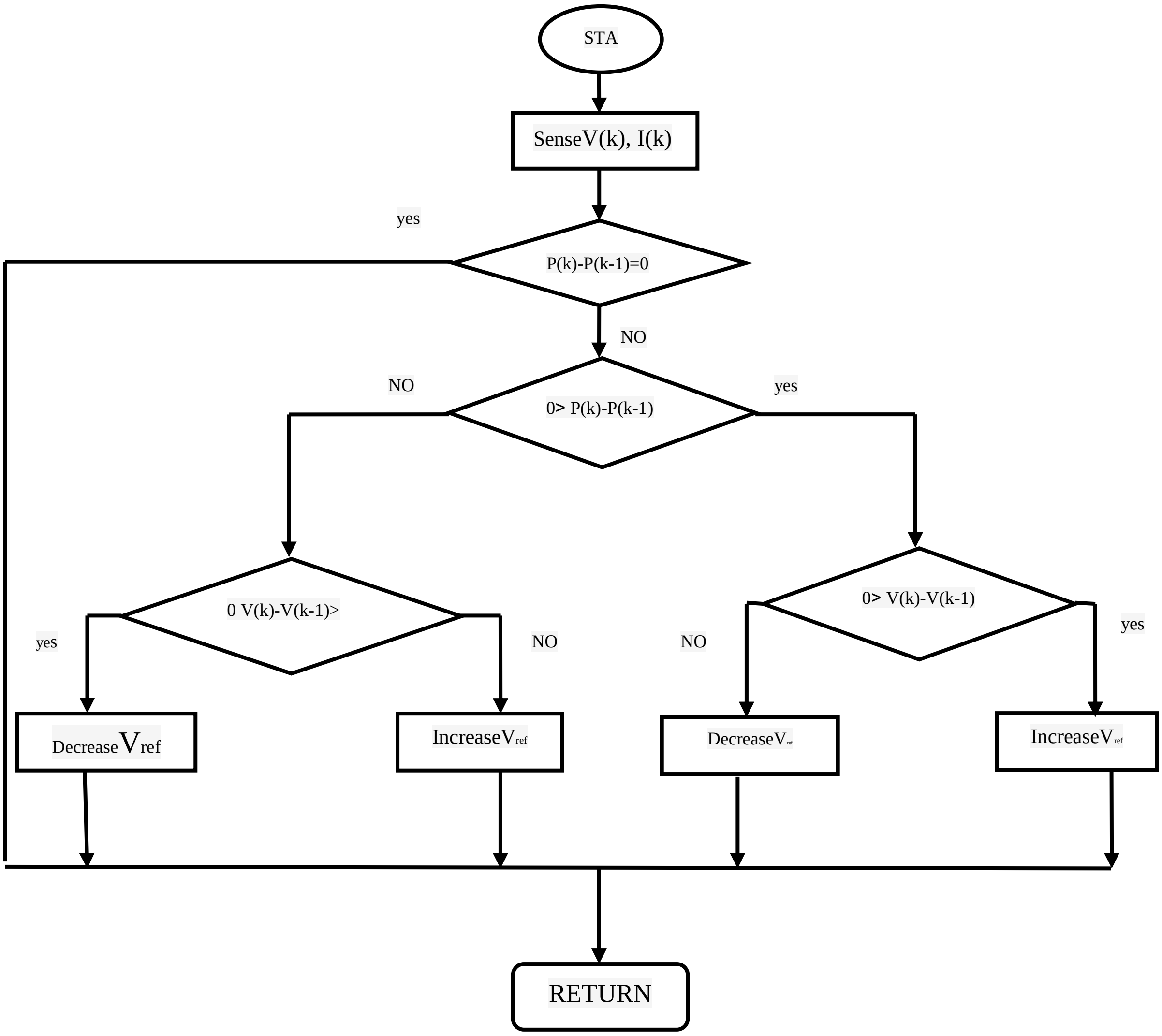


Figure II.16: Basic MPPT P&O algorithm

II.3.2.Conductance increment:

This technique is based on knowledge of the change in GPV conductance and knowledge of the position of the operating point in relation to a ppm [38][39][40], thus the module conductance photovoltaic is defined by the ratio between current and the voltage of the GPV as shown below:

$G=\frac{I_{pv}}{V_{pv}}$

The evolution of the power of the module (P_{pv}) in relation to voltage (V_{pv}) gives the position of the function relative to ppm. When the derivative of power is zero, this means that one is on the ppm, if it is positive the point is to the left of the maximum, when it is negative, you are on the right.

if $\frac{\mathrm{dP}_{pv}}{dV_{pv}} > 0$,Pf to the left PPM

The link between conductance and the derivative of the power $\frac{\mathrm{dP}_{pv}}{dV_{pv}}$ can be described by the equation following:

$$\frac{\mathrm{dP}_{pv}}{dV_{pv}} \frac{d(I_{pv}.V_{PV})}{dV_{pv}} = \mathrm{I}_{pv} + V_{pv}\frac{\mathrm{dI}_{pv}}{dV_{pv}} \backsimeq \mathrm{I}_{pv} + V_{pv}\frac{\mathrm{dI}_{pv}}{dV_{pv}}$$

From where, we can then write new conditions on the conductance variation:

if $\frac{\mathrm{dI}_{pv}}{dV_{pv}} > - \frac{\mathrm{I_{pv}}}{V_{pv}}$,the Pf is left of the PPM

if $\frac{\mathrm{dI}_{pv}}{dV_{pv}} =- \frac{\mathrm{I_{pv}}}{V_{pv}}$,the Pf on the PPM

if $\frac{\mathrm{dI}_{pv}}{dV_{pv}} < - \frac{\mathrm{I_{pv}}}{V_{pv}}$,the Pf is right of the PPM

The maximum power can then be tracked by making comparisons at each instant of the conductance value ($\frac{\mathrm{dI}_{pv}}{dV_{pv}}$) as illustrious the algorithm of figure (8).

V_r Corresponds to the reference voltage and forces the GPV to operate at this value. If we are at the PPM, then the voltage V_r corresponds to the optimum tension V_{opt} Once the PPM has been reached, the operating point can be maintained at this position until a change in temperature is detected.

$\Delta\ I_{\mathrm{pv}}$This then indicates a change in climatic conditions, therefore a new PPM to be sought. For this the algorithm increments or decrements the value of V_r until reaching the PPM [41] the block diagram of this method is illustrated in figure (8).

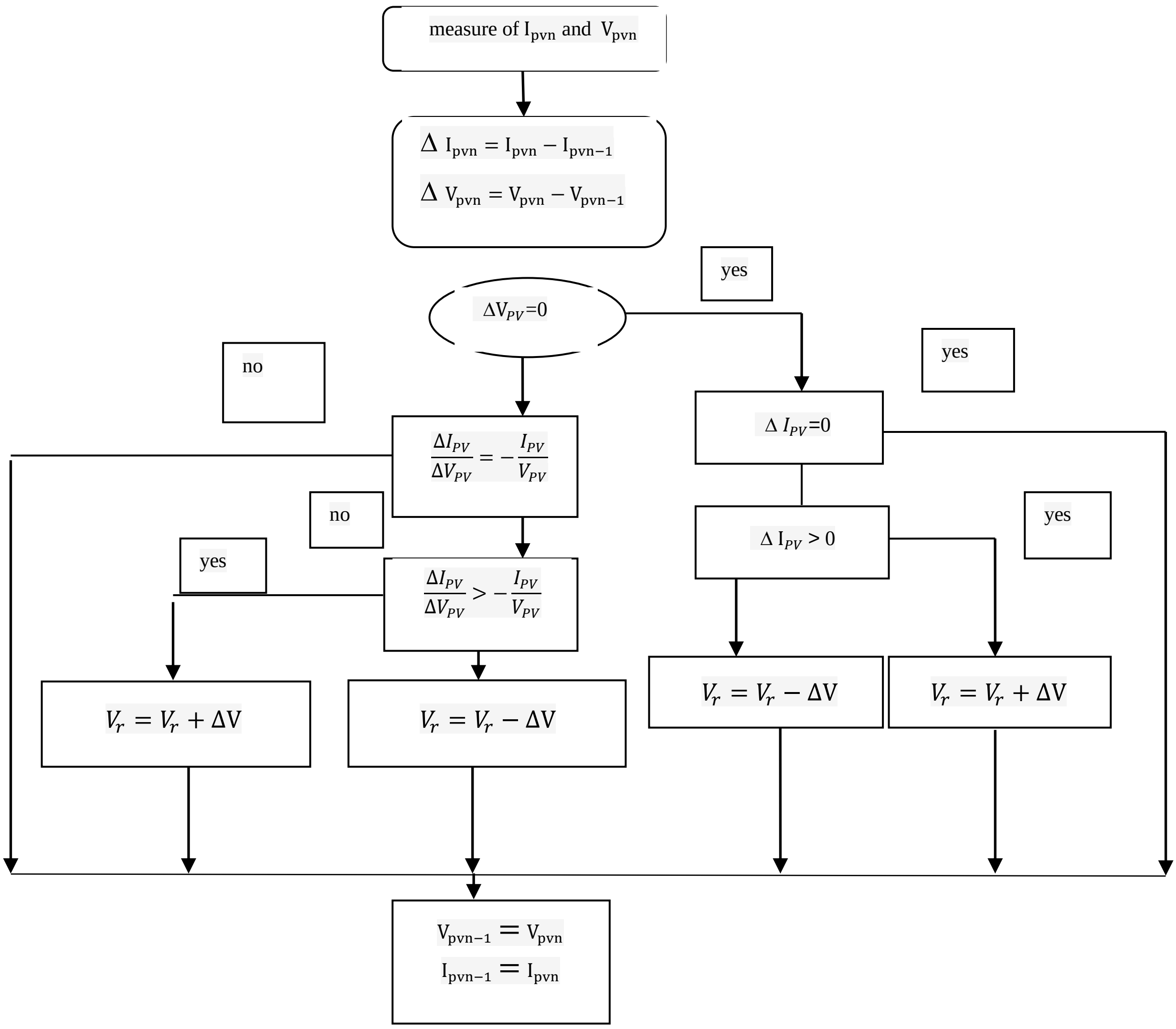


Figure II.17: Conductance increment command algorithm

II.4.Modeling and simulation of boost coverer DC/DC

Operating principle of the Boost converter

The main application of the boost converter is the regulation food. The output voltage is higher than the input voltage. When the switch is closed, the diode D is blocked, so the stage of output is isolated. When the switch is open, the output voltage receives the energy of the inductor as well as the input. In equilibrium state analyses presented here, the output filter capacitor is assumed to be very important to ensure a constant output voltageu0 (t) ≈ U0. The Boost converter is analysed in the steady state, all parameter current, voltage and duty cycle are dc values. The switches are ideal, and the losses in the elements inductive and capacitive are neglected. The DC input voltage of the converter is assumed to have zero internal impedance , it could be a source of battery. A simplified diagram of the Boost converter is shown in Figure II.19. It consists of a power MOSFET as a switch denoted by Q_s, a diode D, an inductor L, a filter capacitor C and the load resistance R charge. A DC input source un provided power to the converter and u0 represents the output voltage. The switch is turned on and off at the switching frequency fs = 1/T with the duty cycle D = ton/T, where ton is the interval of time during which the switch is in the closed on state. The resistance of load R charge requires a stable supply voltage greater than the input voltage u in, while V_p is the control signal of the Mosfet of Power full. More precisely V_p is of a square waveform. During the power-up phase (V_p, which is high level), Q_s is closed when diode D is blocked. Then the inductance current increases with time as the current charge comes from the capacitor C. The duration of this phase is defined by T_1; when V_p goes low, the circuit enters the power-down phase. Q_s is open, the current of inductance which cannot be changed abruptly is transferred to the output through diode D which must be on, part of this current is restored in the capacitor, while the rest passes through the load R charge The duration of this phase is T_2 Depending on the control laws and the values of the components, the inductor current can reach zero, thus entering the wheel phase free in which the Mosfet Q_s and the diod D are reached and the current of the charge is supplied only by the capacitor. The period of this phase is defined by T_3. Depending on the presence or absence of the third phase the circuit works in continuous or discontinuous mode respectively.

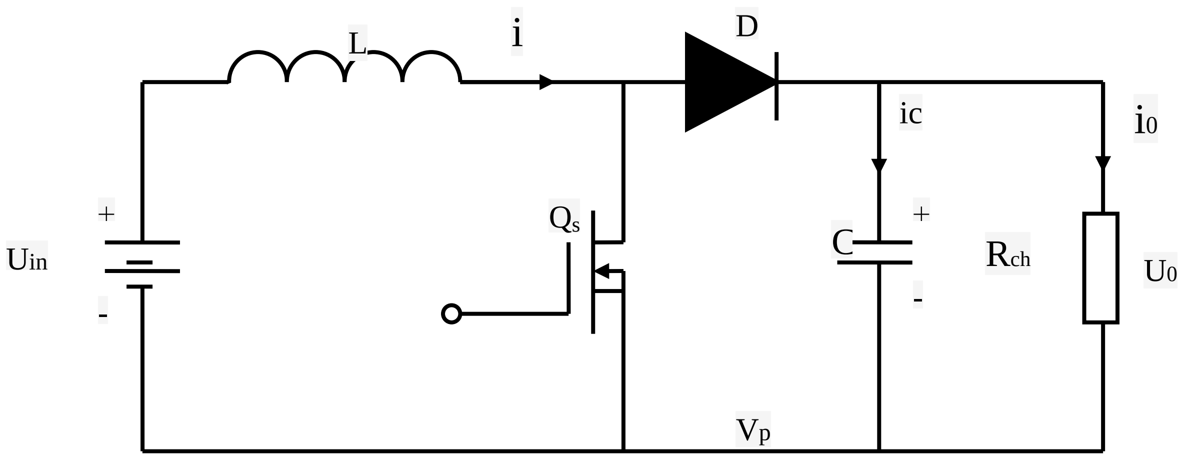


Figure II.18: Simplified diagram of the Boost converter.

There are a variety of possible DC-DC converters, but in the list of converters, only the first three converters need be described, which are basically non-isolated input output terminals [42].

New technology electronic devices must meet certain criteria such as high quality, reliability, size, weight and low cost. Linear power regulators, whose operating principle is based on a current or voltage divider, can provide a very high-quality output voltage. However, this type of regulators remains inefficient because their main field of application is at low power levels.

Switching regulators called DC/DC converters use electronic switches, based on semiconductors such as: thyristor, power transistor or IGBT, etc., because they generate a low power loss when switching d one state to another. These converters provide high energy conversion efficiencies and can operate at high frequencies. The dynamic characteristics of DC/DC converters improve with increasing operating frequencies. High operating frequencies the refore allow for faster dynamic response to rapid changes in load current or input voltage

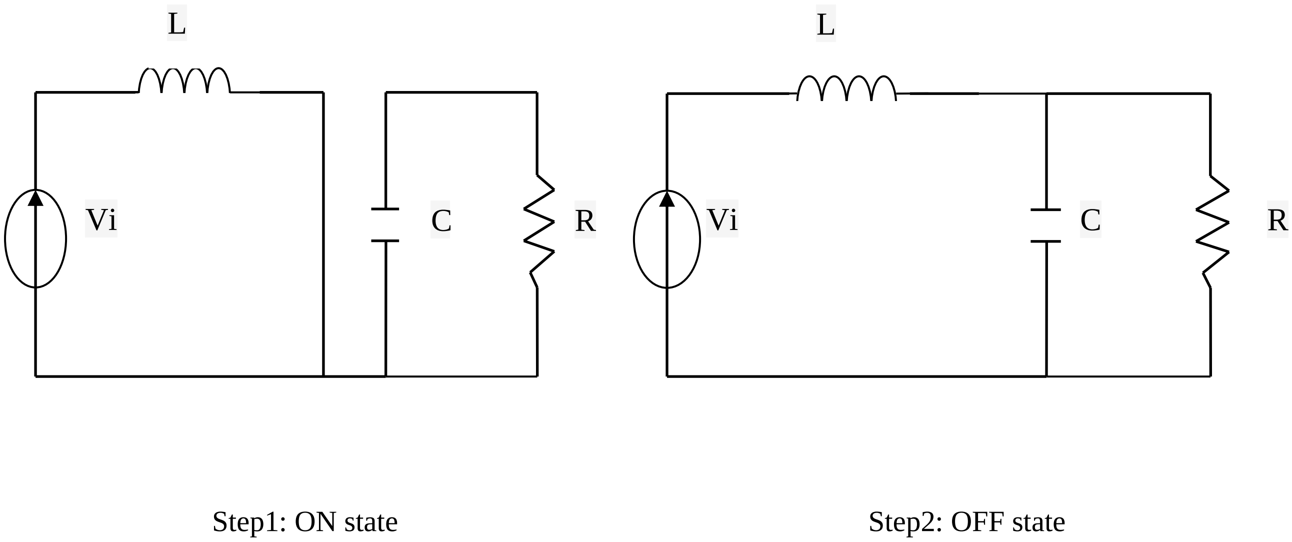


Figure II.19: Operation modes of boost converter

In the boost converter, semiconductor switch is turned ON and OFF during a switching period. Two different operation modes occur in a switching period as seen in Figure II.21. The ON state topology that the controlled switch is closed, in this mode, input voltage is applied to inductor directly, and inductor current increases. Inductor voltage and current equations are given in (10). Output capacitor feeds the load and discharges, simultaneously while inductor stores energy. The equations of the capacitor seen in (11). The second mode that switch is OFF in, in this mode, the energy stored in the inductor is transferred to the output so the inductor current decreases. The load is fed, and the capacitor charges. The equations of the mode are seen in (12) and (13). The differential equations depending on the switching function (S) obtained by combining differential equations in (10)-(13). The mathematical model can be applied in Simulink by (14) and (15). In the equations, S function takes value 0 and 1

$$\left.\begin{matrix} v_L = v_i \\ \frac{di_L}{dt} = \frac{v_i}{L} \end{matrix}\right\} \mathbf{S = 1} \qquad \text{(II.10)}$$

$$\left.\begin{matrix} i_c = -\frac{v_0}{R} \\ \frac{dv_0}{dt} = -\frac{v_0}{RC} \end{matrix}\right\} \mathbf{S = 1} \qquad \text{(II.11)}$$

$$\left.\begin{matrix} v_L = v_i - v_0 \\ \frac{di_L}{dt} = \frac{vi - v_0}{L} \end{matrix}\right\} \mathbf{S = 0} \qquad \text{(II.12)}$$

$$\left.\begin{matrix} i_c = i_L - \frac{v_0}{R} \\ \frac{dv_0}{dt} = \frac{i_L}{C} - \frac{v_0}{RC} \end{matrix}\right\} S = 0 \qquad \text{(II.13)}$$

$$\frac{di_L}{dt} = \frac{vi - v_0(1-S)}{L} \qquad \text{(II.14)}$$

$$\frac{dv_0}{dt} = \frac{i_L(1-S)}{C} = \frac{v_0}{RC} \qquad \text{(II.15)}$$

Simulation and results of boost converter

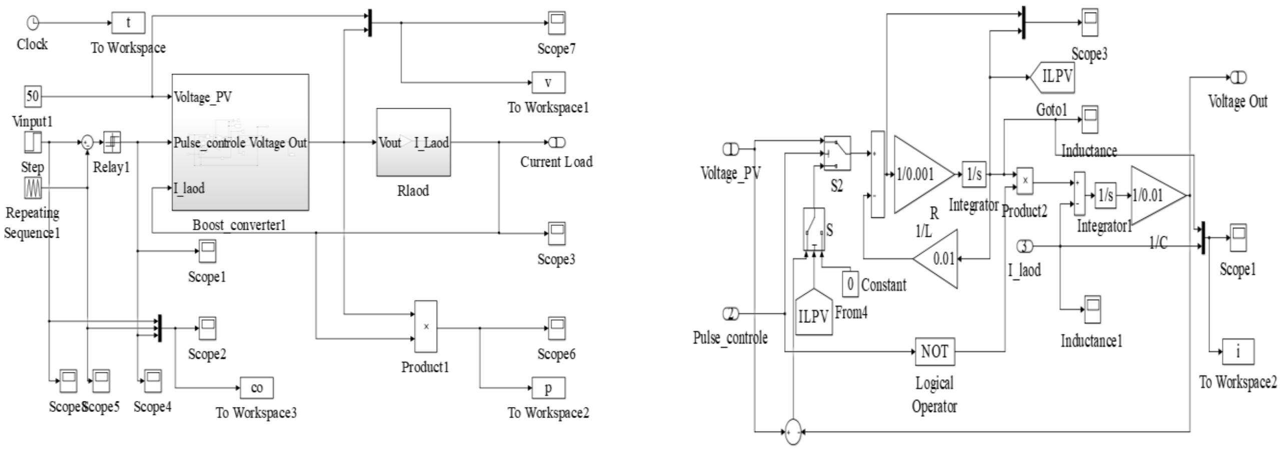


Figure II.20: Simulation of Boost Converter

Figure II.20, presents a simulation of the boost converter based on the previously shown mathematical model and its results are as follows.

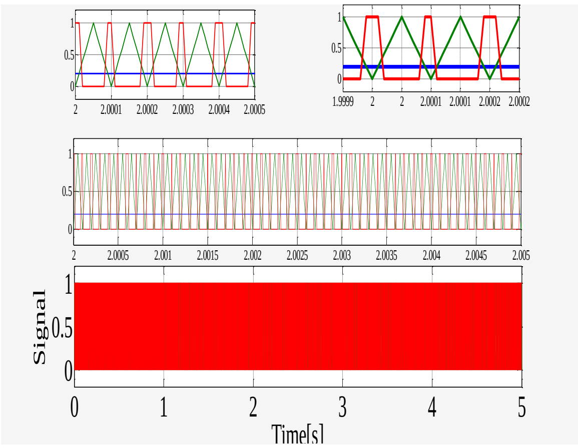


Figure II.21: PWM for Boost converter

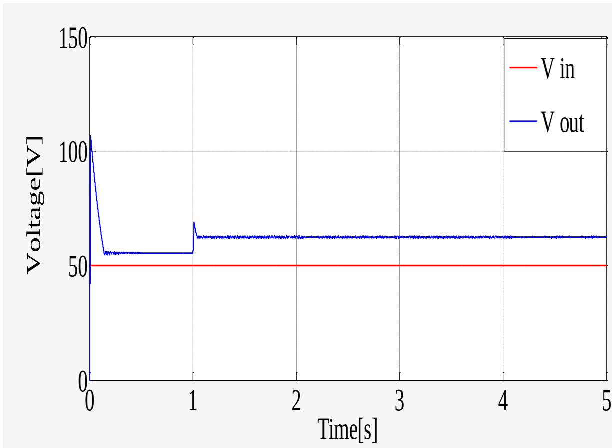


Figure II.22: Voltage input and out Boost converter Voltage

We have Figure II.21, that PWM is produced after comparing repeating sequence reference value. In Figure II.22, we notice at time 0 (S) that the input[v] is equal to 50 [v] and the output is greater than 50 [v]. This is because it is a boost converter.

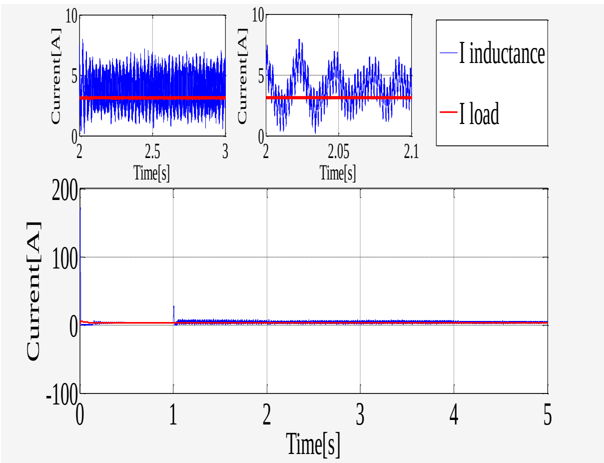


Figure II.23: Current of Load and current of inductance

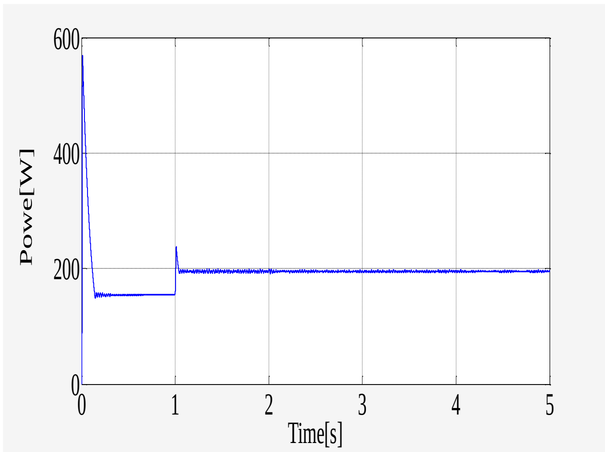


Figure II.24: Power of boost converter

In Figure II.23, we notice that I load is constant and I inductance is variable and this is due to charging and discharging. In Figure II.24, we notice that at moment 1 (s) the value of power increases, this is due to the increase in PWM.

II.5. Conclusion

The characteristics of the photovoltaic system have a highly non-linear behaviour. Therefore, maximum power point trackers (MPPT) play an important role in extracting energy from photovoltaic (PV) arrays as they draw the maximum output power (MPP) available regardless of continuous changes in temperature and irradiation conditions. Therefore, the DC-DC boost converter amplifies the generated DC voltage for use as tools in MPPT of the photovoltaic system. In this chapter, the MPPT algorithms of Perturb and Observe (P&O) and the conductance increment algorithm were presented in order to implement them in the next chapter. Then, modelling and simulation of the DC/DC boost were carried out where the results validate the model used.

Chapter III:

Photovoltaic system associated with inverter

III.1.Introduction

In this chapter , the modeling of the three-phase inverter and the boost DC/DC converter has been developed, then the association of the boost converter with the inverter will be carried out after voltage control by PWM techniques. Next, we will associate the photovoltaic system with the MPPT using the converted DC/DC boost. Otherwise, the MPPT of the photovoltaic system is connected to the inverter where it regulates the power of the solar panel and to the inverter where it regulates the power of the solar panel and is converted from DC to AC by the inverter, in the last part of this chapter, we have simulated an MPPT system with solar PV panel connected to DC/AC inverter.

Finally, the associated control effectiveness for the PV system will be approved based on the simulation results.

III.2. Modeling of three phases inverter :

Inverters are circuits that convert DC to AC, more precisely; inverters transfer power from a DC source to an AC load [43]. Basically, in single phase inverter, it happened by switching the two switches, and in three-phase inverters it happened by sequence of switching the switches in each leg of the full-bridge.

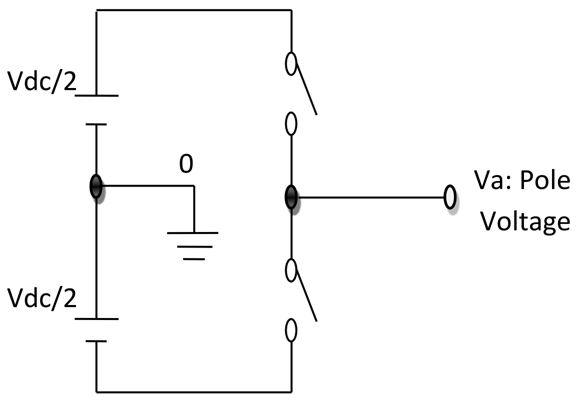


Figure.III.1: Single-phase Inverter circuit diagram

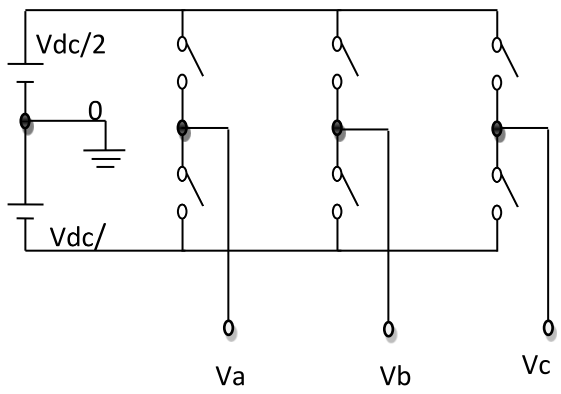


Figure.III. 2: Three-phase inverter circuit diagram

The two-level voltage three-phase inverter consists of two switches per arm. The latter have the particularity of being bidirectional and fully controllable when opening and closing. They can be either MOSFETs for low powers and very high frequencies, IGBTs for large powers and high frequencies, or GTOs for very high powers and low frequencies. To ensure the flow of current in both directions, the switch must be placed in antiparallel with a diode.

The general structure of a two-level voltage inverter is shown in Figure.III.3.

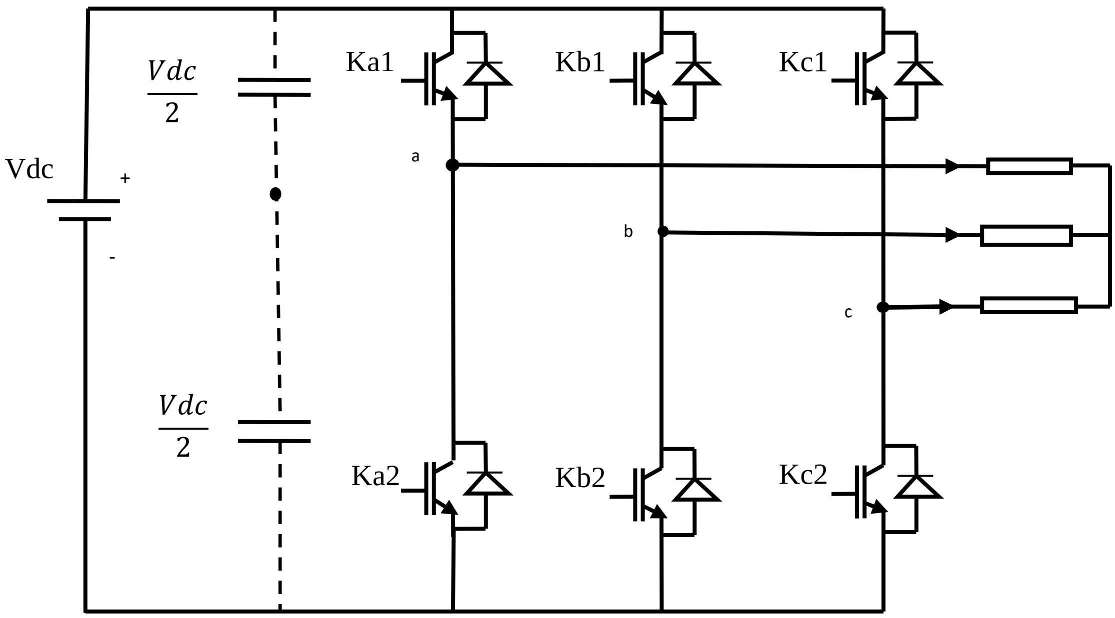


Figure.III.3: Block diagram of the three-phase voltage inverter

The reference voltages are the desired phase-to-neutral voltages U_{an}; U_{bn}; U_{cn} referenced with respect to the neutral point.

The state of the switches, assumed to be perfect, can be defined by three Boolean command quantities S_i (i= a, b, c)::

•If $S_i = 1$ the case where the upper switch is closed and the lower one open.

•If $S_i = 0$ the case where the upper switch is open and the lower one closed.

Under these conditions, the phase voltages U_{ao}, U_{bo} and U_{co} can be written as a function of the control signals S_i**:**

$$U_{ao} = \begin{cases} \frac{V_{dc}}{2}, & Sa = 1 \\ -\frac{V_{dc}}{2}, & Sa = 0 \end{cases} \rightarrow U_{ao} = Ka * \frac{V_{dc}}{2} \quad \text{(III.1)}$$

$$U_{bo} = \begin{cases} \frac{V_{dc}}{2}, & Sb = 1 \\ -\frac{V_{dc}}{2}, & Sb = 0 \end{cases} \rightarrow U_{bo} = Kb * \frac{V_{dc}}{2} \quad \text{(III.2)}$$

$$U_{co} = \begin{cases} \frac{V_{dc}}{2}, & Sc = 1 \\ -\frac{V_{dc}}{2}, & Sc = 0 \end{cases} \rightarrow U_{co} = Kc * \frac{V_{dc}}{2} \quad \text{(III.3)}$$

From the definition of the equations U_{ao}, U_{bo} and U_{co}, we have K_a, K_b and K_c presents the situation 1 or -1 depends on S_i.

The load is considered to be balanced, resulting in :

$$U_{an} + U_{bn} + U_{cn} = 0 \quad \text{(III.4)}$$

$$\begin{cases} U_{ao} + U_{on} = U_{an} \\ U_{bo} + U_{on} = U_{bn} \\ U_{co} + U_{on} = U_{cn} \end{cases} \quad \text{(III.5)}$$

From the sum of equations 5, we have

$$(U_{ao} + U_{bo} + U_{co}) + 3\,U_{on} = U_{an} + U_{bn} + U_{cn} \quad \text{(III.6)}$$

Substituting (4) into (6) gives us :

$$U_{on} = -\frac{1}{3}\,(U_{ao} + U_{bo} + U_{co}) \quad \text{(III.7)}$$

Substituting (7) in (5) we get :

$$\begin{cases} U_{an} = \frac{2}{3}\,U_{ao} - \frac{1}{3}U_{bo} - \frac{1}{3}U_{co} \\ U_{bn} = -\frac{1}{3}\,U_{ao} + \frac{2}{3}U_{bo} - \frac{1}{3}U_{co} \\ U_{cn} = -\frac{1}{3}\,U_{ao} - \frac{1}{3}U_{bo} + \frac{2}{3}U_{co} \end{cases} \quad \text{(III.8)}$$

Substituting (1, 2 and 3) in (8) we obtain :

$$\begin{cases} U_{an} = \frac{2}{3}\ Ka * \frac{V_{dc}}{2} - \frac{1}{3}Kb * \frac{V_{dc}}{2} - \frac{1}{3}Kc * \frac{V_{dc}}{2} \\ U_{bn} = -\frac{1}{3}Ka * \frac{V_{dc}}{2} + \frac{2}{3}Kb * \frac{V_{dc}}{2} - \frac{1}{3}Kc * \frac{V_{dc}}{2} \\ U_{cn} = -\frac{1}{3}Ka * \frac{V_{dc}}{2} - \frac{1}{3}Kb * \frac{V_{dc}}{2} + \frac{2}{3}Kc * \frac{V_{dc}}{2} \end{cases} \tag{III.9}$$

The different combinations of the three quantities (K_a, K_b, K_c) make it possible to generate eight voltage vectors, two of which correspond to the zero vector. With the phase-to-neutral voltages as a function of the command quantities :

$$\begin{bmatrix} U_{an} \\ U_{bn} \\ U_{cn} \end{bmatrix} = \frac{V_{dc}}{2} \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ -\frac{1}{3} & \frac{2}{3} & -\frac{1}{3} \\ -\frac{1}{3} & -\frac{1}{3} & \frac{2}{3} \end{bmatrix} \begin{bmatrix} Ka \\ Kb \\ Kc \end{bmatrix} \tag{III.10}$$

This equation represents MLI

III.3.Association of Inverter with boost converter DC/DC

In order to link inverter and converter we control V_{ref} by comparing it with V_{out} Boost and the line between V_{ref} and V_{out} Boost we modify it by regulator PI in order to collect duty value and compare it with repeating sequence for PWM production as represented in figure III.4.

After obtaining the reference value of the tension, it is applied to Inverter, which in turn is a load for boost converter.

That's why the inverter stream is calculated in boost converter .

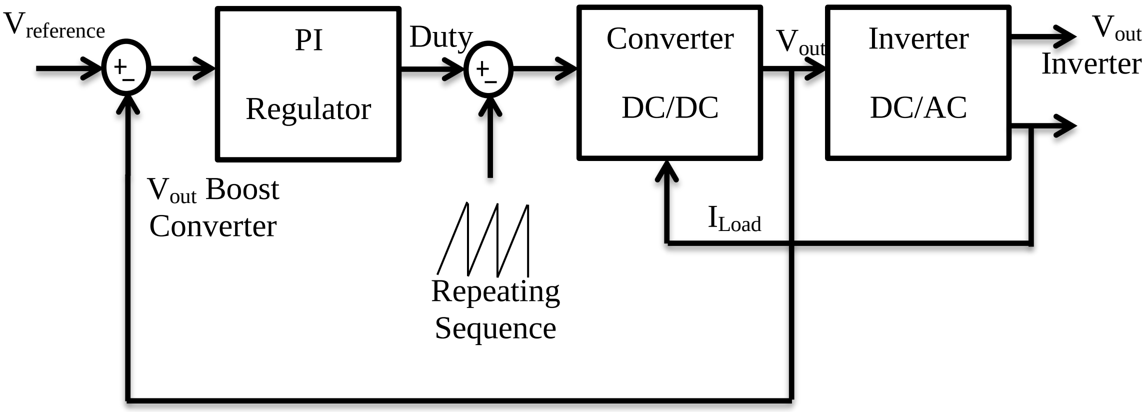


Figure.III.4: Diagrammed associated Boost converter with inverter controlled by PWM

Simulation and results :

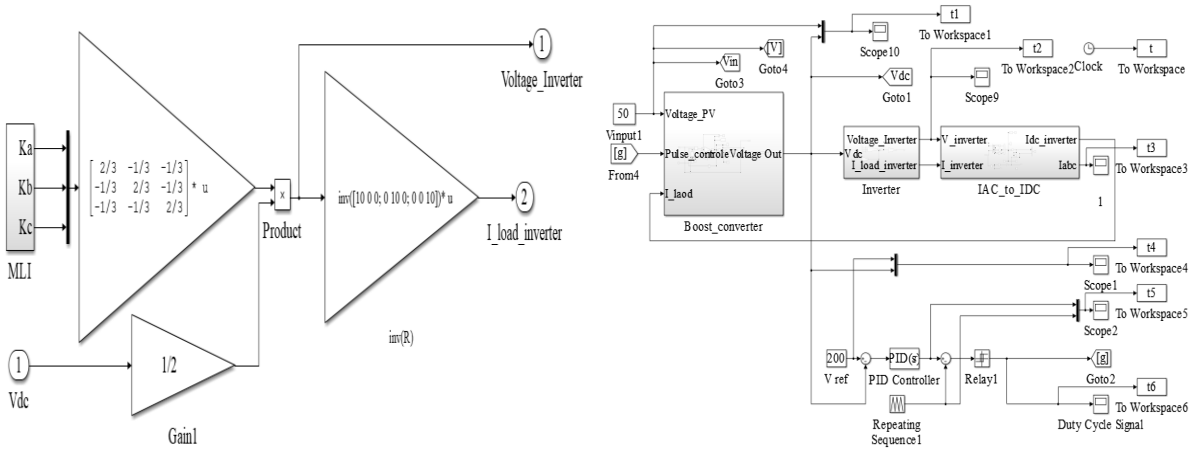


Figure.III.5: Simulation of associated inverter with Boost Converter DC/DC

We associated inverter with boost converter in Matlab and controlled it by PWM duty signal so we get from this experience the following results for both output boost converter voltage , inverter voltage and current .

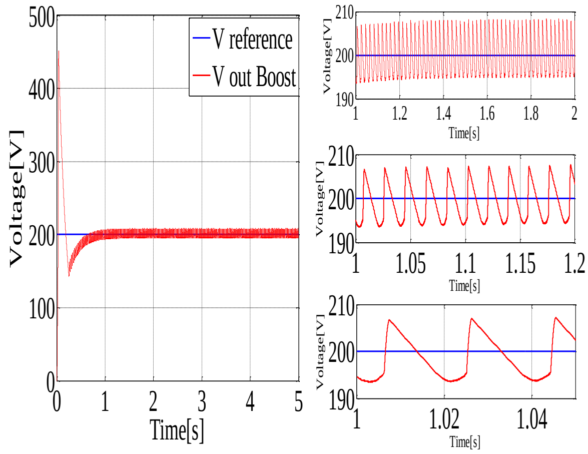


Figure.III.6: Reference voltage and Boost Converter Output Voltage

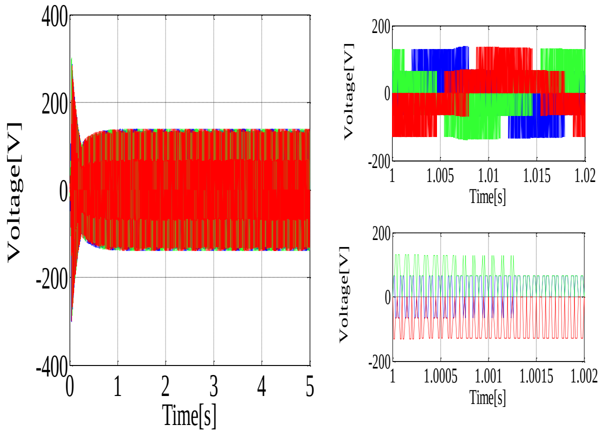


Figure.III.7: Voltage of three phase-inverter

Note at Figure.III.6 both of V_{ref} and V_{out} boost have the same value, but V_{out} Boost has a slightly fluctuating value and this is due to charging and unloading inductance

And Figure.III.7 shows the value of voltage obtained from inverter that we linked to boost converter and PWM controller

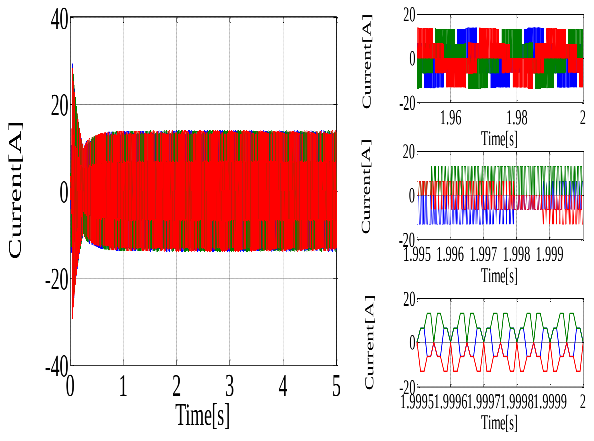


Figure.III.8 : Current of R Load

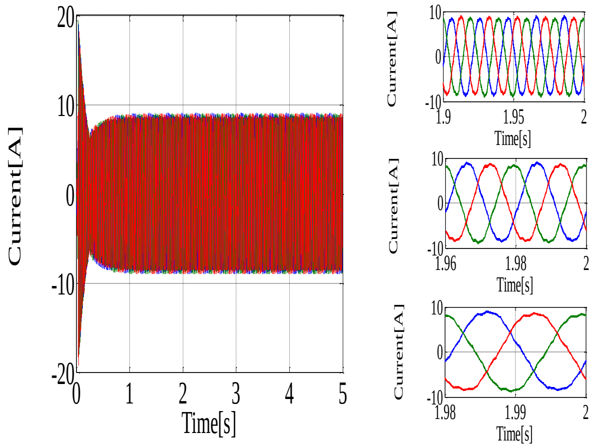


Figure.III.9: Current of RL Load

Figure.III.8 shows the value of current obtained from inverter that we linked to boost converter at R load, we noticed that it resembled voltage obtained in Figuer.III.6. Because they look so close .

Figure.III.9 shows the value of current obtained at RL load from inverter that we linked to boost converter. We noticed it's close to signal sinusoidal.

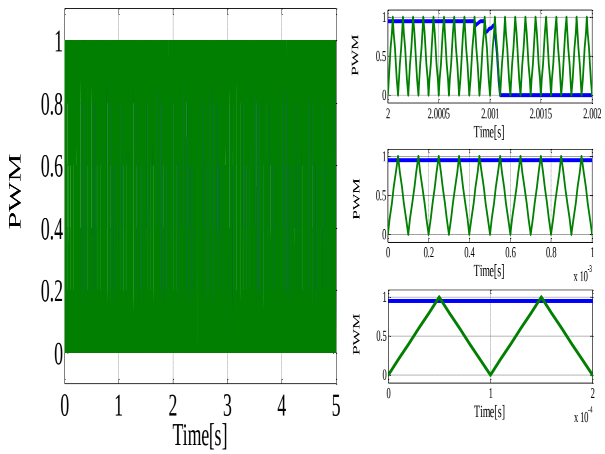


Figure.III.10 : PWM controlled by PI regulator

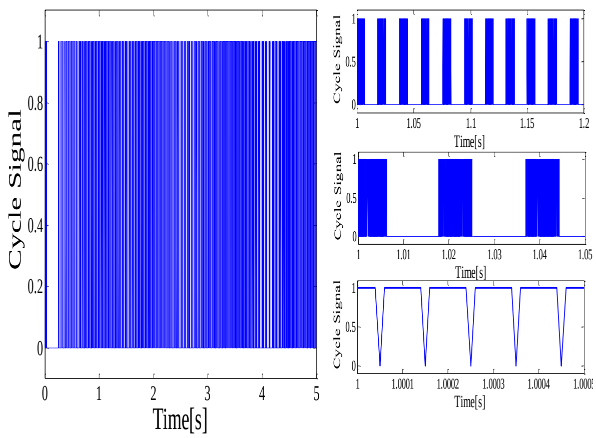


Figure.III.11: Duty cycle signal

In Figure.III.10 gives us the PWM signal from PI regulator , Which compares V_{ref} with V_{out} Boost in order to collect duty value and compare it with sequence repeating as shown in the format (see Figure.III.11)

III.4. Implementation of P&O algorithm for MPPT of PV solar by boost DC/DC converter :

The P&O MPPT algorithm diagram was explained in Chapter II.

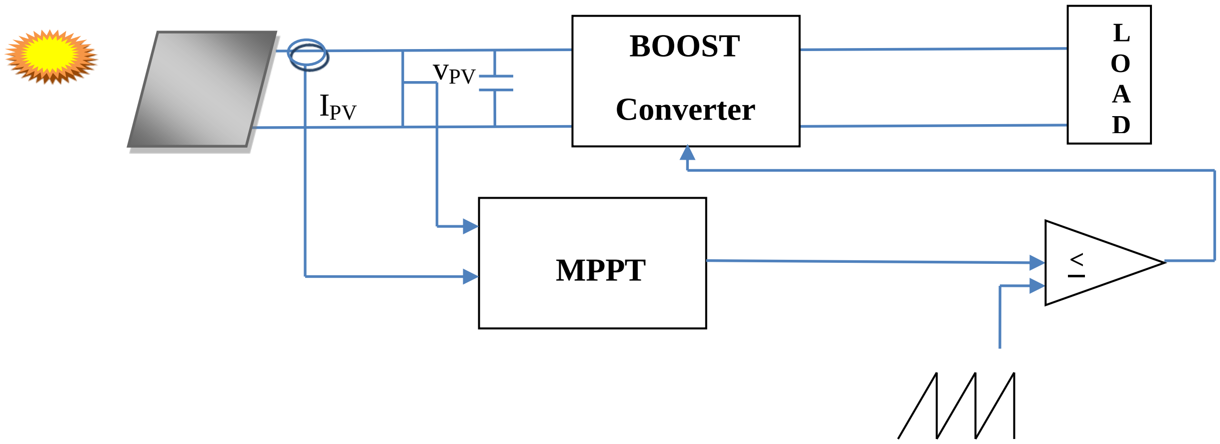


Figure.III.12: Diagrammed of MPPT based on P&O Algorithm for PV Solar System with a Boost Converter

The P&O method is now widely used because of its ease of implementation however it has some problems related to oscillations around the PPM that it generates in an established regime because the procedure for finding the GPP must be repeated periodically, forcing the system to oscillate permanently around the PPM , once this last one is reached. These oscillations can be minimized by reducing the value of the variable of disruption. However, a low increment value slowed down GPP research . must Done find a compromise between precision and speed. This makes this command difficult to optimize [44].

To have the best connection between the "PV" a non-linear source and a load to produce the best power , Maximum Power Point Tracking (MPPT) is developed . It will force the generator to work at its Maximum Power Point , Inducing an overall improvement in the efficiency of the system . The point of operation is determined by the intersection of its electrical characteristic (I-V) with that of the load.

This point of operation varies because the working conditions vary and/or the load varies at all times. This is why, often, we do not operate at the MPP, and the power screwed up to the load is less than the maximum power [45] .

The method of disturbance and observation (P&O) is a widely used approach in MPPT research . because it is simple and requires only voltage and current measurements of the photovoltaic panel V_{pv} and I_{pv} respectively (see Figure.III.12).

As part of this work , we analyze the design of a digital MPPT control (P&O) which is applied to DC-DC booster converters and DC-AC inverter

III.4.1 Simulation and results :

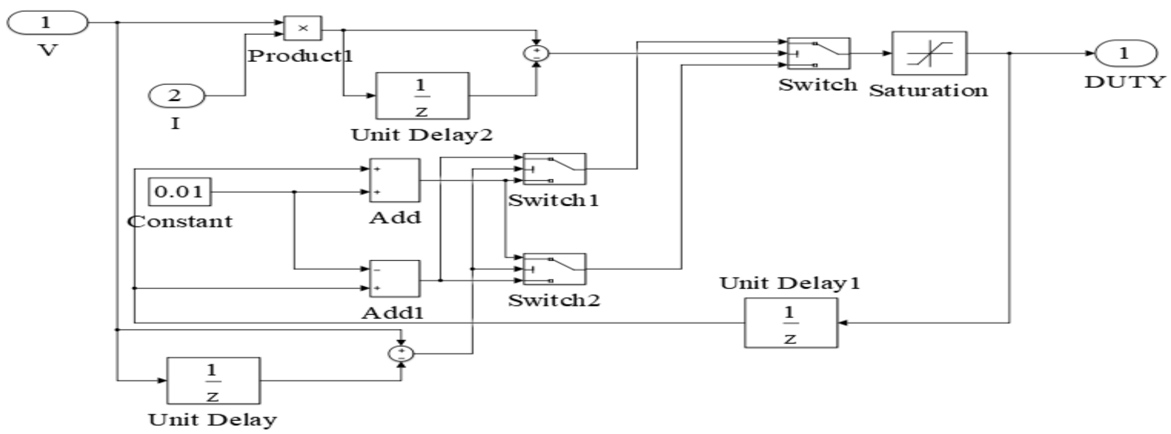


Figure.III.13: Simulation of MPPT based on P&O

Figure.III.13 Shows us the interior design of MPPT based on P&O, where both current and voltage from the solar panel enter , And she's doing her part by giving us Duty Cycle Signal .

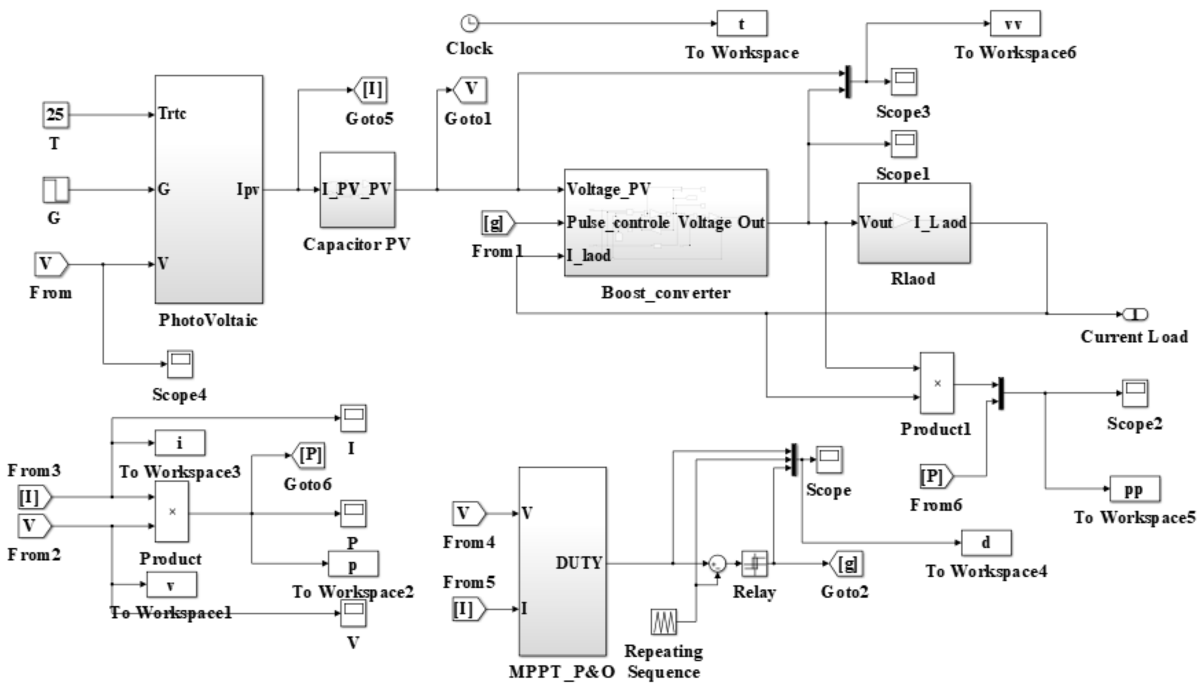


Figure.III.14: Simulation of Photovoltaic panel associated with Boost Converter Controlled by MPPT based on P&O

Figure.III.14 Shows us the final shape of the PV panel associated with boost converter where both temperature and sun's rays enter the solar panel controlled by MPPT, In order to connect the solar panel with boost converter, we control the tension of the solar panel as well as the current through MPPT and compare it with repeating sequence in order to collect duty value , After obtaining the reference value of the tension is applied to R Load, which in turn is charged by a ratio to Boost Converter, so the R Load current is calculated in Boost Converter, and the temperature is T=25C° and the sun’s rays at the moment is 0 seconds in harsh value G=1000w/m^2, and after 3 seconds the sun’s rays becomes G=600w/m^2 , So we get the following results .

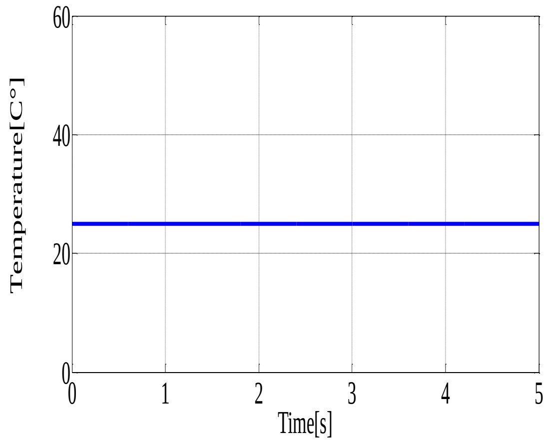


Figure.III.15 : Input temperature [C°]

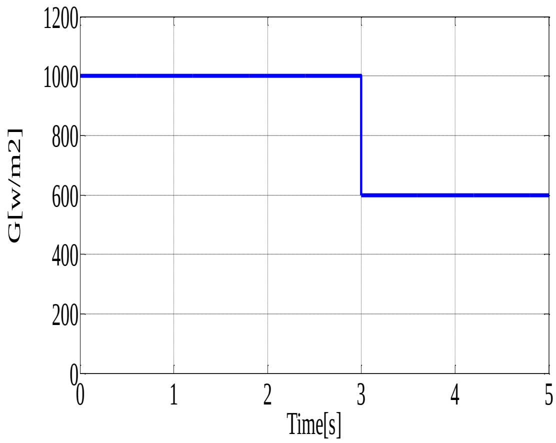


Figure.III.16: Sun’s rays [w/m^2]

Figure.III.15 shows us the constant temperature value of T=25C° for all times. However, Figure.III.16 shows the sun’s rays value of G=1000w/m^2(t=0s) and G=600w/m^2(t=3s)

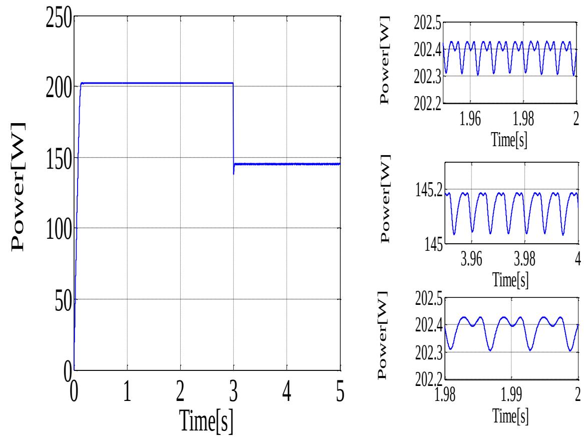


Figure.III.17 : MPPT based on P&O. PV panel power extraction profile

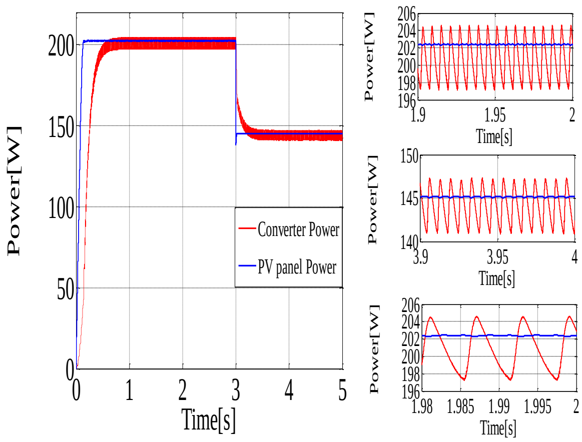
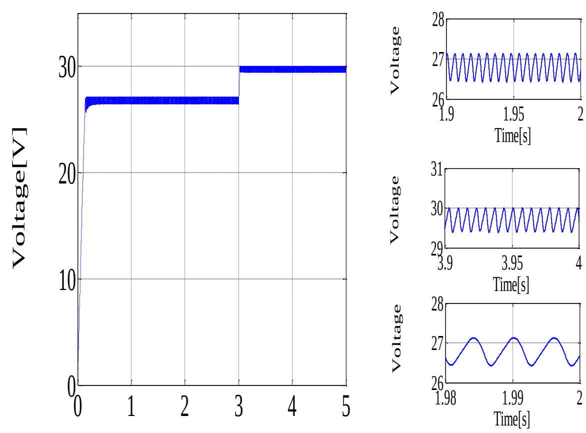


Figure.III.18: PV panel Power & Boost Converter Power

Figure.III.17 and Figure.III.18 shows us the power value of the solar panel as well as boost converter, where we compared them and found that they had the same value , and we noticed that boost converter's power has some fluctuations in value and this is due to the charging and unloading of inductance .

There is also a decline (drop) in power value at 3 seconds , and this is due to the lack of Sun's rays .



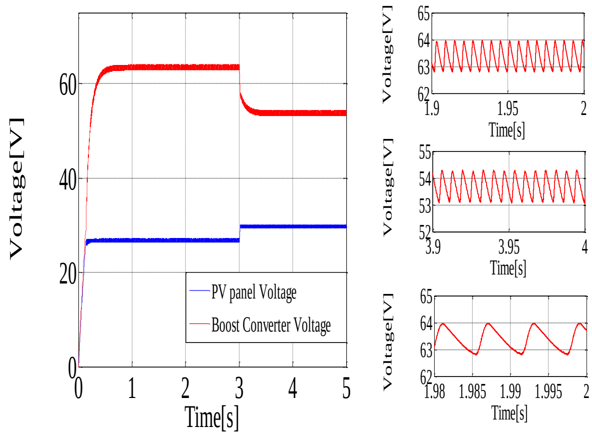


Figure.III.19 : MPPT based on P&O. PV panel voltage extraction profile

Figure.III.20: PV panel voltage & Converter voltage

Figure.III.19 and Figure.III.20 show the voltage value at solar panel and boost converter where we compared them and found that the power value of Boost converter is higher and that is because it is boost and we noticed that the power of the boost converter has some fluctuation in value and this is due to the charging and discharging inductance

There is also a drop in the power value of boost Converter in 3 seconds, which is due to the decline in the value of Sun's rays because it has non-linear properties and at the same time increased at the solar panel

This is because when power is lacking MPPT try to find the greatest ability and through PV properties the value of V_{in} was more than the previous value at 3 seconds and this in the expulsion fit requires v_{out} boost to be lower than before.

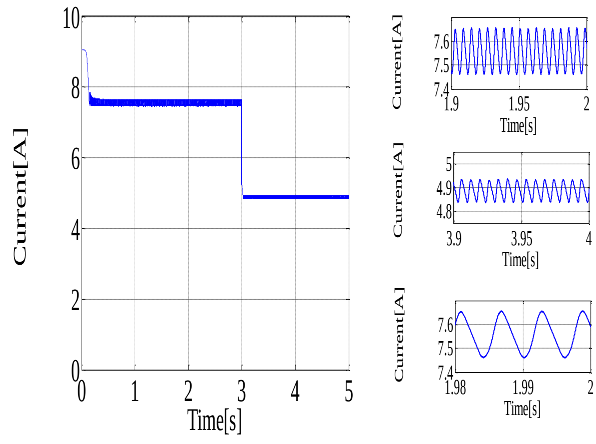


Figure.III.21 : Current corresponding to the MPPT controller based on P&O

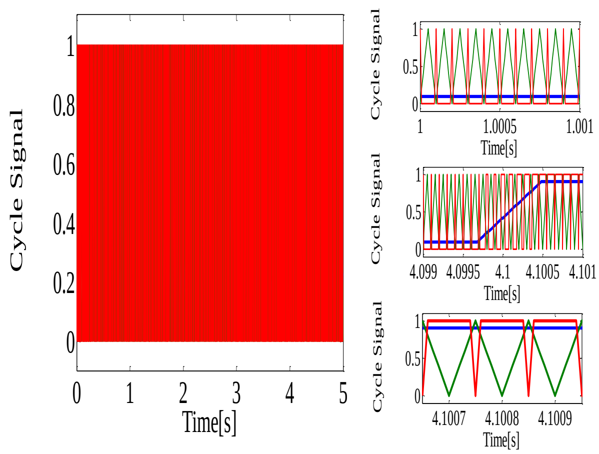
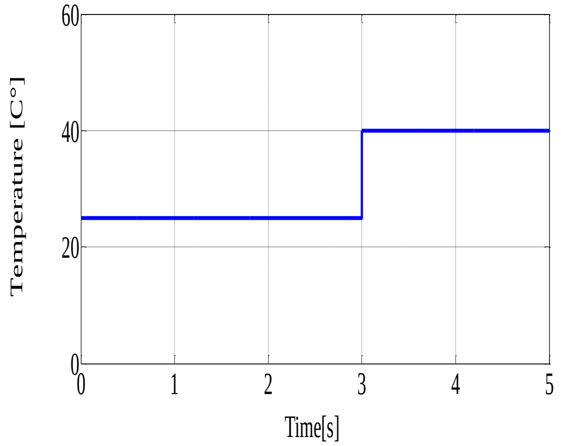


Figure.III.22: Duty cycle ratio corresponding to the P&O-based MPPT controller

Figure.III.21 shows the value of the current at the solar panel and we found that there is a descent in power value in the 3-second time moment due to the decline in the value of sun's rays . Also because when the power is lacking MPPT tries to find the greatest ability and through the characteristics of solar panel , the value of PV voltage was more than the previous value at 3 seconds and from it requires that the current be lower than before

Figure.III.22 shows us the value of collecting duty from MPPT controller based on P&O and comparing it with repeat sequences as described in the format

For the next simulation the final shape of the PV panel associated with boost converter where both temperature and sun's rays input the solar panel controlled by MPPT. In order to connect the solar panel with boost converter, we control the voltage of the solar panel as well as the current through MPPT and compare it with repeating sequence in order to collect duty value . After obtaining the reference value of the Voltage is applied to R load, which in turn is charged by a ratio to boost converter, so the R load current is calculated in boost converter. The temperature at the initial moment is T=25C° at 0 seconds and then increases at 3 seconds to T=40C° shown in Figure.III.23. However, Figure.III.24 shows us the sun’s rays value of G=1000w/m^2



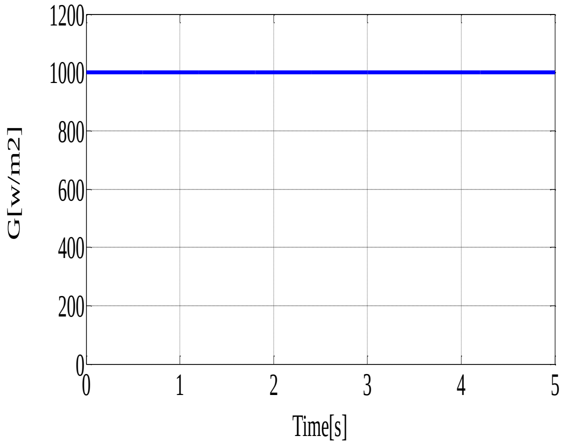


Figure.III.23 : Temperature [C°]

Figure.III.24 Sun's rays [w/m^2]

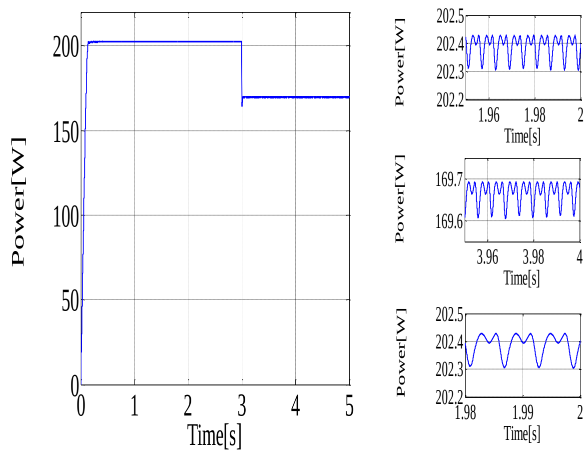


Figure.III.25 : MPPT based on P&O. PV panel power extraction profile

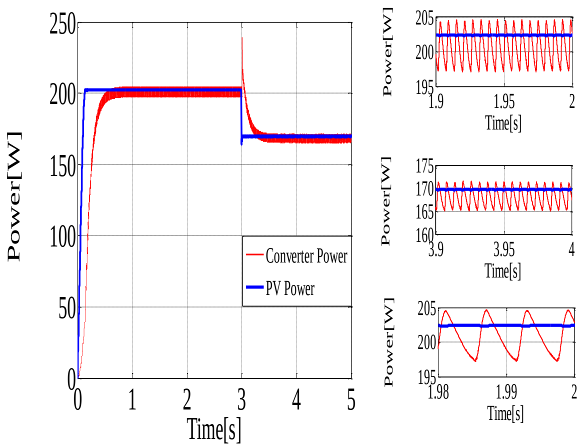


Figure.III.26: PV panel Power & Boost Converter Power

Figure.III.25 and Figure.III.26 show the power value of the solar panel as well as boost converter, where we compared them and found that they had the same value , and we noticed that boost converter's power has some fluctuations in value and this is due to the charging and unloading of inductance .

There is also a decrease in the value of power at the moment of 3 seconds and this is because there is an increase in temperature .

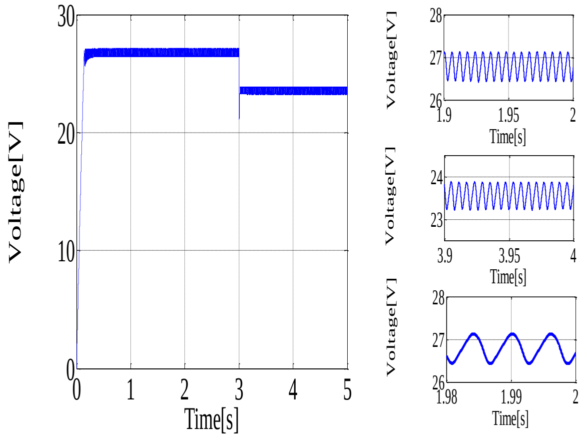


Figure.III.27 : MPPT based on P&O. PV panel voltage extraction profile

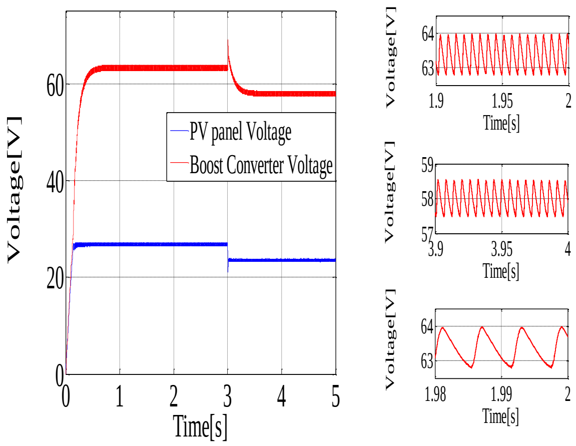


Figure.III.28: PV panel voltage & Converter voltage

Figure.III.27 and Figure.III.28 show us the value of voltage at solar panel and boost converter where we compared them and found that the power value of boost converter is greater and that's because it's boost, as we noticed that boost converter's power has some fluctuations in value and this is due to charging and unloading inductance .

We also noticed a drop in the power value of boost converter in 3 seconds, which is due to the increase in the value of temperature and the same time at the solar panel

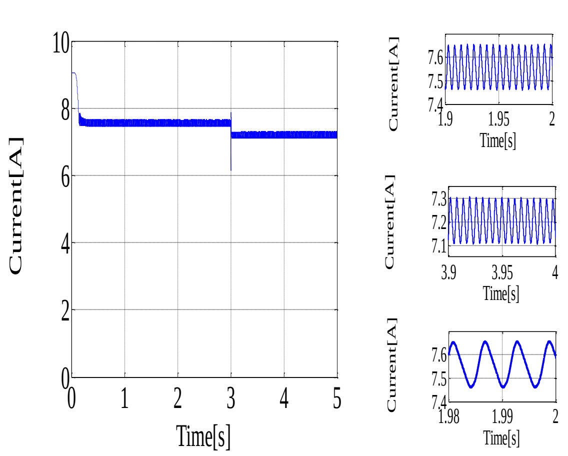


Figure.III.29 : PV current corresponding to the MPPT controller based on P&O

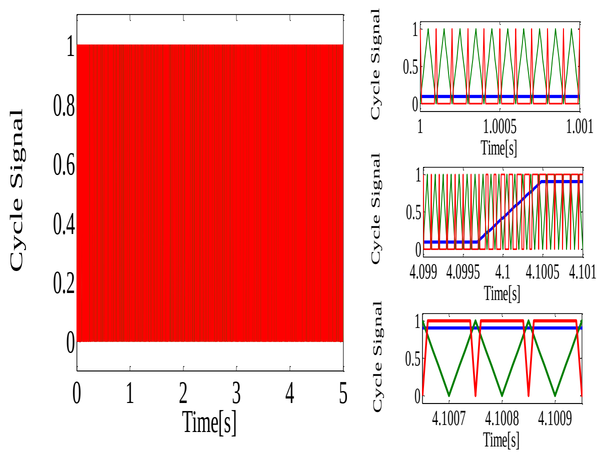


Figure.III.30: Duty cycle ratio corresponding to the P&O-based MPPT controller

Figure.III.29 Shows the value of the current in solar panels and we found that there is a drop in the value of energy in the moment of time 3 seconds due to the increase in temperature. Also because when it lacks power due to a temperature change of 3 seconds MPPT tries to find the largest power capacity and this is through the characteristics of solar panels, the reason was that the current is lower than before

Figure.III.30 shows us the value of collecting duty from MPPT controller based on P&O and comparing it with repeat sequences as described in the format

III.5.MPPT of PV solar for associated inverter with boost converter:

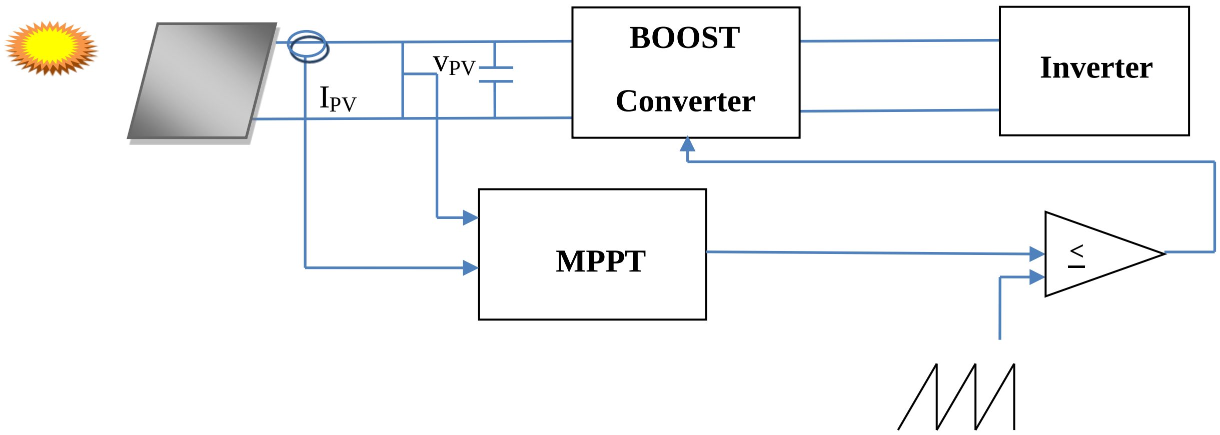


Figure.III.31: Diagrammed of MPPT based on P&O Algorithm for PV Solar System Associated Inverter with a Boost Converter

The method of disturbance and observation (P&O) is a widely used approach in MPPT research , because it is simple and requires only voltage and current measurements of the photovoltaic panel V_{pv} and I_{pv} respectively (see Figure.III.31).

As part of this work , we analyze the design of a digital MPPT control (P&O) which is applied to PV panel associated inverter with boost converter

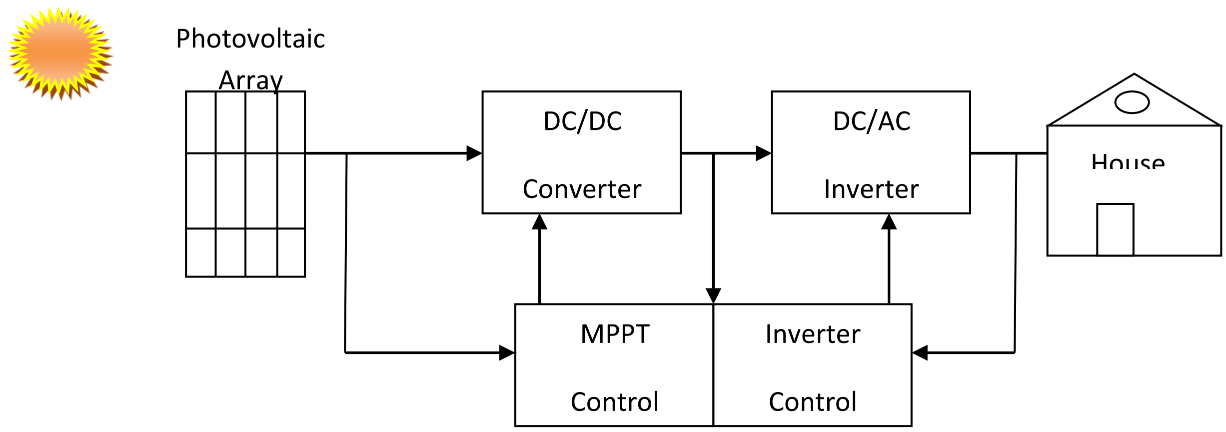


Figure.III.32: Block diagram of Photovoltaic power system

Figure.III.32 Shows the mass scheme design of block diagram of Photovoltaic power system, where both the current and voltage of solar panels enter, and MPPT does its part by giving us the signal of the working cycle, and connect it with inverter and boost converter and power access to the house

Simulation and results :

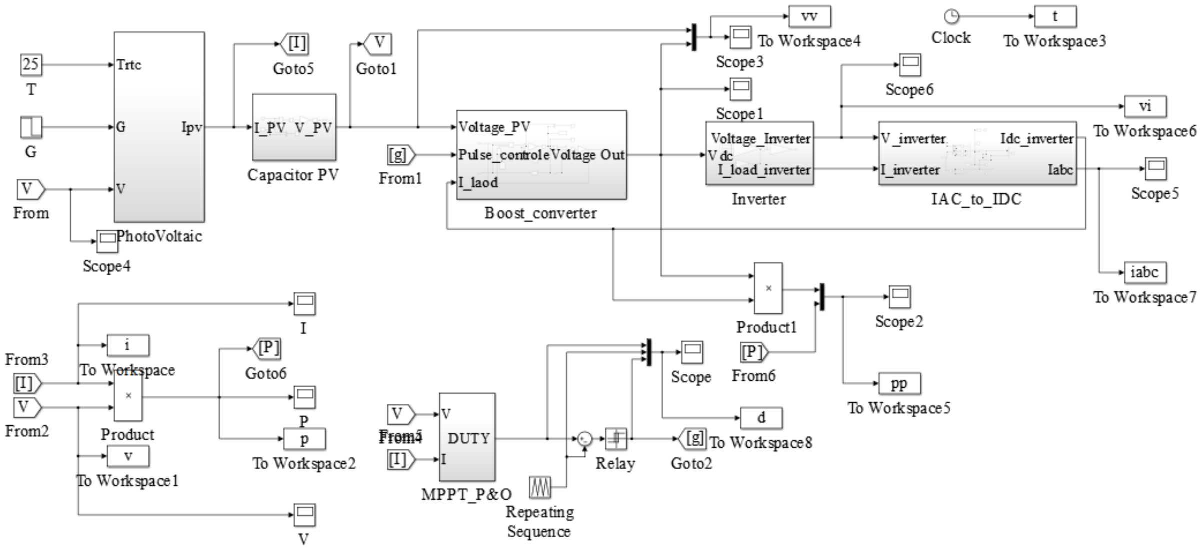
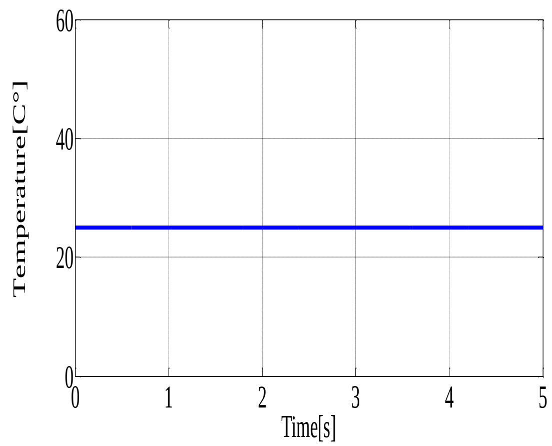


Figure.III.33: Simulation of Photovoltaic panel associated Inverte with Boost Converter Controlled by MPPT based on P&O

Figure.III.33 Shows us the final shape of the PV panel associated inverter with boost converter where both temperature and sun's rays enter the solar panel controlled by MPPT, In order to connect the solar panel with boost converter, we control the tension of the solar panel as well as the current through MPPT and compare it with repeating sequence in order to collect duty value , after obtaining the reference value of the tension is applied to R load, which in turn is charged by a ratio to boost converter, so the R load current is calculated in boost converter, and the temperature is T=25C°constante and the sun’s rays at the moment is 0 seconds in harsh value G=1000w/m^2, and after 3 seconds the sun’s rays becomes G=600w/m^2 , So we get the following results .



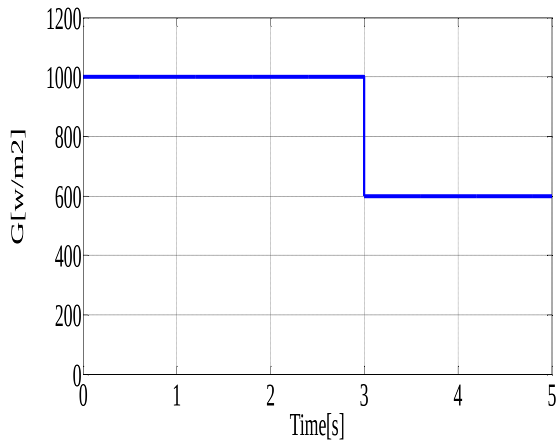
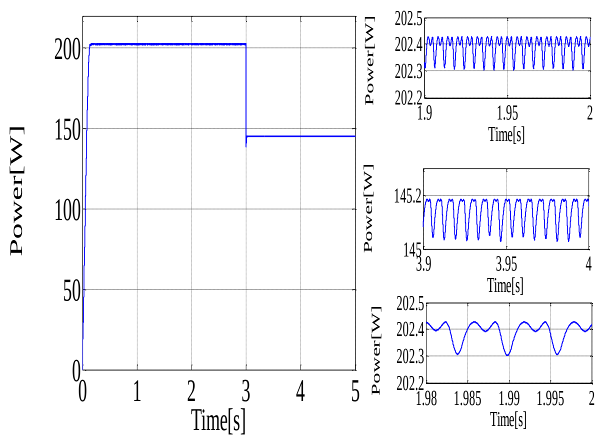


Figure.III.34 : Temperature [C°]

Figure.III.35: Sun's rays [w/m^2]

Figure.III.34 shows us the temperature value of T=25C°

Figure.III.35 shows us the sun's rays value of G=1000w/m^2(t=0s) and G=600w/m^2(t=3s)



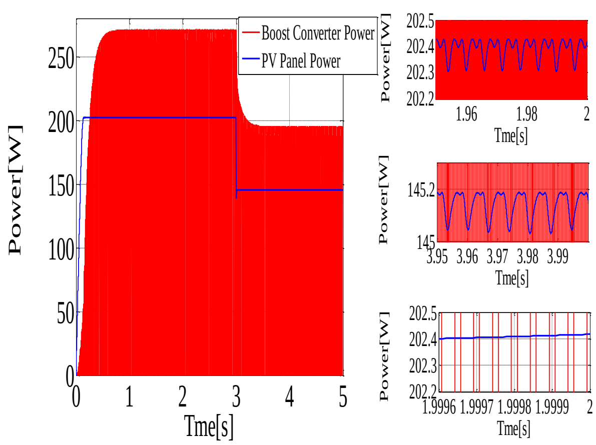
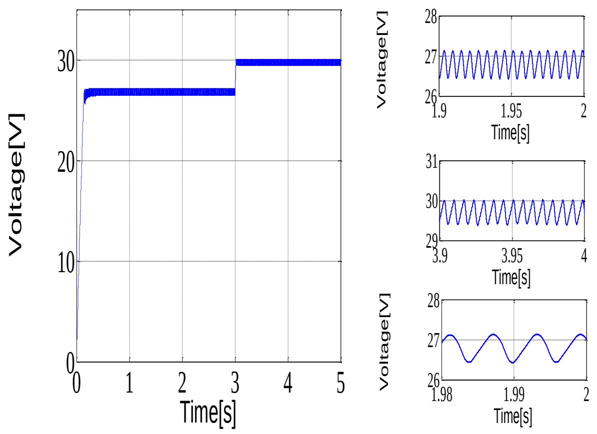


Figure.III.36 : MPPT based on P&O. PV panel power extraction profile

Figure.III.37: PV panel Power & Boost Converter Power

Figure.III.36 and Figure.III.37 shows us the power value of the solar panel as well as boost converter, where we compared it and found that boost is worth more , and we noticed that boost converter's power has fluctuations in value and this is due to the charging and unloading of inductance .

There is also a decline (drop) in power value at 3 seconds , and this is due to the lack of Sun's rays .



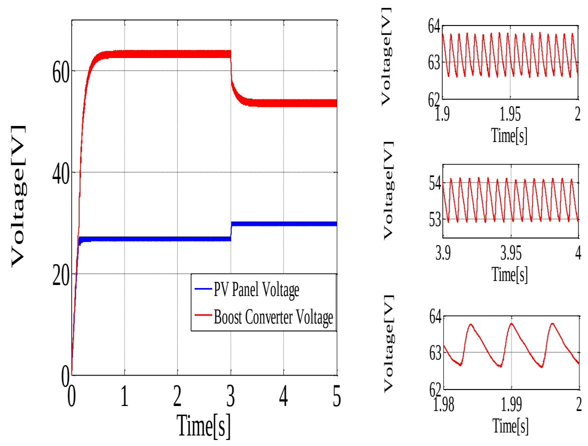


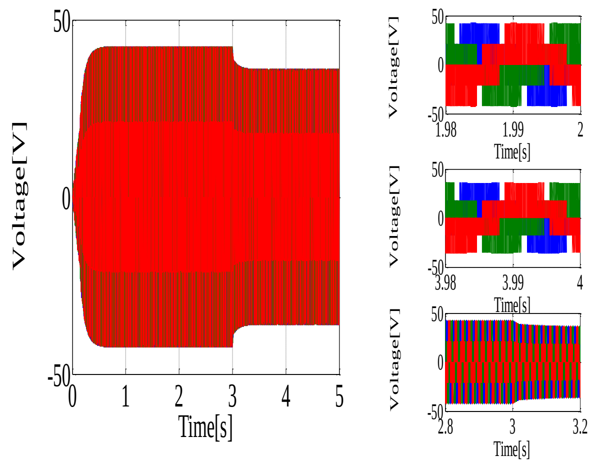
Figure.III.38 : . PV panel voltage extraction profile based on MPPT P&O

Figure.III.39: PV panel voltage & Converter voltage

Figure.III.38 and Figure.III.39 shows us the value of voltage at solar panel and boost converter where we compared them and found that the power value of boost converter is greater and that's because it's boost, as we noticed that boost converter's power has some fluctuations in value and this is due to charging and unloading inductance

There is also a drop in the power value of boost converter in 3 seconds, which is due to the decline in the value of Sun's rays because it has non-linear properties and at the same time increased at the solar panel

This is because when power is lacking MPPT try to find the greatest ability and through PV properties the value of V_{in} was more than the previous value at 3 seconds and this in the expulsion fit requires v_{out} Boost to be lower than before



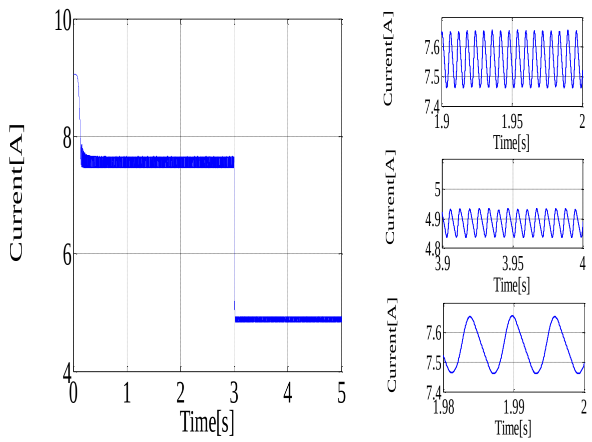


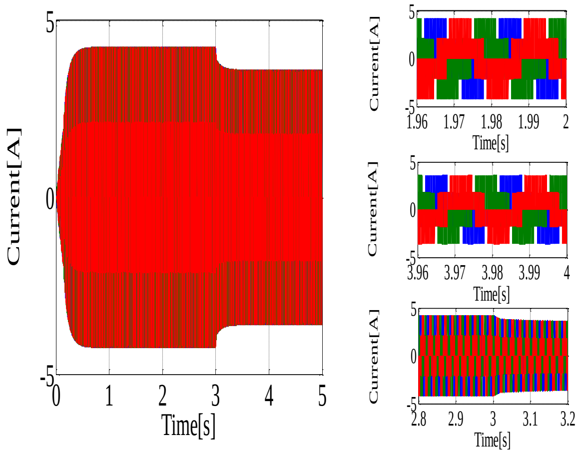
Figure.III.40: Inverter voltage

Figure.III.41 : PV current corresponding to the MPPT controller based on P&O

Figure.III.40 shows us the value of voltage at inverter associated with boost converter, as we noticed that boost converter's power has some fluctuations in value and this is due to charging and unloading inductance

There is also a decline (drop) in power value at 3 seconds , and this is due to the lack of Sun's rays .

Figure.III.41 showing the value of the current at the solar panel and we found that there is a descent in power value in the 3-second time moment due to the decline in the value of sun's rays . Also because when the power is lacking MPPT tries to find the greatest ability and through the characteristics of solar panel , the value of PV voltage was more than the previous value at 3 seconds and from it it requires that the current be lower than before



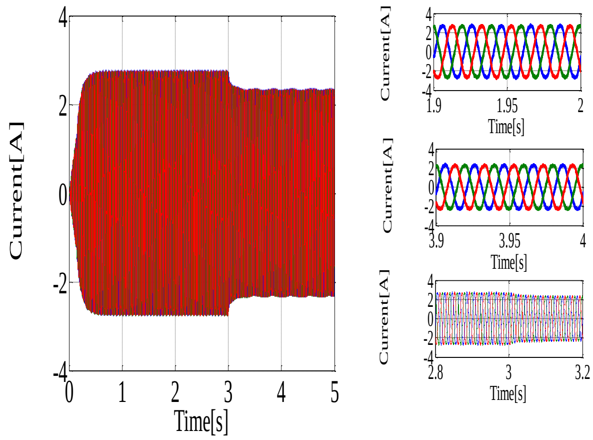


Figure.III.42: Converter Current R load

Figure.III.43: Converter Current RL load

Figure.III.42 shows the value of current obtained from inverter that we linked to boost converter at R load, we noticed that it resembled voltage obtained in (see Figuer.III.40). Because they look so close . There is also a decline in power value at 3 seconds , and this is due to the lack of sun's rays .

Figure.III.43 shows the value of current obtained at RL load from inverter that we linked to boost converter. We noticed it's close to signal sinusoidal , There is also a decline in power value at 3 seconds , and this is due to the lack of Sun's rays .

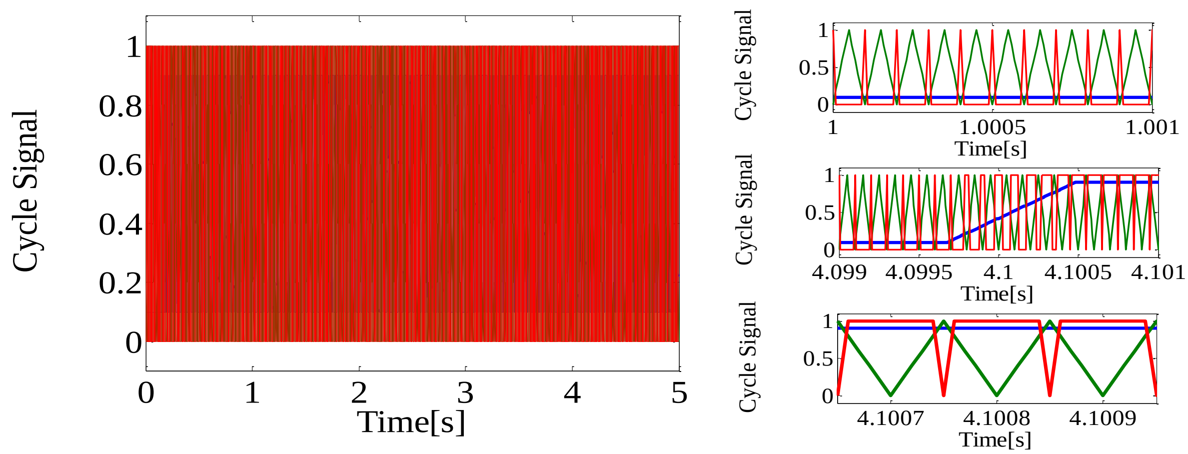
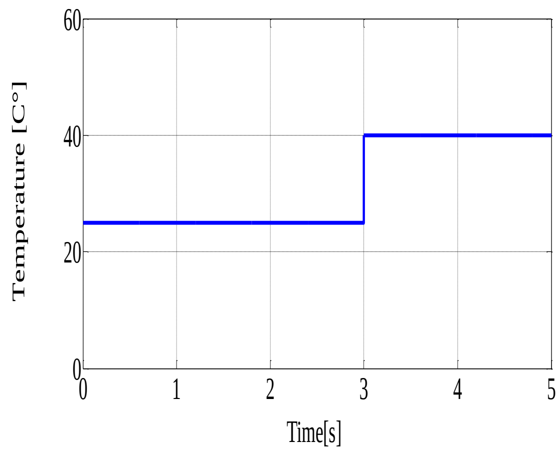


Figure.III.44: Duty cycle ratio corresponding to the P&O-based MPPT controller

Figure.III.44 shows us the value of collecting duty from MPPT Controller based on P&O and comparing it with repeat sequences as described in the format

For the next simulation the final shape of the PV panel associated inverter with boost converter where both temperature and sun's rays enter the solar panel controlled by MPPT. In order to connect the solar panel with inverter linked boost converter, we control the voltage of the solar panel as well as the current through MPPT and compare it with repeating sequence in order to collect duty value , after obtaining the reference value of the tension is applied to R load, which in turn is charged by a ratio to boost converter, so the R load current is calculated in boost converter. The temperature at the initial moment is T=25C° at 0 seconds and then increases at 3 seconds to T=40C° by the sun's rays as it is thaw where G=1000w/m^2 constant .



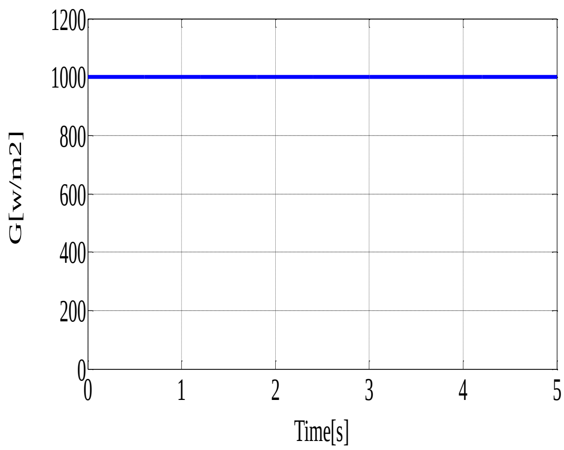
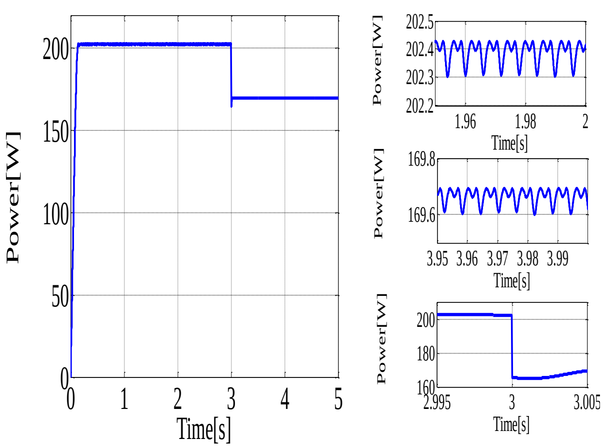


Figure.III.45 : Temperature input [C°] **Figure.III.46:** Sun's rays [w/m^2]

Figure.III.45 shows us the temperature value of T=25C°(t=0s) and T=40C° (t=3s)

Figure.III.46 shows us the sun's rays value of G=1000w/m^2



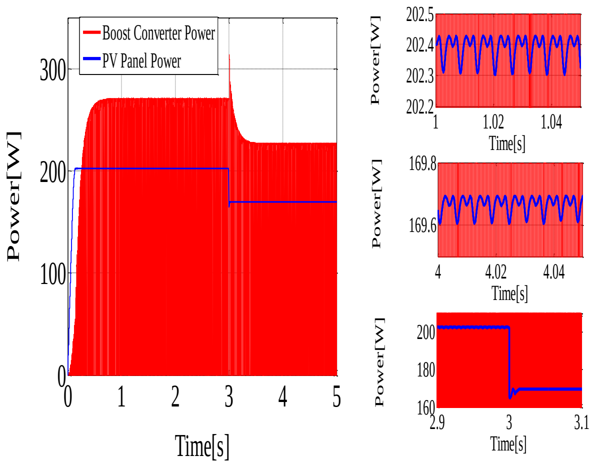
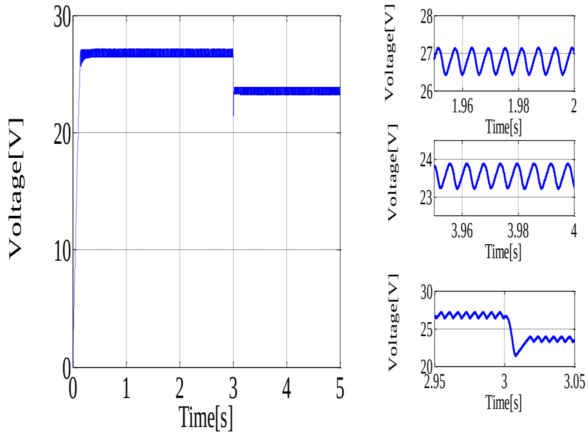


Figure.III.47 : MPPT based on P&O. PV panel power extraction profile

Figure.III.48: PV panel Power & Boost Converter Power

Figure.III.47 and Figure.III.48 show the value of voltage at inverter associated with boost converter, as we noticed that boost converter's power has some fluctuations in value and this is due to charging and unloading inductance

There is also a decrease in the value of power at the moment of 3 seconds and this is because there is an increase in temperature .



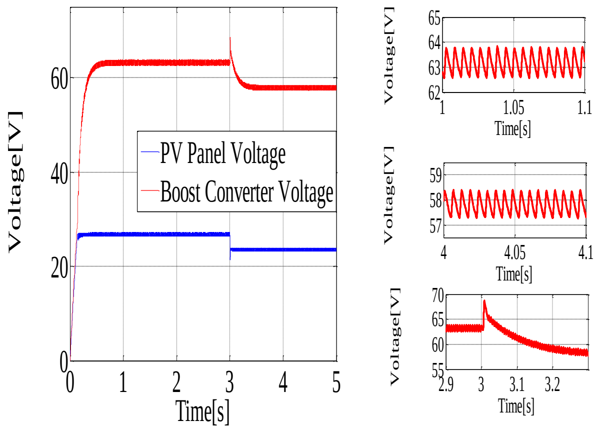
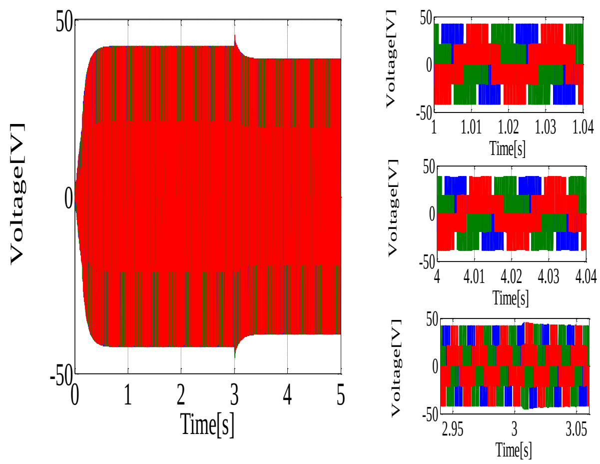


Figure.III.49 : MPPT based on P&O. PV panel voltage extraction profile

Figure.III.50: PV panel voltage & Converter voltage

Figure.III.49 and Figure.III.50 shows us the value of voltage at solar panel and boost converter where we compared them and found that the power value of boost converter is greater and that's because it's boost, as we noticed that boost converter's power has fluctuations in value and this is due to charging and unloading inductance

We also noticed a drop in the power value of boost converter in 3 seconds, which is due to the increased in the value of temperature and the same time at the solar panel



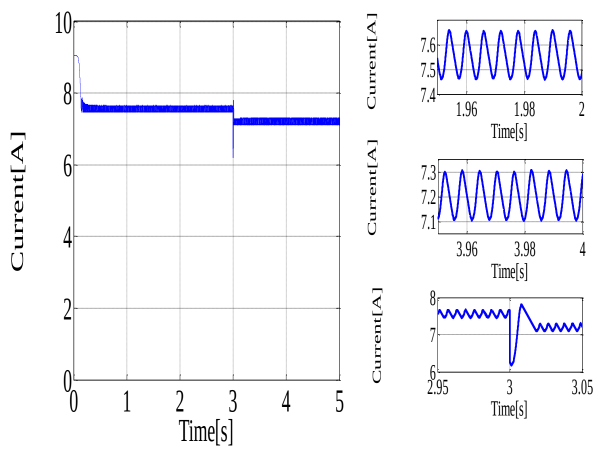


Figure.III.51 : Inverter Voltage

Figure.III.52 : PV current corresponding to the MPPT controller based on P&O

Figure.III.51 shows us the value of voltage at inverter associated with boost converter, as we noticed that boost converter's power has some fluctuations in value and this is due to charging and unloading inductance

There is also a drop in power value at 3 seconds , and this is due to the Increased temperature .

Figure.III.52 shows us the value of the current at the solar panel and we found that there is a descent in power value in the 3-second time moment due to the decline in the value of Increased temperature. Also because when the power is lacking MPPT tries to find the greatest ability and through the characteristics of solar panel , the value of PV voltage was more than the previous value at 3 seconds and from it it requires that the current be lower than before

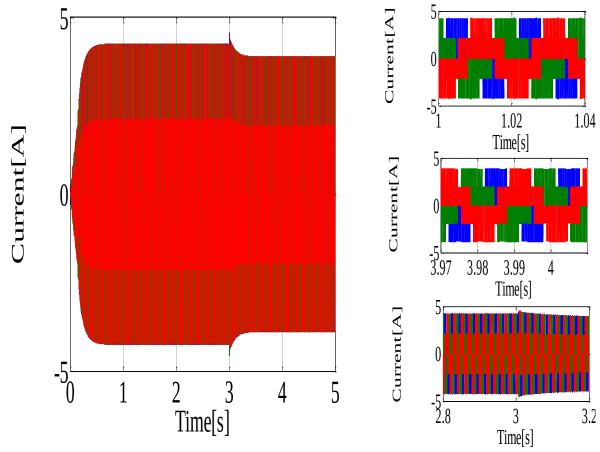


Figure.III.53 : Current inverter for R load

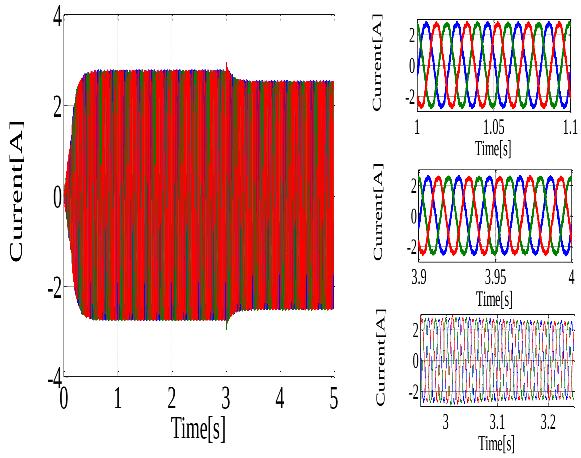


Figure.III.54: Current inverter RL load

Figure.III.53 shows the value of Current obtained from inverter that we linked to boost converter at R load, we noticed that it resembled voltage obtained in (see Figuer.III.51), because they look so close . There is also a decline in power value at 3 seconds , and this is due to the Increased temperature.

Figure.III.54 shows the value of current obtained at RL load from inverter that we linked to boost converter. We noticed it's close to signal sinusoidal, There is also a decline in power value at 3 seconds , and this is due to the Increased temperature.

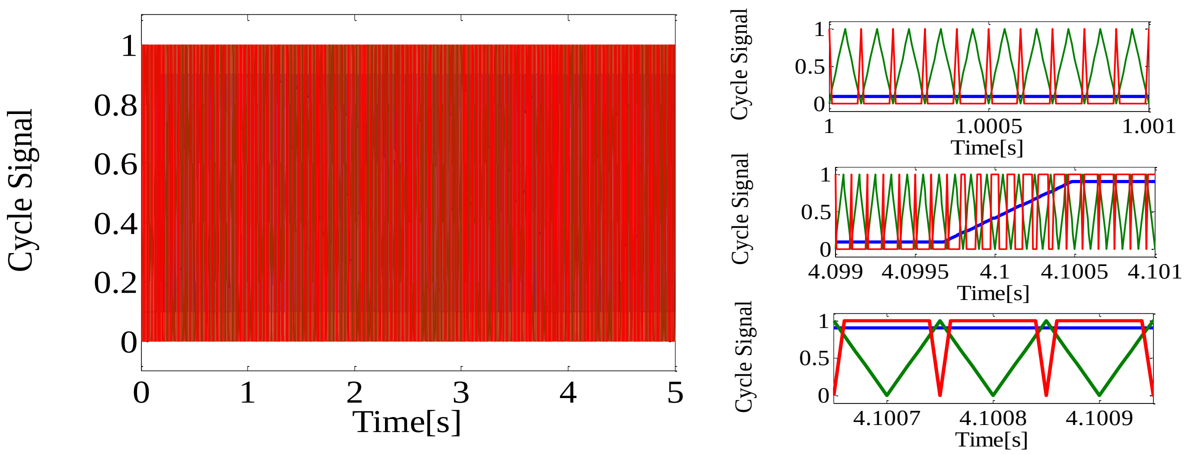


Figure.III.55: Duty cycle ratio corresponding to the P&O-based MPPT controller

Figure.III.55 shows us the value of collecting duty from MPPT Controller based on P&O and comparing it with repeat sequences as described in the format

III.6.Conclusion :

This chapter, the association of the different converters for photovoltaic system. The DC/DC converter was developed for the implementation of the MPPT P&O algorithm in Simulink Matlab.

The inverter is the important device to exploit AC electrical energy for this the modeling and simulation of three-phase inverter was developed with a boost converter with voltage loop control by PI regulator, then the association of the PV system with MPPT and inverter was made in Simulink.

Presented results of Simulink were in different situations for temperature and light intensity to endorse its effect on power also to show effectiveness of MPPT control

General conclusion

General Conclusion :

This project presents a simulation model of the electric part of photovoltaic system associated with inverter controlled by MPPT. The DC/DC converter is very important part for the DC bus of inverter and it is developed in order to extract the maximum amount from the photovoltaic generator. Otherwise, the association of inverter with of photovoltaic system gives much advantage in this system when we can be exploited for many applications as: AC load for isolated areas, use for Uninterruptible Power Supply UPS, prepared for connected to grid etc.

We can conclude our work in three parts as follow:

The first part contains all the details of renewable energy sources, solar radiation, and a description of photovoltaic elements and their applications in various fields. Through this study, we show the importance of solar energy for food security through its applications in agriculture and water desalination, as well as energy security through the adoption of clean and sustainable energy. Otherwise, we describe many types of photovoltaic cells, their components, and how to collect and protect solar panels

The second part, the photovoltaic system's characteristics show a strong lack of linearity. As a result, maximum power point trackers (MPPTs) play an important role in collecting power from photovoltaic (PV) producers because they draw the maximum power output (MPP) achievable despite constant temperature and irradiance variations. As a result, the DC-DC boost converter raises the DC voltage generated, which can then be used as tools in the photovoltaic system's MPPT. The Perturb and Observe (P&O) MPPT algorithms and the conductance increment method were given in this chapter so that they may be implemented in the next chapter. The DC/DC increase was then modelled and simulated, with the results validating the model utilized.

The last part discussed the connections between the various photovoltaic converters. The MPPT P&O algorithm was implemented in Simulink Matlab with the help of a DC/DC converter.

In order to harness AC electrical energy, a three-phase inverter was designed and simulated using a boost converter with voltage loop management by a PI regulator, followed by the integration of the PV system with MPPT and inverter in Simulink.

Simulink data were shown in various conditions for temperature and light intensity to support its effect on power and to demonstrate the effectiveness of MPPT control.

As perspective of this work are grid connected PV systems to optimize energy consumption, also using associated inverter for micro-grid application for better energy exploitation

Bibliographic references

[1]International Conference for Renewable Energies. Bonn, Germany, in June 2004. Download link: http://www.renewables2004. de/pdf/conference_report.pdf.

[2] Declaration of Panama: Energy for Sustainable Development. AG/DEC. 52 (XXXVII-O/07) Approved in the Fourth Plenary Session, held on 5 June 2007, of the Thirty-seventh Regular Session of the General Assembly of the OAS. Download link: http:// www.summit-americas.org/vp/ag_52_dec_pan_en.pdf.

[3] S. Hadji, 2018. Optimisation de la conversion énergétique pour les systèmes à énergiephotovoltaïque. Thèse de doctorat, Université de Sétif 1.

[4] A. Becquerel, 1839. Mémoire sur les effets électriques produits sous l'influence desrayons solaires. Comptes Rendus Séances Hebd., vol. 9, p. 561-567.

[5] Zouhair El Jouad, 2016. Réalisation et caractérisation des cellules photovoltaïques organiques.Physique [physics]. Université d'Angers.

[6] Solectrac Electric Tractors; 2020. / [Accessed 10 January 2020].

[7] A. B. Arostegi, 2013. New Optimized Electrical Architectures of Photovoltaic Generators withHigh Conversion Efficiency. Thèse Doctorat, Université Toulouse 3 Paul Sabatier, pp. 167.

[8] 2007 World PV Industry Reports, Annual World Solar PV Industry Report by Marketbuzz 2008.

[9] A. Inoue, M.H. Ali, R. Takahashi, T. Murata, J. Tamura,A calculation method of the total efficiency of wind generator,in: Proceedings of Power Electronics and Drives Systems (PEDS),Kuala Lumpur, Malaysia, 2, 2005, pp. 1595–1600.

[10] Key World Energy Statistics 2007, Annual technical report of the International Energy Agency.

[11] Renewables, Global Status Report 2006, Technical report by the REN21, Renewable Energy PolicyNetwork for the 21st Century, 2006.

[12] World Energy Intensity: Total Primary Energy Consumption perDollar of Gross Domestic Product using Purchasing Power Parities:1980–2004, Technical Report by the Energy Information Administration, Report released December 2008.

[13] M.E. McCormick, Ocean Wave Energy Conversion, Dover Publications, Mineola, NY, 2007.

[14] Weselek A, Ehmann A, Zikeli S, Lewandowski I, Schindele S, Hogy P. Agrophotovol- €

taic systems: applications, challenges, and opportunities. A review. Agron Sustain Dev. https://doi.org/10.1007/s13593-019-0581-3. 2019;39:35.

[15] Lasnier, F., Ang, T.G., 1990. Photovoltaic Engineering Handbook. Adam Higler,

Princeton, NJ, p. 258.

[16] Global Status Report. Renewable 2017. 72; 2017. https://doi.org/10.1016/j.rser. 2016.09.082.

[17] Goetzberger A, Zastrow A. On the coexistence of solar-energy conversion and plant cultivation. Int J Sol Energy 1982;1:55–69. https://doi.org/10.1080/01425918208909875.

[18] Pringle AM, Handler RM, Pearce JM. Aquavoltaics: synergies for dual use of water area for solar photovoltaic electricity generation and aquaculture. Renew Sustain Energy Rev 2017;80:572–84. https://doi.org/10.1016/j.rser.2017.05.191.

[19] Kim B, Lee S, Kang S, Jeong M, Gim GH, Park J, et al. Aquavoltaic system for harvesting salt and electricity at the salt farm floor: Concept and field test. Sol Energy Mater Sol Cells 2020;204:110234. https://doi.org/10.1016/j.solmat.2019.110234

[20] Hassanien RHE, Li M, Dong LW. Advanced applications of solar energy in agricultural greenhouses. Renew Sustain Energy Rev 2016;54:989–1001. https://doi.org/10.1016/j. rser.2015.10.095.

[21] Morrison J, Morikawa M, Murphy M, Schulte P. Water scarcity & climate change: growing risks for businesses and investors; 2009.

[22] Environmental Impacts of Renewable Energy Technologies, Briefing paper of the "Union of Concerned Scientists", August 2005.

[23] Scognamiglio A, Garde F, Ratsimba T, Monnier A, Scotto E. Photovoltaic greenhouses:a feasible solutions for Islands? Design, operation, monitoring and lessons learned from a real case study. In: 6th World Conf. Photovolt. Energy Convers; 2014. p. 1169–70.

[24] Sgroi F, Tudisca S, Di Trapani A, Testa R, Squatrito R. Efficacy and efficiency of Italian energy policy: the case of PV systems in greenhouse farms. Energies 2014;7:3985–4001.

[25] Rocamora MC, Tripanagnostopoulos Y. Aspects of PV/T solar system application for ventilation needs in greenhouses. In: Int. Symp. Greenh. Cool., vol. 719; 2006. p. 239–46.

[26] Sonneveld PJ, Swinkels G, Van Tuijl BAJ, Janssen HJJ, Gieling TH. A Fresnel lenses based concentrated PV system in a greenhouse. In: Int. Symp. High Technol. Greenh. Syst. GreenSys2009, vol. 893; 2009. p. 343–50.

[27] A SH. Solar fencing unit and alarm for animal entry prevention; 2017. Energy Statistics from the US Government, Report released JuneDecember 2008

[28] International Energy Annual 2006, World Energy Consumption in Standard U.S. Physical Units, Technical Report by the Energy Information Administration, Official Energy Statistics from the US Government, Report released June-December 2008.

[29] 2007 World PV Industry Reports, Annual World Solar PV Industry Report by Marketbuzz 2008.

[30] J.W. Tester, E.M. Drake, M.J. Driscoll, M.W. Golay, W.A. Peters, Sustainable Energy: Choosing Among Options, The MIT Press, Cambridge, MA, 2005.

[31] W.A. Hermann, Quantifying global exergy resources, J. Energy 31 (12) (2006) 1685–1702.

[32] Global Wind Energy Markets, Technical report by the Global Wind Energy Council, February 2008.

[33] Mohammed Wazed S, Hughes BR, O'Connor D, Kaiser CJ. A review of sustainable

solar irrigation systems for Sub-Saharan Africa. Renew Sustain Energy Rev 2018;81:1206–25. https://doi.org/10.1016/j.rser.2017.08.039.

[34] Alonso C. Contribution à l’optimisation , la gestion et le traitement de l’énergie. Habilitation à diriger des travaux de recherches. Université PAUL SABATIER – TOULOUSE III, 2003.

[35] Aouchiche N, Becherif M, HadjArab A, Aitcheikh MS, Ramadan HS, Cheknane A. Dynamic Performance Comparison for MPPT-PV Systems using Hybrid Pspice/Matlab Simulation. Int Energy ElectricPower System 2016;17:529–39. https://doi.org/10.1515/ijeeps-2016-0074.

[36] Cottier J-M, Mermoud A, Villoz M, Graf J. Centrales photovoltaïques Guide pour le dimensionnement et la réalisation de projets A l’usage des bureaux d’ingénieurs. Programme d’action PACER – Energies renouvelables. Office fédéral des questions conjoncturelles; 1996.

[37] Touilnacer Eddine et Ghenbazi slimane ,modélisation et simulation d'un system photovoltaïque ,Mémoire de master académique ,université El Oued,2015

[38] A.Dolara,R.Faranda,S.Leva" Energy comparison of seven MPPT techniques for systems" J.Electromagnetic Analysis&Application,3:152-162,2009.

[39] C. Cabal, ‘Optimisation Energétique de l’Etage d’Adaptation Electronique Dédié à la Conversion Photovoltaïque’, Thèse de Doctorat, Université Paul Sabatier, Toulouse 3, Décembre 2008

[40] J. Fadat, ‘Chaîne de Conversion d’Energie Photovoltaïque Commande MPPT’, La Revue 3EI, N°43, Décembre 2005.

[41] J.L. Santos, F. Antunes, A. Chehab and C. Cruz, ‘A Maximum Power Point Tracker for PV Systems Using a High Performance Boost Converter’, Solar Energy, Vol. 80, N°7, pp. 772 – 778, 2006.

[42].[Evren ISEN / Elec Lett Sci Eng 17(1) (2021) 30-41].

[43] D. W. Hart, Power Electronics. Valparaiso University, Valparaiso, Indiana,2010

[44] M.ARROUF ,,Optimisation de !"ensemble onduleur, moteur et pompe branche sur un generateur photovolta"ique", these doctorats universite de Constantine,2007.

[45]Meflah, « Modelisation et commande d'une chine de pompage photovolta"ique», Memoire de Magistere, Universite de Tlemcen, Algerie, 2011.