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Dedications

To our dear parents ¸ for the great love with which they have surrounded us since our birth ¸ for their patience ¸

Their sacrifices and their encouragement.

To our dear brother and sisters wishing them success in their lives.

To all our friends from Faculty science and technology University of Tissmsilt (Ait Abdelkader Nour islam , Belkhir Bilal , Teiri Khelifa, Meziane Rezzouk , Garou Ahmed , Bouaamama Sidahmed ,Gergour Taha , Morsli Ramdhan) for the pleasant moments we spent together.

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Index of Symbols

Nomenclature

I_{sc}	Short circuit current
V_{oc}	Open circuit voltage
I_m	Current at maximum power point
η	Efficiency
Pm	Maximum output power
Pin	Input power
A	Solar cell area
Q	Angle at which day light falls
T	Operating temperature

Abbreviations

PV	photovoltaic
CSP	Concentrating solar power
LFR	linear Fresnel reflector
P_m or P_{max}	Maximum power point
V_m	Voltage at maximum power point
FF	Fill factor
STC	standard test conditions
SWH	Solar Water Heating
KW	Kilo Watt
MW	milli Watt
RISC	reduced instruction set computer
MIPS	Million instructions per second

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General Introduction

With the unavoidable shortage of fossil fuel sources in the future, renewable types of energy have become a topic of interest for researchers, technicians, investors and decision makers all around the world. New types of energy that are getting attention include hydroelectricity, bioenergy, solar, wind and geothermal energy… Because of their renewability, they are considered as favorable replacements for fossil fuel sources. Among those types of energy, solar photovoltaic (PV) energy is one of the most available resources. Solar photovoltaic (PV) technology is a method of generating electricity by directly converting sunlight into usable electrical power. By utilizing specialized semiconductors, PV systems harness the energy from sunlight and convert it into clean, sustainable electricity [1].

However, the angle of sunlight with respect to solar cell greatly affects the output power. The goal of this project is to build a prototype of light tracking system at smaller scale, but the design can be applied for any solar energy system in practice. It is also expected from this project a quantitative measurement of how well tracking system performs compared to system with fixed mounting method.

This work has been structured into three chapters.

The first chapter provides a theoretical overview of renewable energies with the operating principle of each type of renewable energy.

The second chapter is devoted to the study of a photovoltaic system, its various technologies, as well as its electrical parameters.

Chapter three provides a detailed description of the design and implementation of a solar tracking system.

Finally, we conclude with a general conclusion and prospects for future work.

Chapter 1
Introduction to Renewable Energy Systems

1.1 Introduction

Renewable energy is energy from natural sources that is replenished in greater quantities than consumed. This chapter provides an overview of renewable energy sources (wind turbines, geothermal energy, biomass, hydroelectric power, solar energy...), the principles of operation of each energy system and their advantages and disadvantages.

1.2 Hydro Energy

In hydro power plants (see figure 1), energy of water falling from a certain height is used to generate electrical energy. Water falling from a height has stored potential energy. This energy could then be utilized to rotate the hydro turbines for generation of electricity.

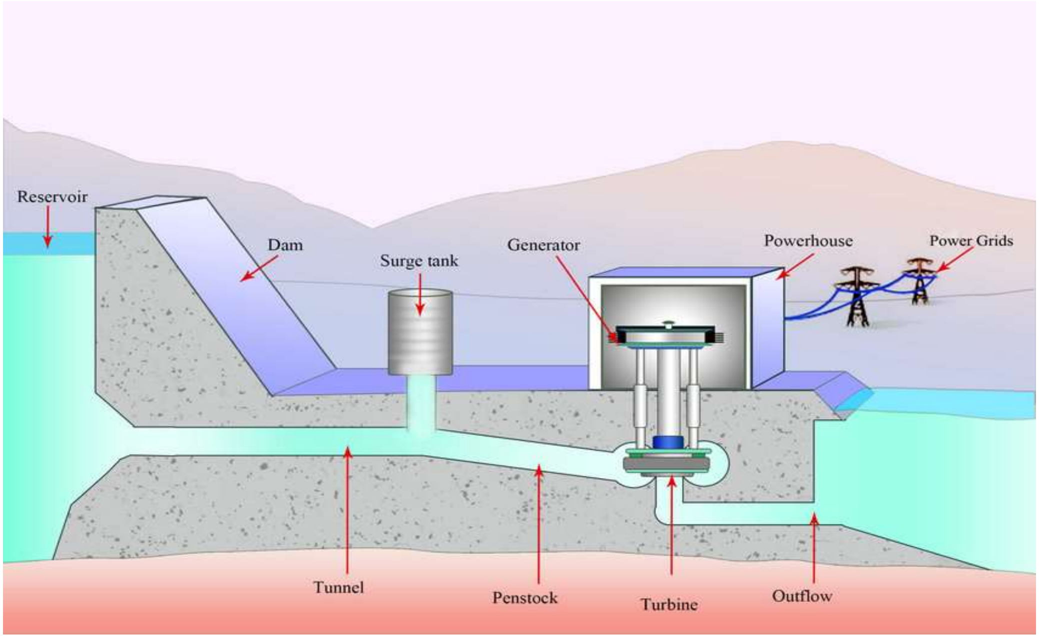

Figure 1-1 *Sketch of a hydropower plant with an upstream surge tank [2]*

Large hydro projects make use of huge tanks or dams to store water in their catchment areas. This water is then allowed a free passage through pipes or channels to water turbines that are placed at the bottom of the tank. The potential energy of water is then used to rotate the turbine for electricity generation. Around the world, large amount of electricity is generated using this method.

The energy of running water in small water streams, rivers and canals is called kinetic energy of water (similar to energy of blowing wind). Similar to wind energy technology, kinetic energy of water can also be converted into electricity. A small water turbine is placed in the movement of water. The turbine converts kinetic energy water into electrical energy. There are water turbines of small capacity in the range of few kW to few tens of kW are available. Thus, wherever there is moving water some electrical energy can be generated [3].

1.3 Biomass

Biomass is the most widely used renewable energy source in the world today. It is mainly used in solid form and in small amounts as liquid fuel and gas. The use of biomass in energy production has increased only slightly in modern times. Biomass can be used to meet a wide range of energy needs, including power generation, home heating, vehicle fuel and to provide process heat for factories. Biomass potential includes wood as well as animal and plant waste [4].

Biomass is the biodegradable fraction of products, wastes and residues from agriculture, forestry and related industries, and the organic fraction of industrial and municipal waste [5].

1.3.1 Bioenergy

Bioenergy is a global term for heat and energy derived from organic matter [6].

Bioenergy is energy produced from biomass and is defined in a similar manner by all major organizations and countries around the world. The Food and Agriculture Organization of the United Nations (FAO) defines bioenergy as all energy derived from biofuels, where biofuels are fuels produced directly or indirectly from biomass [7].

The International Energy Agency (IEA) considers bioenergy to be energy generated from matter produced directly or indirectly through photosynthesis, used as a feedstock for the manufacture of fuels and as a substitute for petrochemicals and other energy-intensive products [8].

Different ways of using bioenergy: Biomass power plants for electricity and heat (mainly with wood as raw material), biomass district heating systems (wood, peat, possibly also decentralized), biogas district heating (biogas. produced by fermentation). Fuels in the form of: first generation bioethanol (fermentation of sugar), vegetable oils (rapeseed, soybean), biodiesel (transesterification of vegetable oils), biomethane (from biogas). Fuels for the BTL (Biomass to Liquids - Biomass to Liquids) and bioethanol industries are obtained from second generation cellulose. A third-generation fuel extracted from algae [9].

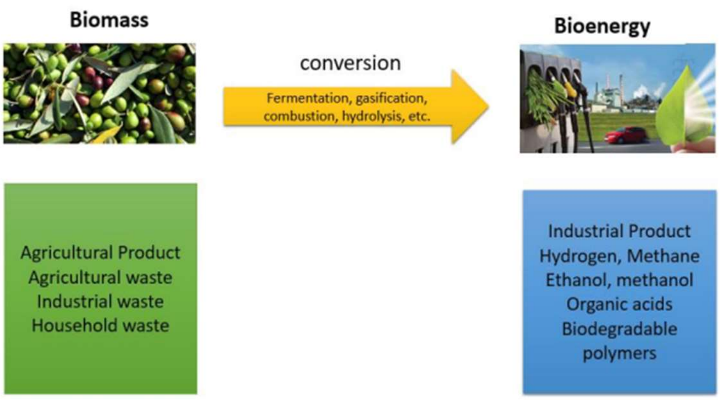

Figure 1-2 *the transformation of the biomass to energy.*

1.3.2 Technology applications of biomass

The energy released when burning biomass mimics natural processes. Energy derived from biomass is therefore a renewable energy source and, unlike fossil fuels, its use usually does not release carbon dioxide into the environment. Biomass is unique among all renewable energy sources in that it is efficiently stored solar energy. Furthermore, it is the only renewable carbon source that can be converted into solid, liquid, and gaseous fuels [10].

Biomass can be used directly (e.g., burning wood for heating and cooking) or indirectly through conversion technologies to convert it into liquid or gaseous fuels (e.g., ethanol from sugar crops or biogas from animal manure) [11].

The net energy available when burning biomass ranges from about 8 MJ/kg for green wood to 20 MJ/kg for dry plant material and up to 55 MJ/kg for methane., as compared with about 27 MJ/kg for coal, many biomasses fired electricity generators use wood and waste materials of forestry and agricultural processes [12].

1.4 Geothermal Energy

Geothermal energy is a sustainable and clean energy source produced from the earth's naturally occurring heat.

This energy can be obtained from a variety of sources, including hot water and hot rocks beneath the surface. The flat bottom is located 10 feet below the surface, ensuring a constant temperature of approximately 10 to 16 °C (50 to 60 °F). This temperature can be used in ground source heat pumps, which can be used to heat and cool buildings. A ground source heat pump system consists of a heat pump, an air supply system (pipes) and a heat exchanger consisting of pipes buried in the ground near the building. In winter, the heat pump draws heat from the heat exchanger and pumps it through the indoor supply air system to heat the building. In summer, the process is reversed, with the heat pump transferring heat from the indoor air to the heat exchanger, which cools the building [13].

In winter, the heat pump draws heat from the heat exchanger and pumps it through the indoor supply air system to heat the building. In summer, the process is reversed, with the heat pump transferring heat from the indoor air to the heat exchanger, which cools the building. The heat extracted from the indoor air in summer can also be used for hot water heating for free.

Overall, geothermal energy is a promising renewable energy source with the potential to reduce greenhouse gas emissions and mitigate climate change [14].

1.4.1 Geothermal electricity production

Geothermal plants draw steam or hot water from wells a mile or more underground. Steam or hot water is piped from the well to drive a traditional steam turbine, which in turn drives an electrical generator. Typically, the water is then returned to the surface to refill the reservoir and complete the renewable energy cycle.

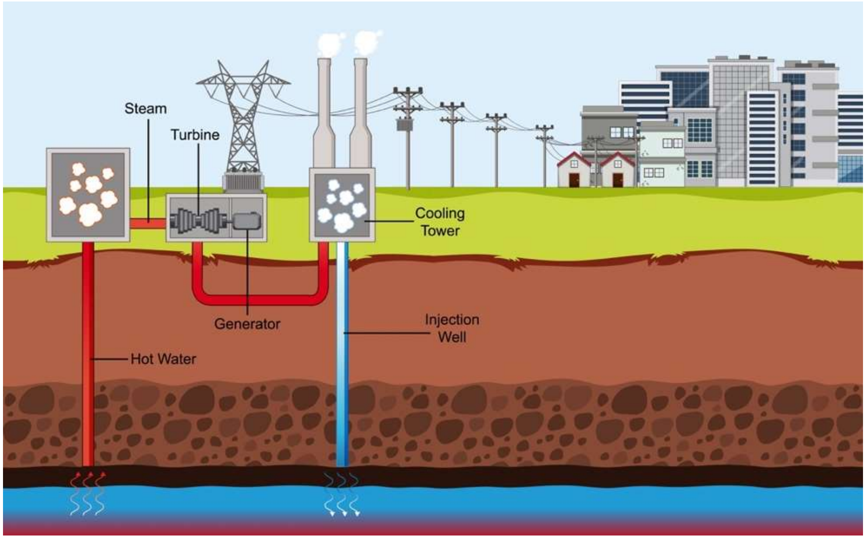

Figure 1-3 *Geothermal power production [15]*

1.5 Solar Energy

Solar technologies tap directly into the infinite power of the sun and use that energy to produce heat, light, and power.

1.5.1 Solar Water Heating (SWH)

Solar energy can be used to heat water for your home or your swimming pool. Most solar water heating systems consist of a solar collector and a water storage tank [16].

Solar water-heating systems use collectors, generally mounted on a south-facing roof, to heat either water or a heat-transfer fluid, such as a nontoxic antifreeze. The heated water is then stored in a water tank similar to one used in a conventional gas or electric water-heating system as show the figure 1-4 [17].

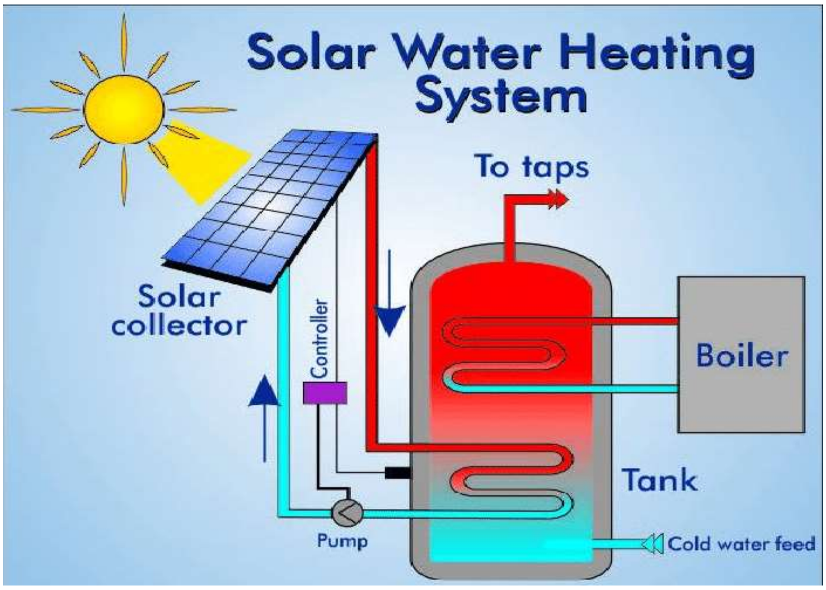

Figure 1-4 *Block diagram of Solar Water Heating System [16]*

There are basically two types of solar Water Heating (SWH) [19-20] flat plate collector and evacuated tube SWHs.

a) The flat-plate collector

is an insulated, weatherproof box containing a dark absorber plate under a transparent cover, as shown in Figure 1.5.

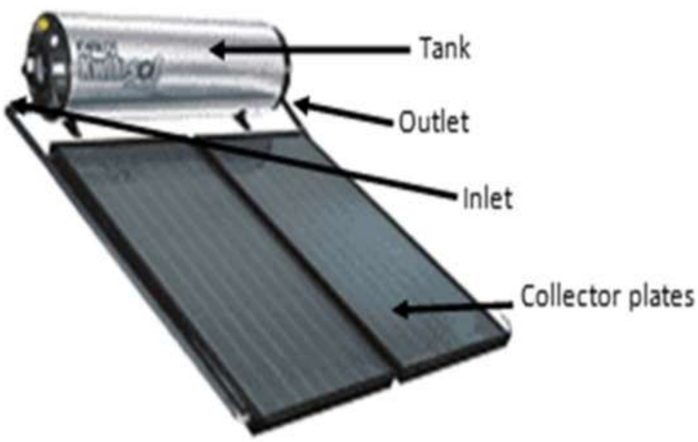

Figure 1-5 *A flat plate collector SWH [17]*

b) The evacuated-tube collectors

are made up of Rows of parallel, transparent glass tubes. Each tube consists of a glass outer tube and an inner tube, or absorber, covered with a coating that absorbs solar energy but inhibits heat loss, as shown in Figure 1.6.

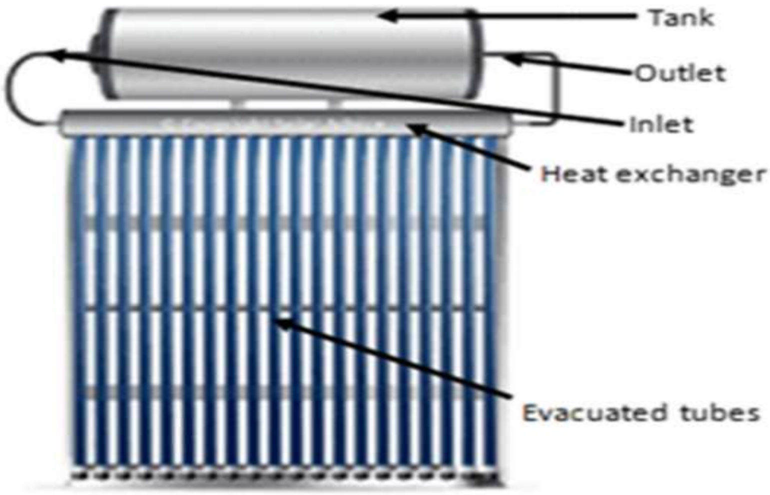

Figure 1-6 *Evacuated tube SWH [18]*

In both systems, in either the evacuated tubes or the flat plate collector, solar energy is converted into heat to increase the temperature of the heating water. The tank acts as the thermal energy storage of the gained heat that is contained in the storage water tank.

Both systems can function as a passive or active system.

Passive solar water heating systems

use natural convection or household water pressure to circulate water through a solar collector to a storage tank. They have no electric.

Active solar water heating systems

uses an electric pump to circulate water through the system. Active systems are usually more expensive than passive systems, but they are also more efficient.

The amount of hot water a solar water heater produces depends on the type and size of the system, the amount of sun available at the site, proper installation, and the tilt angle and orientation of the collectors [19].

1.5.2 Solar Electricity Production

Solar photovoltaic and concentrated solar energy are the two primary methods solar energy systems use to generate electricity.

1.5.2.1 Solar photovoltaic energy

This technology converts sunlight directly into electricity. Solar electricity has been a prime source of power for space vehicles since the inception of the space program. It has also been used to power small electronics and rural and agricultural applications for three decades.

Although many types of solar electric systems are available today, they all consist of basically three main items: *modules* that convert sunlight into electricity; *inverters* that convert that electricity into alternating current so it can be used by most household appliances; and possibly or sometimes *batteries* that store excess electricity produced by the system. The remainder of the system [20] (See figure 1-7)

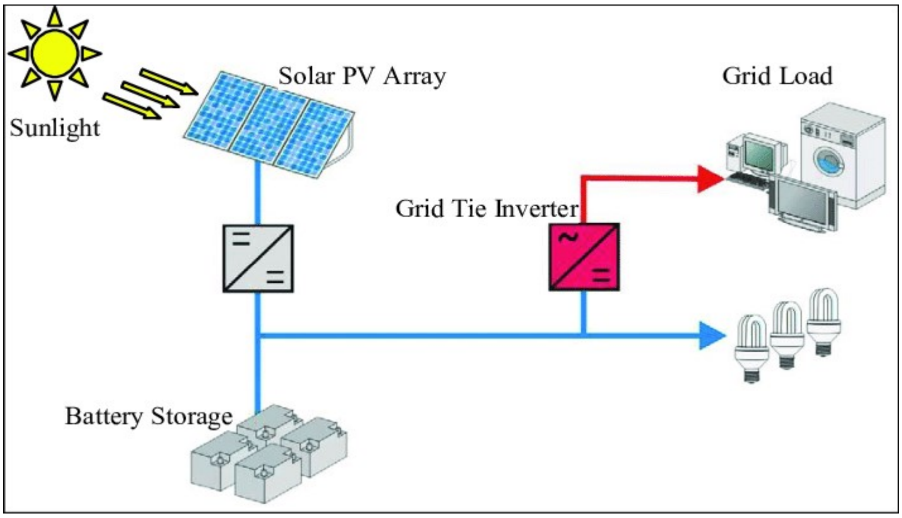

Figure 1-7 *Basic Standalone-Solar-Electric-Systems [21]*

1.5.2.2 Solar Thermal Electricity

Unlike solar electrical systems that convert sunlight into electricity, solar thermal electrical systems convert solar heat into electricity by using the principle of Solar Concentrate power (CSP). This technology is used primarily in large scale power plants for powering cities and communities, especially in the South where consistent hours of sunlight are greater.

In CSP or solar thermal technologies, the solar radiations are concentrated to produce steam or hot air. This steam or hot air is then used to generate electricity using a conventional power cycle [22].

The four types of CSP technologies used currently are as follows [23].

A) Parabolic Troughs

The parabolic trough solar power plant is a well-established and successful technology for generating electricity from solar energy. It consists of multiple parabolic trough solar collectors, which are filled with heat transfer fluid and arranged in loops to track the sun from East to West [24] [25].

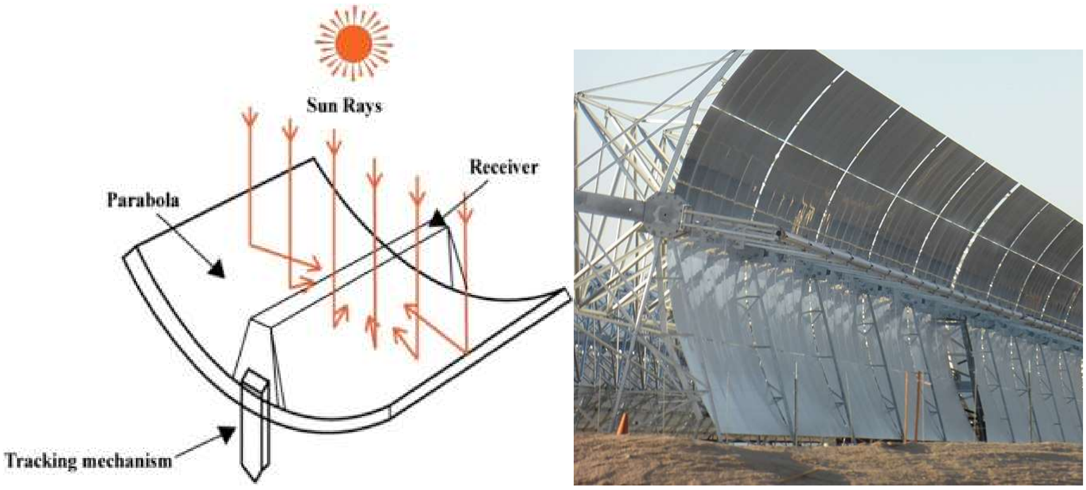

Figure 1-8 *parabolic trough solar power plant [26]*

B) Linear Fresnel reflector system

The linear Fresnel power plant is a type of concentrating solar power (CSP) technology that is similar in configuration to parabolic trough plants. The main difference is that a linear Fresnel reflector (LFR) is used as the solar collector in the solar field [27].

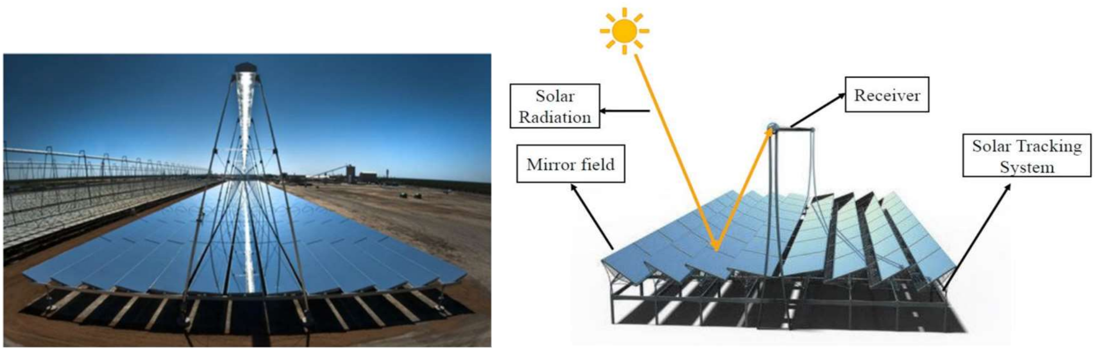

Figure 1-9 *Linear Fresnel Reflector system representation [28]*

C) Solar tower power

the solar tower power plant, also known as the central receiver technology consists of a solar field with circular two-axis tracking arrays made up of flat or slightly bent heliostats that concentrate solar radiation onto a central receiver [29], (see figure 1-10)

Figure 1-10 *Solar power tower at Sevilla, Spain [30]*

D) Parabolic dish systems

The parabolic dish reflector is a two-axis point-focus system that concentrates solar energy onto a receiver attached to the focal point of the dish [31].

Figure 1-11 *Stirling dish system [32]*

1.6 Wind Energy

Wind energy, also known as wind power, is the conversion of the kinetic energy of the wind into mechanical or electrical energy. This is done by using turbines that capture the wind's energy and convert it into usable power. Wind energy is considered a form of renewable energy, like solar power, because it relies on natural resources that are constantly replenished by the sun's heat and the rotation of the Earth [33].

1.6.1 Wind Energy Conversion System

The block diagram of a typical wind energy conversion system is shown in Figure 1-12

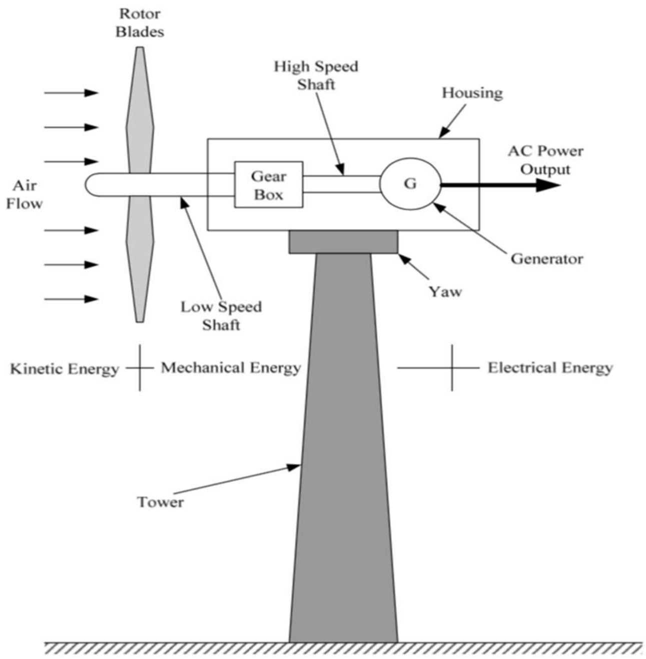

Figure 1-12 *Block diagram of a typical wind energy conversion system.*

The main components of a modern wind turbine are the tower, azimuth shaft, rotor and nacelle housing the gearbox and generator. The tower supports the main part of the wind turbine and keeps the rotating blades level to capture enough wind energy. The yaw mechanism is used to turn the rotor blades of a wind turbine against the wind. Wind turbines capture the kinetic energy of the wind in a rotor, which consists of two or more blades. The gearbox converts the lower speed of the wind turbine to a higher speed on the generator side. The generator generates electricity while its shaft is driven by the wind turbine, maintaining its performance according to specifications through the use of appropriate control and monitoring techniques. In addition to monitoring performance, these control systems also include safety measures to protect the entire system.

The horizontal axis configuration and the vertical axis configuration are two distinct design configurations available for wind turbines. While the vertical axis machine resembles an egg beater and is commonly referred to as the Darrieus rotor (named after its inventor), the majority of modern turbines utilize the horizontal axis design [34].

1.7 Advantages of Renewable Energy

Renewable energy refers to energy that is generated from natural sources that are replenished continuously, such as solar, wind, hydro, geothermal, and biomass. Here are some advantages of renewable energy [35] [36]:

Reduces greenhouse gas emissions: Renewable energy sources produce little or no greenhouse gas emissions, which helps to reduce the amount of carbon dioxide and other pollutants in the atmosphere.

Reduces dependence on fossil fuels: Renewable energy sources help to reduce the world's dependence on finite resources such as oil, coal, and natural gas, which are subject to price fluctuations and geopolitical tensions.

Lowers energy costs: The cost of renewable energy technologies such as solar and wind has decreased significantly over the past decade, making them increasingly competitive with traditional fossil fuel sources.

Creates jobs and stimulates economic growth: The renewable energy sector is a growing industry that provides jobs and economic benefits, particularly in rural areas where wind and solar projects are often located.

Improves energy security: Renewable energy sources are widely distributed and can be harnessed in many parts of the world, reducing dependence on imported energy sources and improving energy security.

Increases energy efficiency: Renewable energy technologies are often more efficient than traditional fossil fuel sources, which helps to reduce overall energy consumption and increase energy efficiency.

Promotes sustainable development: Renewable energy sources support sustainable development by providing clean energy that meets current energy needs without compromising the ability of future generations to meet their own energy needs.

1.8 Challenges of Renewable Energy

There are several challenges associated with renewable energy, which include:

Intermittency: One of the biggest challenges with renewable energy is its intermittency. Solar and wind power, for instance, are dependent on weather conditions, and their availability can vary significantly over time. This makes it difficult to ensure a consistent supply of energy to meet the demands of the grid.

Energy Storage: The intermittency of renewable energy sources makes energy storage a critical challenge. Energy storage technologies like batteries, pumped hydro storage, or flywheels can be used to store surplus energy generated during times of high availability to be used later when the availability is low.

Grid Integration: Integrating renewable energy sources into the existing power grid is another challenge. The grid infrastructure was designed to work with centralized power generation, and adding distributed generation from renewable sources can cause technical issues like voltage fluctuations and power quality problems.

Cost: Although renewable energy sources have become more cost-competitive over time, the initial investment required for the installation of renewable energy systems can still be high. The cost of renewable energy technologies like solar and wind power is still higher than that of traditional fossil fuel power plants in some cases.

Public Perception: Despite growing awareness of climate change and the need for renewable energy, there is still some resistance to renewable energy development, often based on concerns about aesthetics, property values, or wildlife impacts [37].

1.9 Conclusion

In this chapter, we have provided an overview of some renewable energy concepts (wind, geothermal, biomass, hydro and solar energy). Chapter 2 will focus on a detailed study of photovoltaic systems.

Chapter 2

Solar Photovoltaic System

2.1 Introduction

Solar energy is a renewable energy source that is pollution-free, eco-friendly, and requires minimal maintenance among all renewable sources. Two types of solar energy technologies are currently available, namely solar photovoltaic (PV) and solar thermal [38].

Photovoltaic solar technology is an elegant technology that directly converts sunlight into electricity using panels made of semiconductor cells. It is based on a natural phenomenon called the photoelectric effect, which is certain materials are absorbed incident radiation and emitted electrons to generate an electric current [39].

In this chapter, the operating principle of a photovoltaic cell is presented, as well as the various solar cell technologies and the electrical characteristics of PV cells.

2.2 Principles of solar cell operation

The basic structure of a PV cell is a PN junction as show the following figure 2-1

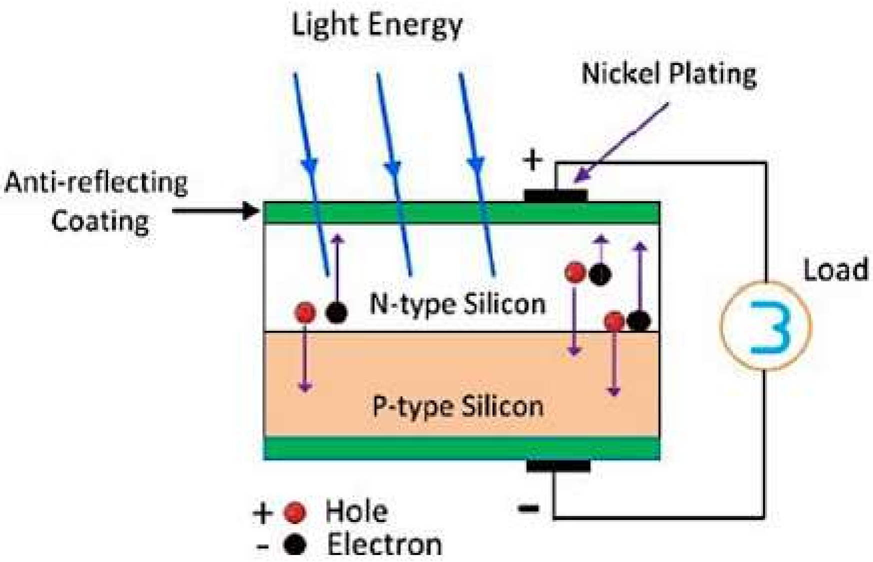

Figure 2-1 *Principles working of solar cell*

When the cell absorbs a photon, if its energy is greater than the band gap of the semiconductor, an electron is able to jump out in the crystal structure creating a hole-electron pair, which normally disappears as the electron recombines with hole. In order to avoid the recombination a barrier is created by doping the silicon, on one side with small amount of a group III element (for ex. Boron) to form p-silicon and on the other side with a small amount of a group V element (for ex. Phosphorus) to form the n-silicon. The presence of the barrier does not allow the recombination, creating an excess of electrons in the n-silicon and a lack of them in the p-silicon. If an external electrical circuit is built the electrons are free to move from the n-silicon to the p-silicon passing by the electrical circuit, thus producing electricity [40] [41].

2.3 Solar cell technologies

The solar cells are classified into three generations as show in figure 2.2 [42].

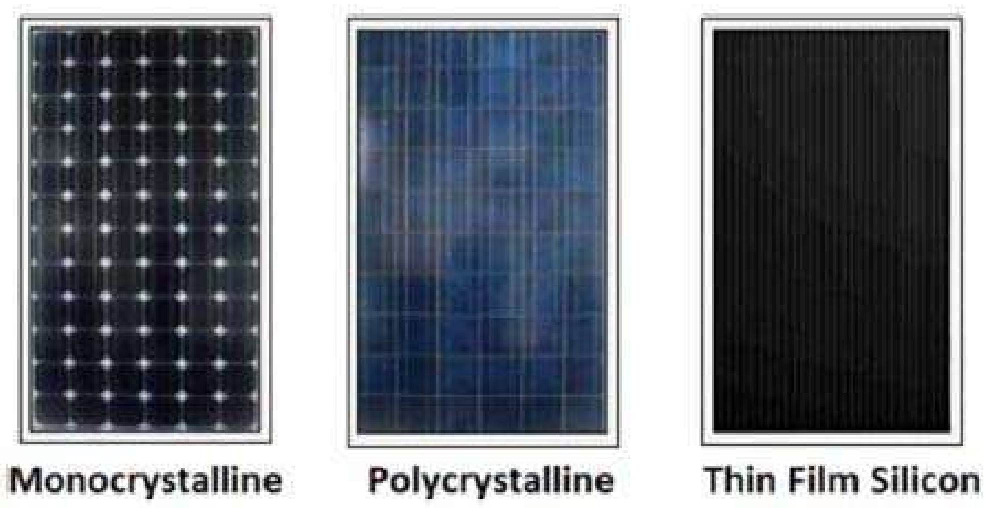

Figure 2-2 Different silicon technologies *[43]*

2.3.1 Monocrystalline Silicon Modules

They offer high efficiency (15-20) % and good heat tolerance characteristics in a small footprint but it is quite expensive.

2.3.2 Polycrystalline Silicon Modules

They offer less efficiency than the monocrystalline modules (13-16) %. Moreover, the process of manufacturing them is simpler and cheaper and also less heat tolerance characteristics in a small footprint.

2.3.3 Thin film.

They offer an efficiency of (4-12) % and heat tolerance characteristics that are less than the crystalline modules. Also, they are available in a price that are slightly higher than the polycrystalline and lower than the monocrystalline modules [44].

2.4 From cells to modules and array

The cells converted solar radiation directly into electricity. It consist various kinds of semiconductor materials. It has two types: positive charge and negative charge shown on figure 2-3. This cell technology are used to design solar cells with low cost as well as high conversion efficiency. When the cell absorbed photons from sunlight, electrons are knocked free from silicon atoms and are drawn off by a grid of metal conductors, pressure a flow of electric direct current. Solar cell PV made up of many chemicals.

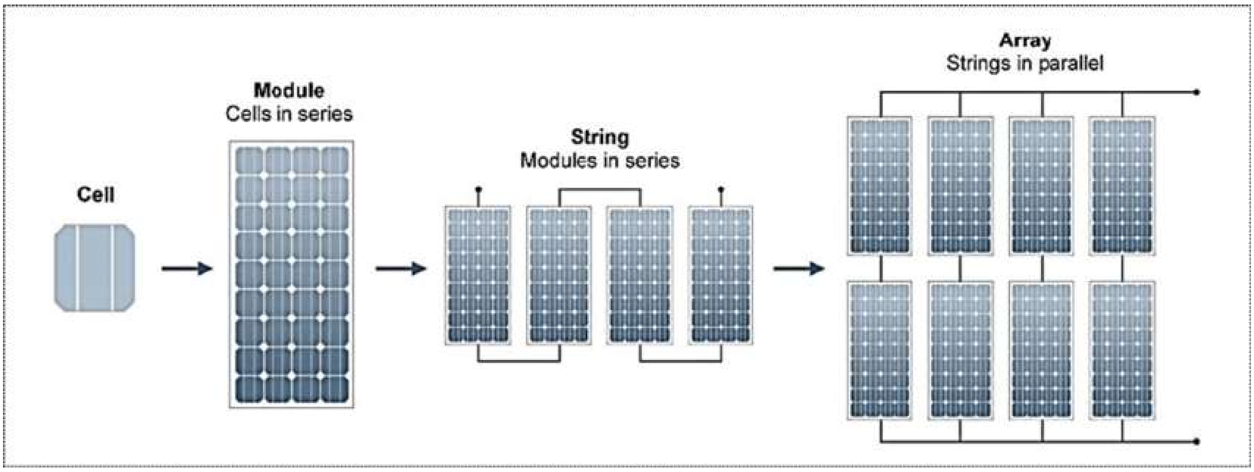

Figure 2-3 *Configuration of cell, module and array [45]*

2.4.1 Photovoltaic Module

A PV module (see figure 2-3) consists of solar cell circuits sealed in an environmentally protective laminate and are the fundament building blocks of PV system. Generally, sizes from 60W to 170W. Usually a number of PV modules are arranged in series and parallel to meet the energy requirement.

2.4.2 Photovoltaic Panel

It includes one or more PV modules assembled as a pre-wind, field instable unit. In this panel PV cell is series connections (see figure 2-3). Solar panels are made up of individual PV cells connected together.

2.4.3 Photovoltaic Array

It is containing of several amount of PV cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. It generates maximum 180W in full sunshine. Large the total surface area of the area of the array, more solar electricity it will produce [48].

2.5 Characteristic of photovoltaic cell/module

A solar cell converts the sunlight into electricity. There are several parameters of solar cells that determine the effectiveness of sunlight to electricity conversion. The list of solar cell parameters is following [46]:

- Short circuit current (I_{SC}),
- Open circuit voltage (V_{OC}) and
- Maximum power point (Pm or Pmax)
- Current at maximum power point (I_m)
- Voltage at maximum power point (V_m)
- Fill factor (FF)
- Efficiency (η)

These parameters can be given by Current-Voltage curve (I-V curve) of a solar cell and power voltage curve as show the figure 2-4.

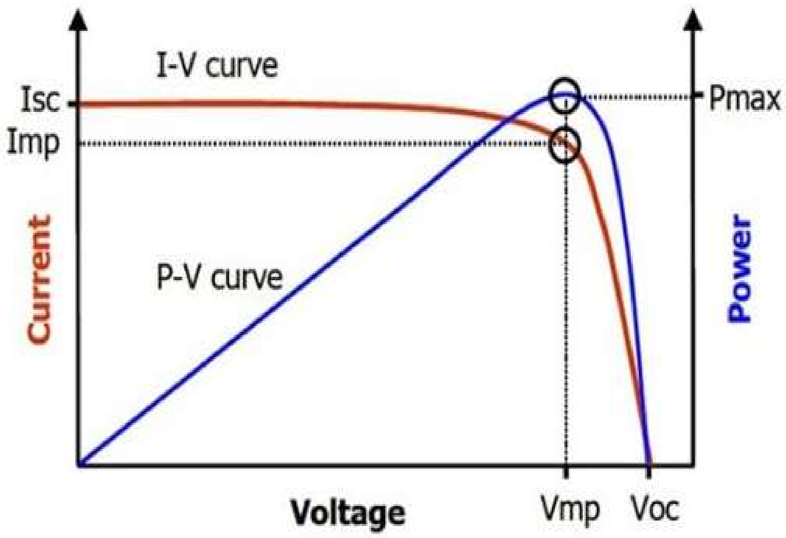

Figure 2-4 *The P-V and I-V curve of solar cell*

Normally, the value of the cell parameters is given by a manufacturer or scientist at standard test conditions (STC) which is corresponding to 1000 W/m^2 of input solar radiation and 25°C cell operating temperature [46].

Short circuit current (I_{sc}): It is the maximum current a solar cell can produce. It is measured in Ampere (A) or milli-ampere (mA). The value of this maximum current depends on cell technology, cell area, amount of solar radiation falling on cell, angle of cell, etc.

Open circuit voltage (V_{oc}): It is the maximum voltage that a solar cell produce. It is measured in volts (V) or sometimes milli-volts (mV). The value of this maximum open circuit voltage mainly depends on cell technology and operating temperature.

Maximum power point (P_m or P_{max}): It is the maximum power that a solar cell produces under STC. It is given in terms of watt (W).

Current at maximum power point (I_m): This is the current which solar cell will produce when operating at maximum power point. The I_m will always be lower than I_{sc}. It is given in terms of ampere (A) or milli-ampere (mA).

Voltage at maximum power point (V_m): This is the voltage which solar cell will produce when operating at maximum power point. The V_m will always be lower than V_{oc}. It is given in terms of volt (V) or milli-volt (mV).

Fill factor (FF): The fill factor is the ratio between the maximum power

(Pmax = Imp×Vmp) generated by a solar cell and the product of Voc with Isc (see Fig. 2-4),

[46]

$$FF = \frac{Imp \times Vmp}{Isc \times Voc} \quad (1)$$

Or

$$FF = \frac{Pm}{Isc \times Voc} \quad (2)$$

Where:

- Im is the Current at maximum power point.
- Vm is the Voltage at maximum power point
- Isc is the Short circuit current
- Voc is the Open circuit voltage
- Pm is the Maximum power point

Here the expression for Pmax or Pm

$$P_m = I_{sc} \times V_{oc} \times FF \qquad (3)$$

Efficiency (h): The efficiency of a solar cell is defined as the maximum output power (P_m or P_{max}) divided by the input power (P_{in}). The efficiency of a cell is given in terms of percentage (%), which means that this percentage of radiation input power is converted into electrical power. P_{in} for STC is considered as 1000 W/m^2. This input power is power density (power divided by area), therefore, in order to calculate the efficiency using P_{in} at STC, we must multiply by solar cell area. Thus, efficiency can be written as [47]:

$$\eta = \frac{Pm}{Pin} = \frac{Isc \times Voc \times FF}{Pin \times A} \qquad (4)$$

Where

- P_m is the maximum output power
- P_{in} is the input power
- A is the solar cell area

2.6 Impacts of different parameters on the I-V & P-V curves behavior

There are five common factors that affect the power generated by solar cells. They are as follows

- The conversion efficiency (η)
- The amount of light (P_{in})
- The solar cell area (A)
- The angle at which day light falls (q)
- The operating temperature (T)

For example, The P-V electrical characteristics of the PV array for different values of irradiation and temperatures are shown in the following figures 2-5 and 2-6 :

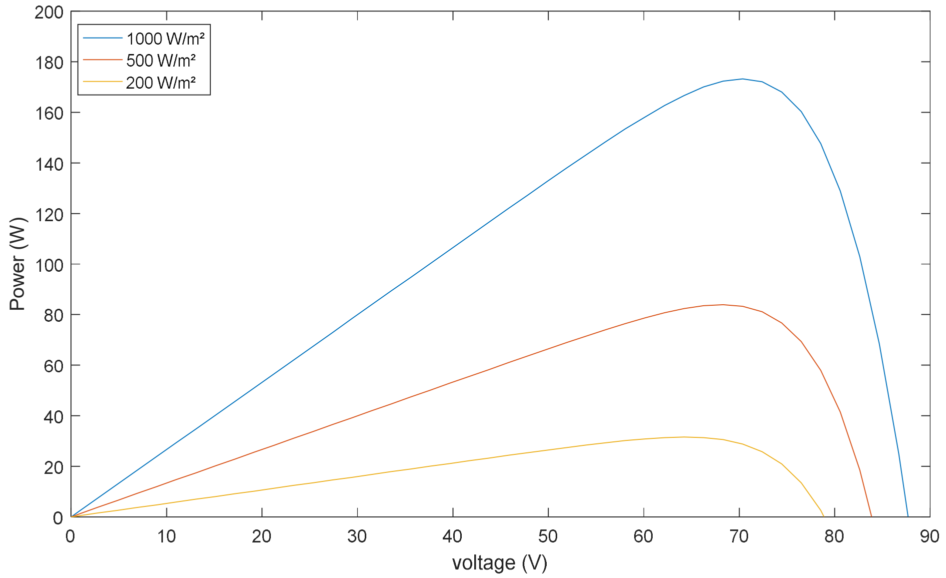

Figure 2-5 *The P-V characteristics for PV array with varying irradiation at 25°C*

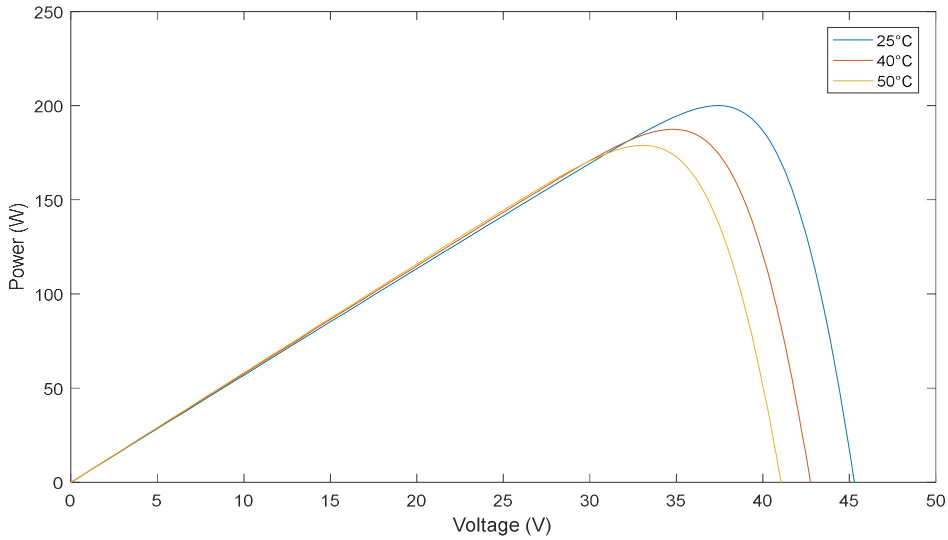

Figure 2-6 *The P-V characteristics for PV array with various temperature at 1000w/m²*

The preceding figures show that the P-V characteristic of a photovoltaic is naturally nonlinear, because the position of the maximum power varies with the irradiation and the PV temperature, and for each wind irradiation and temperature, it is necessary that the system finds the maximum power [48].

2.7 Advantages and Challenges of Solar Photovoltaic Energy Conversion

Like other technologies, the solar PV technology also has its positive and negative aspects or has its advantages and challenges. These are discussed as follows:

2.7.1 Advantages

Advantages of the solar PV technology is listed below:

Abundant source: Solar cell uses solar radiation energy as input, which is a renewable energy source. Solar radiation energy is available in huge quantity as it is abundant. We will not run in the shortage of solar radiation energy in future. On the other hand, the world is already facing the shortage of fossil fuels-based energy sources.

Environmentally benign: The conversion of solar radiation energy into electrical energy does not emit any polluting products and, therefore, it does not cause damage to the environment like the smoke from use of diesel, petrol and coal does.

Decentralized electricity generation: Since solar radiation energy is available everywhere, the solar PV electricity can be generated everywhere in decentralized manner in small quantities as per the need, unlike the coal-based power plant where electricity can be generated only in centralized manner in large quantities. Decentralized electricity generation results in less losses occurring due to transmission of electricity. In the case of solar PV technology, one can have a small solar lantern, a solar PV system for lighting house, a solar PV system for running water pump, or a solar PV system for lighting whole village or even solar PV system for pumping MW of power into grid.

Modular implementation: Implementation of solar PV technology can be modular. Size of a solar PV system for electricity generation can be increased as per the increase in need of electricity. In the case of a diesel generator or a coal-based power plant, size once fixed cannot be changed. If we need to increase electricity, we need to buy another diesel generator or set up another coal-based power plant [49].

2.7.2 Challenges

In principle, solar PV electricity can be generated to fulfill our entire energy requirement. But there are significant challenges to be overcome in order to make wider use of electricity generated using solar PV technology. These challenges are listed below:

PV electricity cost: The conventional energy sources have always been the most cost-effective way to supply the large amount of electricity needed for modern life. Producing electricity using solar PV technology is more expensive. However, the cost of solar PV electricity has been decreasing rapidly, there is further need to reduce the cost in order to make solar PV electricity affordable by all.

Energy fluctuation: In the case of coal-based power plants, companies can easily stockpile coal to meet the ever-changing demand for electricity, especially during peak demand hours. While the solar radiation energy can't be stored to provide energy for future use. Solar radiation is not available in the night time but there is electricity need in night. Also, during the day time peak radiation availability may not match with peak electricity demand. Therefore, a mechanism for effective energy storage and efficient recovery is required.

Location dependency: Fossil fuel power plants can be placed almost anywhere, as long as a railroad or pipeline can reach the site for bringing coal and gas. In contrast, solar PV electricity generation depends on the availability of solar radiation. The availability of solar radiation varies from place to place. At some places it is more and at some other places it is less. Therefore, solar electricity generation is dependent on location where system needs to be installed [50].

2.8 Conclusion

In this chapter, we provided general descriptions of photovoltaic energy and introduced all the components (cell, module, panel) to facilitate a good understanding of PV system functioning. This chapter allowed us to explore the principle of photovoltaic conversion as well as the different technologies used to achieve it.

Chapter 3

Solar Tracking System

3.1 Introduction

The angle of sunlight with respect to solar cell greatly affects the output power. The solar cell produces maximum power (for given light intensity) when sunlight falls perpendicular to the surface of solar cells. When the light does not perpendicular to solar cells, it always gives less output power than maximum possible output power.

So, one should always try to install a solar cell or module in such a way that most of the time sunlight is close to perpendicular, especially in the afternoon time when the intensity of sunlight is high [48].

In this chapter, we will design and implement a mono-axial solar tracker in the laboratory.

3.2 Solar Tracking System

The mono-axial solar tracking system studied in this work is presented in the following Figure 3-1:

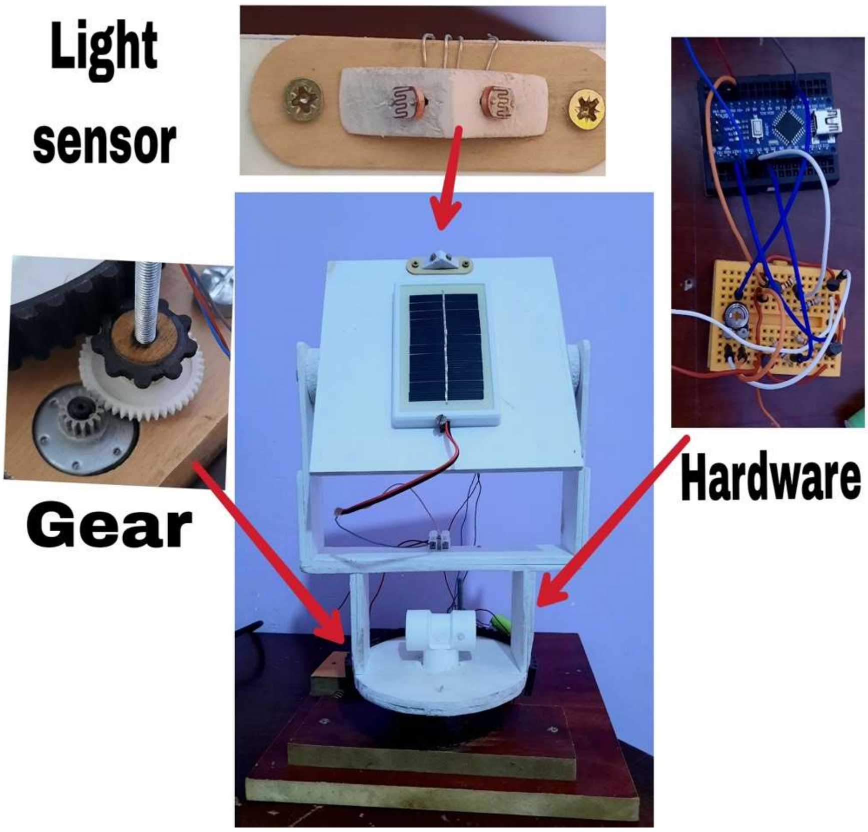

Figure 3-1 solar tracking system

This project consists of using several electronic components to build up the solar tracking mechanism. The main components used are Arduino NANO, light-dependent resistor (LDR), motor DC, and solar panel. This section discusses the specifications of the components used.

3.2.1 Arduino NANO

Arduino Nano is a variant of the Arduino board that is smaller in size compared to the standard Arduino Uno board. Arduino Nano is a compact microcontroller board that utilizes the ATmega328P chip.

The original Arduino Nano was produced by Gravitech and was designed by Gravitech in collaboration with the Arduino team. This Arduino board is particularly suitable for projects that require a compact size and a high level of compatibility with Arduino Uno. Arduino Nano also utilizes the Arduino programming language, which is based on C/C++, enabling users to create prototypes and develop electronic projects similar to other Arduino boards.

Some common uses of Arduino Nano include:

Portable projects: The compact size of Arduino Nano makes it ideal for creating portable electronic projects such as handheld devices, portable sensors, or IoT projects connected to the environment.

Automated control systems: Arduino Nano, with its ATmega328P microcontroller, provides sufficient power for automated control in projects like autonomous vehicles, motor control, or automatic control systems in a wide range of applications.

DIY projects: Arduino Nano is a popular choice for Do-It-Yourself (DIY) projects that require a compact form factor and can be easily integrated into limited spaces.

Overall, Arduino Nano offers a versatile and compact solution for prototyping and developing various electronic projects. [51], [52].

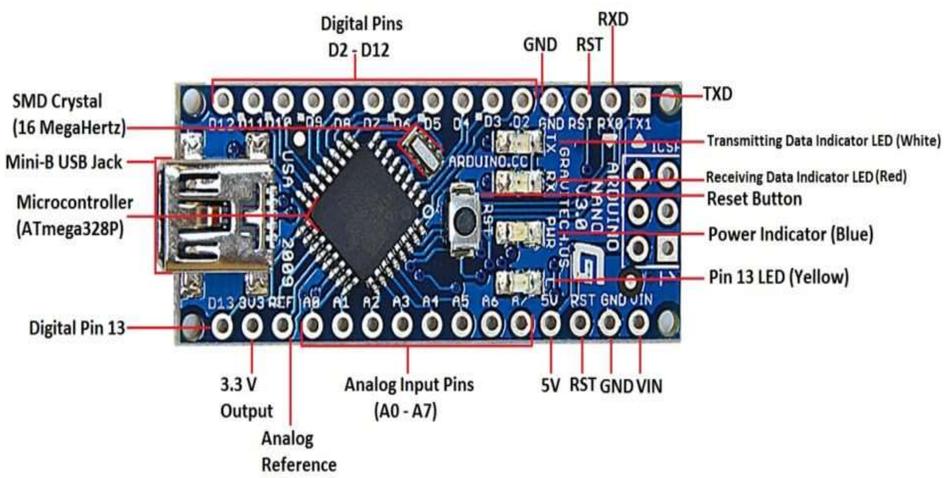

Figure 3-2 *Arduino Nano Pinout*

3.2.1.1 Atmega328P

The ATmega328 (figure 3-3) is a low-power CMOS 8-bit microcontroller grounded on the AVR enhanced RISC (reduced instruction set computer) armature. By executing important instructions in a single clock cycle, the ATmega328/P achieves throughputs close to 1 MIPS (Million instructions per second) per MHz This empowers system contrivers to optimize the device for power consumption versus processing speed. In this work, we target an 8-bit AVR microcontroller, the Atmel ATmega328P. It has 32 KB of flash memory, 1 KB of EEPROM, and 2 kB of RAM [53].

The figure below represents the pinout configuration of ATmega328P in SMD package:

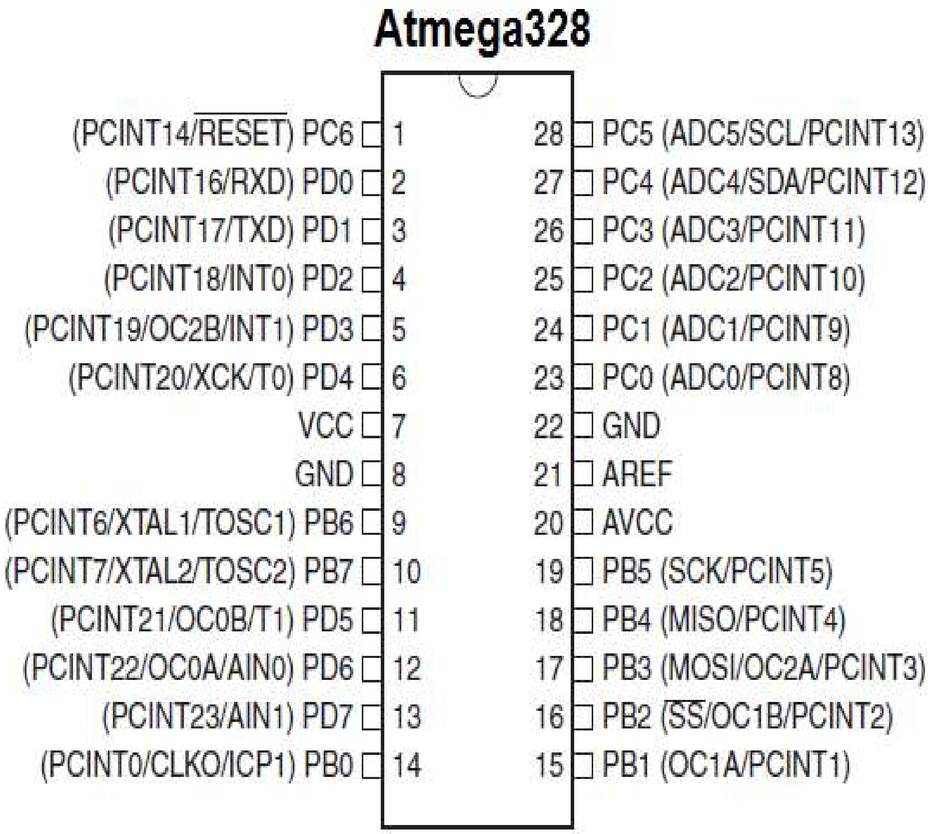

Figure 3-3 *Pinout configuration of ATmega328P*

3.2.2 Light Dependent Resistor (LDR)

A Light Dependent Resistor (LDR) or a photo resistor (see figure 3-4) is a device whose resistivity is a function of the incident electromagnetic radiation. Hence, they are light sensitive devices.

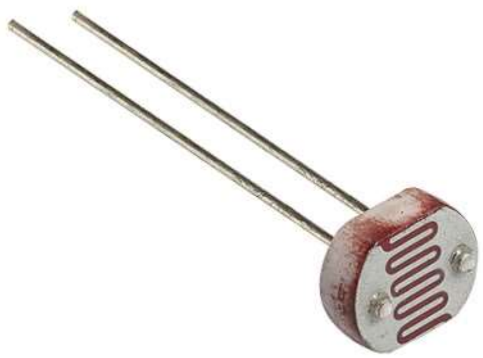

***Figure 3-4** Light Dependent Resistor (LDR)*

They are also called as photoconductors, photo conductive cells or simply photocells. They are made up of semiconductor materials having high resistance. There are many different symbols used to indicate an LDR, one of the most commonly used symbols is shown in the figure 3-5 below. The arrow indicates light falling on it [54].

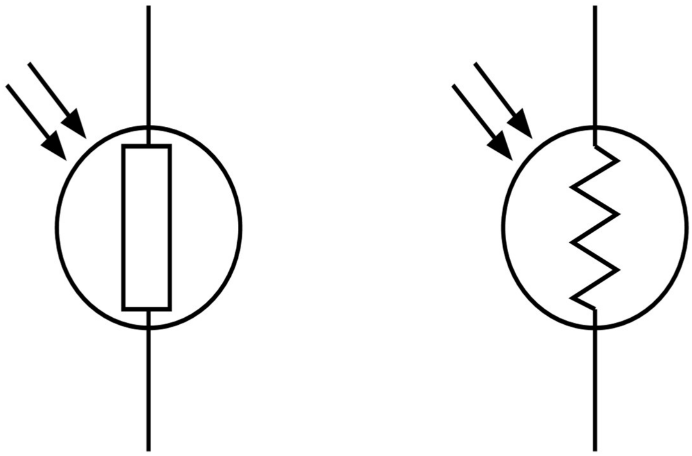

***Figure 3-5** symbol of LDR*

3.2.3 Solar panel

The solar panel is an electrical device that can convert light energy from the Sun into electricity by the photovoltaic effect. Electrical parameters such as voltage, current, and resistance will be varied when the solar cell is exposed to sunlight [55].

Figure 3-6 *solar panel*

3.2.4 Motor DC

A DC motor (figure 3-7), or direct current motor, is a type of electric motor that converts electrical energy into mechanical energy. It operates using the principles of electromagnetism and is commonly used in various applications, ranging from small household appliances to industrial machinery.

Figure 3-7 *Direct current motor*

The basic structure of a DC motor consists of a stator (stationary part) and a rotor (rotating part). The stator typically contains permanent magnets or electromagnetic windings, while the rotor consists of a coil or armature.

When a direct current is supplied to the motor, it creates a magnetic field within the stator. This magnetic field interacts with the magnetic field produced by the rotor, causing a torque that rotates the rotor. The direction of the current flow determines the direction of rotation of the motor [56].

DC motors offer several advantages, including:

- Speed control: DC motors can be easily controlled by adjusting the voltage applied to them, allowing for precise speed control.
- High starting torque: DC motors provide high torque at startup, making them suitable for applications that require quick acceleration.
- Reversibility: By reversing the direction of the current flow, the rotation direction of the motor can be easily changed.
- Simple construction: DC motors have a relatively simple design and are often more compact compared to other motor types [57].

3.2.5 H bridge

An H-bridge (figure 3-8) is an electronic circuit configuration commonly used to control the direction and the speed of a DC motor. It is named after its shape, which resembles the letter "H" when drawn schematically [58].

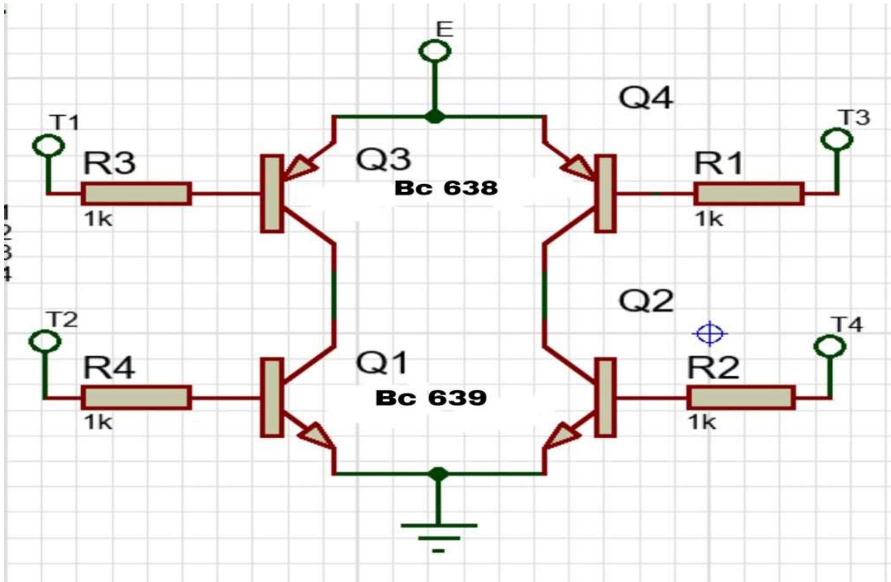

Figure 3-8 *schematic of the H-bridge*

The H-bridge consists of four switches (typically bipolar transistors or MOSFETs) arranged in a specific configuration. The switches are connected to the motor's terminals in such a way that they can control the current flow and direction. The switches are usually driven by a control circuit that provides the appropriate signals to turn them on or off [59].

By selectively turning on and off the switches in the H-bridge, the polarity of the voltage applied to the motor can be changed, allowing the motor to rotate in either direction [60].

3.3 Description of solar tracking system operation

The solar tracking system consists of two LDRs placed in strategic locations to detect the intensity of sunlight.

These LDRs act as sensors and provide input to the Arduino Nano, which processes the data and controls the movement of the DC motor.

The Arduino Nano reads the LDR analog output and determines the direction in which the solar panel should be oriented. If one LDR detects more light than the other,

the Arduino sends the appropriate signals to the H-bridge circuit, which controls the rotation of the DC motor.

The H-bridge allows the engine to move forward or backward, allowing the solar panel to follow the movement of the sun.

The Arduino Nano continuously monitors the LDRs and adjusts the motor rotation according to the changing light intensity. By continuously aligning the solar panel with the position of the sun.

We add a gear to the motor in order to increase the torque and allow the solar panel holder to move easily and smoothly, and since all the components are handmade

We also installed a potentiometer that controls the movement of the solar panel and direct it to the place where the intensity of the light strong enabling the maximum value to be obtained for electric power.

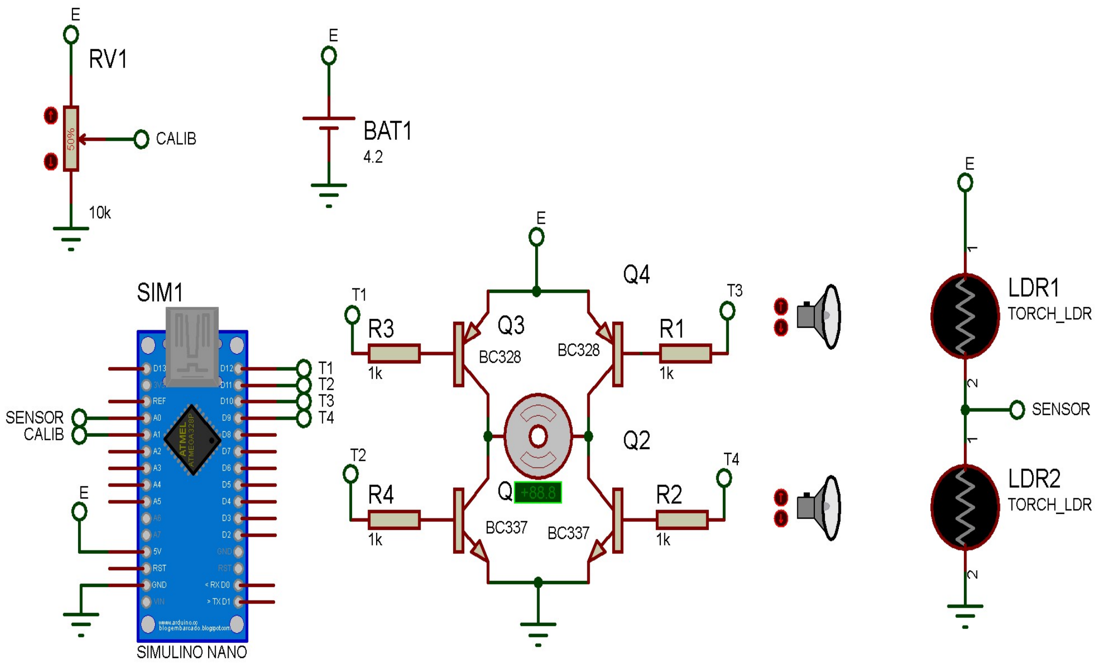

Figure 3-9 Schematic of solar Tracking system

The Arduino-Nano board is a programmable board, the solar tracking program under the Arduino IDE used in this work is given as follows:

```
void setup() {
  Serial.begin(9600);

pinMode(12, OUTPUT);
pinMode(11, OUTPUT);
pinMode(10, OUTPUT);
pinMode(9, OUTPUT);
}

void loop() {

if (analogRead(A0)-analogRead(A1)>5)
   {  digitalWrite(12,0);
       digitalWrite(11,0);
       digitalWrite(9,1);
        digitalWrite(10,1);}

else if (analogRead(A0)-analogRead(A1)<-5)
     {digitalWrite(12,1);
        digitalWrite(11,1);
        digitalWrite(9,0);
        digitalWrite(10,0);}

else {digitalWrite(12,1);
        digitalWrite(11,0);
        digitalWrite(9,0);
        digitalWrite(10,1);}

}
```

3.4 Results and Discussion

This section discusses the result that obtained from the conducted experiments. The experiments had done to compare the result between solar panel without tracking system and solar panel with a tracking system towards the sunlight. The location for experiments is at the area of University Tissmsilt. The experiments were carried out on 1 June 2023 and. All data and results are taken from 09:00 hours until 18:00 hours and the weather is in good condition

The currents, and the overall efficiency between the static solar panel and solar with tracking mechanism is presented in figure 3-9

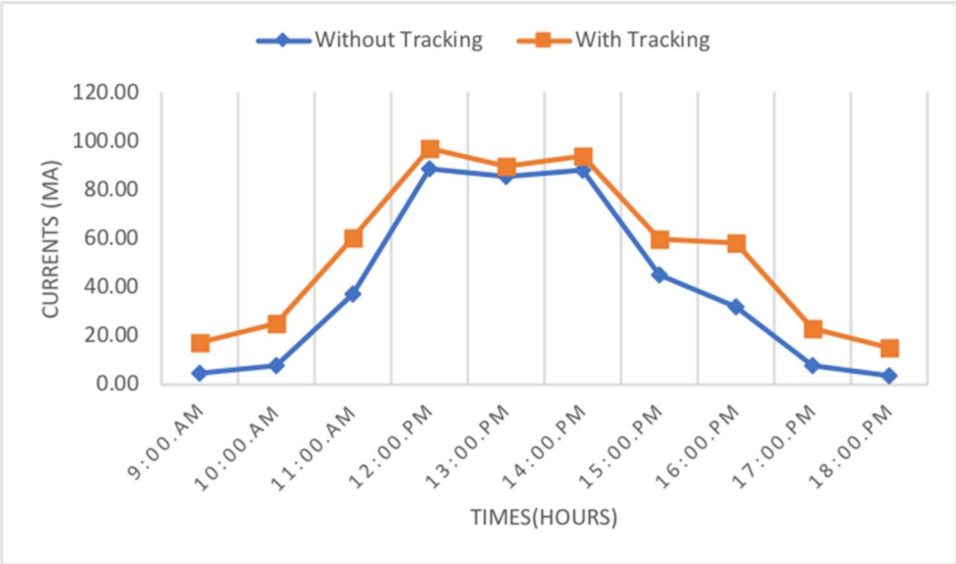

Figure 3-10 *Currents produced by a PV panel with a solar tracker compared to a fixed PV panel.*

The graph presents the results that compare the fixed solar panel to the solar panel with a tracking system Based on the comparison graphs; solar panel with solar tracking mechanism has higher performance than static solar panel while there is a similar value from 12.00 pm until 2.00 pm.

Furthermore, the efficiency (30.87%) is highly significant, indicating that the panel with the tracking system is also superior to the Panel static. However, the following results indicate that the panel with the system allows for better collection of solar energy compared to the fixed panel.

3.5 Conclusion

In this chapter, we presented the control circuit of the solar tracker using photoresistors (LDR) for solar light to optimally orient the PV panel.

Based on the result obtained, the performance of solar panels had an increased efficiency of 30.87% after being implemented with a solar tracking mechanism. It is proved the advantage of a solar tracking mechanism throughout the day as it can track the Sun's position compared with static solar panels. This allows the solar panel to absorb more solar irradiance to generate electricity

General Conclusion

This work aims to study to optimizing the energy efficiency of a photovoltaic system by using a tracking solar system.

In the chapter one, we have provided an overview of some renewable energy concepts (wind, geothermal, biomass, hydro and solar energy).

Then in chapter two, we provided general descriptions of photovoltaic energy and introduced all the components (cell, module, panel) to facilitate a good understanding of PV system functioning. This chapter allowed us to explore the principle of photovoltaic conversion as well as the different technologies used to achieve it.

Finally, in the last chapter, we presented, the control circuit of the solar tracker using Arduino nano to optimally orient the PV panel.

The results obtained demonstrate the proper functioning of the proposed tracking system.

We can conclude that the photovoltaic tracker systems with appropriate control systems can be considered an important factor in increasing the electrical power by 30.87%, compared to the fixed photovoltaic system.

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Abstract:

This work presents the design and construction of a solar tracking system capable of orienting the photovoltaic (PV) panel towards the sun and thus improving the efficiency of the PV system. Firstly, we introduce the different types of renewable energies, their advantages, and disadvantages. Then, we provide a detailed study on photovoltaic solar energy. Finally, we present the sizing and design of a single-axis tracking system for a PV panel based on an Arduino Nano board and light-dependent resistors (LDRs).

Keywords: system, solar tracking, PV, Arduino Nano, LDR.

Résumé :

Ce travail présente le dimensionnement et la conception d’un système de poursuit solaire capable d’orienter le panneau photovoltaïque (PV) vers le soleil et donc d’améliorer le rendement de PV.

Tout d’abord nous avons présenté les différents types des énergies renouvelables, leurs avantages et leurs inconvénients, ensuite une étude détaillée sur l’énergie solaire photovoltaïque est présentée. Enfin, nous avons présenté le dimensionnement et la réalisation d’un système suiveur mono-axe d’un PV à base d’une carte Arduino nano et des photorésistances (LDR).

Mots clés : Système, Poursuit Solaire, PV, Arduino nano, LDR

ملخص:

يقدم هذا العمل تصميم وصناعة نظام تتبع شمسي قادر على توجيه اللوحة الكهروضوئية نحو الشمس وبالتالي تحسين كفاءة النظام الكهروضوئي(PV) .

أولا، قمنا بعرض مختلف انواع الطاقات المتجددة مع ذكر مزايا وعيوب كل نوع. ليتم بعدها التطرق لدراسة مفصلة عن الطاقة الشمسة الكهروضوئية، وأخيرا، قمنا بتقديم تصميم وصناعة نظام تتبع شمسي أحادي المحور للوحة الكهروضوئية يعتمد على أردوينو نانو ، ومقاومات ضوئية (LDRs).

الكلمات المفتاحية: نظام، التتبع الشمسي، لوح شمسي، أردوينو نانو، مقاومة ضوئية.