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Theme

Dimensioning steps of a Direct-Coupled PhotovoltaicWater Pumping System on real well: Case study traditional well in desert area

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Publicly supported on 11/06/2022

In front of the jury composed of:

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Appraisal thanks for Allah who gave us strength, health and success to complete this work to the fullest

Dedicate

To whom was the reason for my existence in this life and made me witness this day and who showered me with love and giving .my mother and my father.

To those who were a mentor, guide and encouragement.

My life partner Ahmed, my sister Asma and my friend Chrifa.

To the one who participated with me every second in preparing this work and contributed to it with everything she had, my friend and colleague Maria.

I dedicate to you the fruit of years of work, effort and fatigue.

Nour el houda

Dedicate

To whom was the reason for my existence in this life and made me witness this day and who showered me with love and giving .my mother and my father.

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I dedicate to you the fruit of years of work, effort and fatigue.

Maria

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Thanks to the evaluation committee

Maria & Nour El-houda

June 2022

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PV: photovoltaic

PVPS: photovoltaic pumping system

δ: declination of the sun

d: is the day of the year

h: sun height

H: Hour angle of the sun

a: Azimuth of the sun

AM: air-mass

Id: direct radiation

Idh: diffuse radiation

GI: global radiation

e: the charge of the electron,

n: the non-ideality factor of the junction,

Voc: open circuit voltage

Isc: short-circuit current

f: the shape factor

h: Energy efficiency

E: Irradiation in W/m2

S: the surface of the cell (or of the module)

Wp: the peak power of a module

Ep: energy produced

Ec: energy consumed

K: correction coefficient

Ep: energy produced per day

Ir: daily irradiation

N: number of days of autonomy

HMT: total head

Hg: geometric height

Ns: static level of a well

Nd: dynamic level of a well

Q: theoretical flow

C: hydraulic constant

P: Electrical power

K: Boltzmann's constant,

T: The effective temperature of the cell in Kelvin,

β : Altitude.

I_0 : diode saturation current.

I_{max} : maximum current

V_{max} : maximum voltage

P_{max}: maximum value of the power

N_s : number of PV model series .

N_p : number of PV model parallel

E_h : the hydraulic energy (Wh/day).

ε_p : the pump efficiency .

E_e : electric energy (Wh) .

D_h : daylight pre hours .

I_{TB}: Test pump direct current.

E: Irradiation at the level of solar panels per square meter.

P1: simulated well depth deep well.

P2: simulated well depth of shallow well.

P3: The water level in the tank.

FF: Fill factor

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GENERAL INTRODUCTION

In light of the changes that the world is witnessing in all fields, from science and technology to the economic conditions of countries, as well as changes in the living conditions of people in all societies, problems have arisen that require a solution that meets the needs. Among these needs is the availability of water and electricity, which has become a great demand, especially in remote areas. arid and semi-arid.

As it is known that the world depends heavily in providing electricity and other energy that man needs in his life on resources or non-renewable sources such as oil and raw materials, but the high demand led to the excessive and irrational consumption of these sources and this resulted in an imbalance in the delay The environment due to the methods of extracting these materials because they are ways of polluting the environment and resulting in many other dangers to human life and also the lack of stock or reserves of these sources.

That is why scientists resorted to renewable sources and harnessed them for use to meet the demand as a solution to the problem. Among these sources, we chose solar energy, which is clean and environmentally friendly energy because the principle of its work depends on the rays emitted by the sun, which is a very rich source. Solar energy is also used in two different ways: Thermal and optical, and each of them has different uses in this work. We chose to use them to produce electricity.

For this reason, scientists resorted to renewable sources and harnessed them for use to meet the demand as a solution to the problem. Among these sources, we chose solar energy, which is clean and environmentally friendly energy because the principle of its work depends on the rays emitted by the sun, which is a very rich source and covers all parts of the globe and Algeria from Countries that are characterized by a large area, where desert areas cover 75% of their total area. It is also considered one of the largest deposits of solar energy in the world in terms of the number of sun hours in it, which is estimated at 3900 hours annually. Solar energy is also used in two different forms: thermal and optical, and each of them It has different uses in this work, we chose to use it to produce electricity.

Because of this terrain, the residents of these areas need the availability of electricity to extract groundwater to extract it as drinking water or irrigation for the grazing lands. We find a lack of nutrition or electrical networks in these areas, so the exploitation of solar energy has become a solution to this problem. This is what is called solar pumping.

Accordingly, the main outlines of this memory sheet are organized as follows: Chapter one gives an overview about the solar and water potential, highlighted in the region. The basic concepts of photovoltaics and the conversion phenomena is discussed in details in Chapter two. The sizing steps of a PV water pumping system is discussed and presented adequately in Chapter three, while the analysis of the experimental data is discussed and commented in Chapter four. Finally, the main conclusions are provided at the end.

Chapter 01

Solar and water potential

1.1 Introduction:

With the increasing demand for electrical energy, especially in areas far from power plants or to the electrical network, such as some desert areas or agricultural lands... Solar panels have become the appropriate solution to meet the needs, due to its advantages such as being clean energy and not polluting the environment Which has become one of our priorities to maintain and ease of installation.

One of the necessary needs is the presence of water in our daily life, but its availability in these areas is difficult, so their resident's resort to extracting water from the ground, and this is done by digging with bales using electricity, and all this is based on measurements the appropriate location.

1.2. Solar energy

The sun it is a great ball of hot gases with diameter 1.4-million-kilometer, thermonuclear furnace fusing hydrogen atoms into helium. The resulting loss of mass is converted into about 3.8×10^{20} MW of electromagnetic energy that radiates outward from the surface into space [1]. This atom is an atom of abundant light, which explains the presence of the amount of light emitted from the sun, which spreads out into space and collides with solid bodies, including the planet Earth.

1.2.1. Solar Spectrum

Radiation is the most suitable means of transferring energy to planets, such as the Earth. One practical characteristic describing it is wavelength or frequency so that we may distinguish different ranges in the electromagnetic spectrum.[3]

Electromagnetic emissions from the sun extend across the electromagnetic spectrum from the highly energetic x-ray region through the ultraviolet, visible, and IR portion of the spectrum to the far IR and radio region. These emissions interact with Earth's own electromagnetic and atmospheric envelope, resulting in large variations in the magnitude of solar radiation available for conversion into other forms of useful energy. Most solar energy conversion systems utilize only part of the solar spectrum.[4] Different kinds of electro-magnetic radiation vary according to their wavelength. (Figure 1.1) shows the most important categories of electromagnetic radiation:

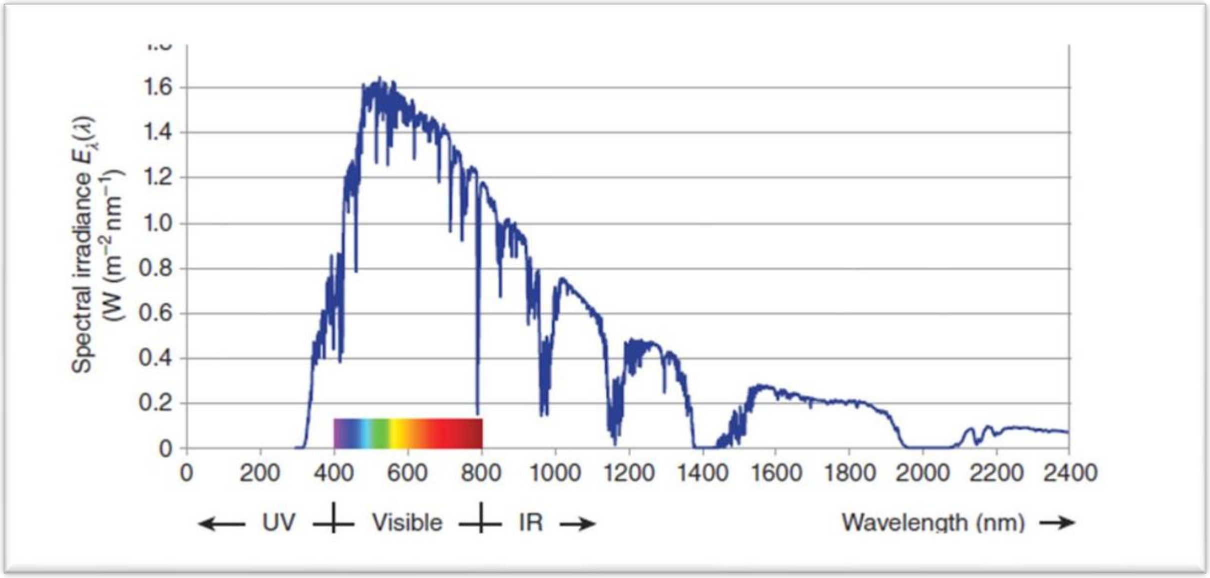


Figure 1.1: Spectrum wavelengths.

1.2.2. Air mass:

The atmospheric characteristic known as air mass (AM) has a significant impact on the solar spectrum. It is directly proportional to the shortest distance traveled by sunrays through the atmosphereon their way to the Earth's surface. As the sun's angle approaches the horizon, the solar intensity reachingthe ground is diminished as the air mass in the way of the rays increases. The pinnacle of solar intensityat the Earth's surface is commonly estimated to be 1kW/m2, but this varies depending on cloudiness, climatic conditions, and seasonal changes. [10]

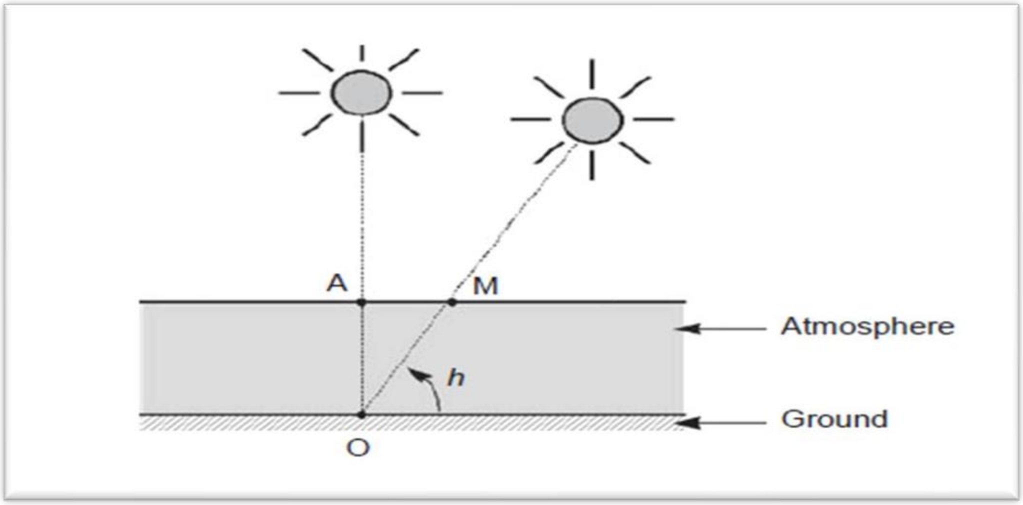


Figure 1.2: Definition of air mass.[11]

This is mostly determined by the Sun's angular height, h, as previously described (Figure 2.9). The length of the Sun's route through the atmosphere can be calculated using the coordinates O, A, and M, as well as the angle h given in Figure 2.11: [11]

$$\boldsymbol{OM = \frac{OA}{sinh}} \qquad \textbf{1.2}$$

Therefore, air mass :

$$\boldsymbol{Airmass = \frac{OM}{OA} = \frac{1}{sinh}} \qquad \textbf{1.3}$$

1.2.3. Solar radiation

The radiation that reaches the Earth’s surface varies in terms of its arrival method and quantity as well, and this is due to the difference in wavelength as shown in the previous figure (1.2). On this basis, we can define the following forms of radiation:

- Direct radiation (direct beam) DNI.
- Diffuse radiation(scattered) DHI.
- Reflected radiation.
- Global radiation GHI .

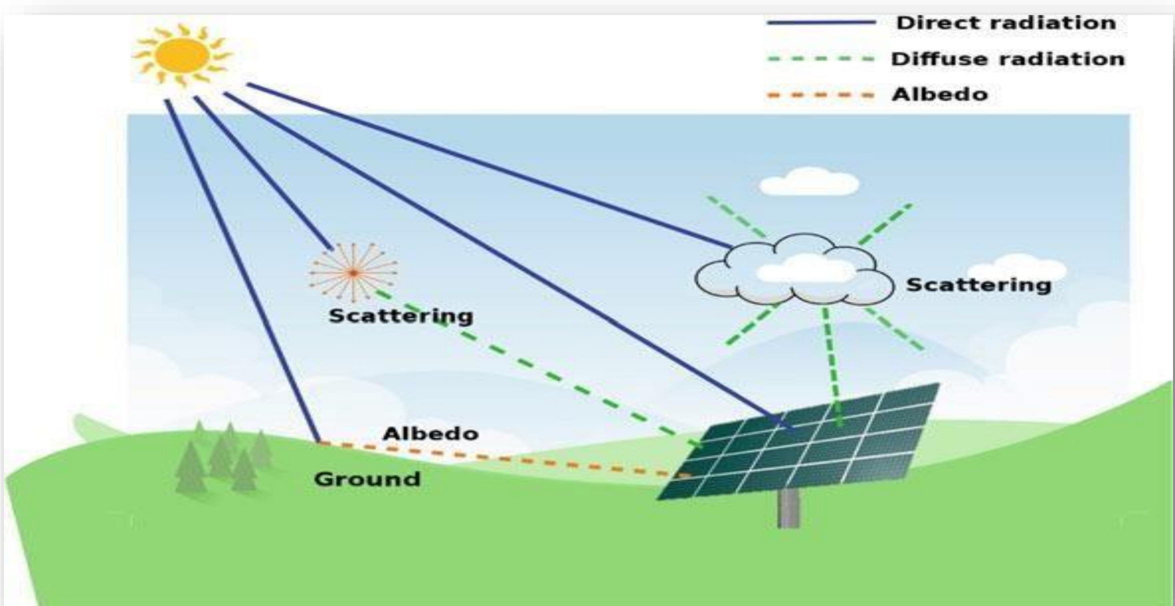


Figure 1.3 : Solar radiation direct, diffuse, reflected.

1.2.4. Type of radiation

a. Direct radiation (Beam):

It is the radiation whose path is from the sun directly to the surface of the earth without being exposed to any obstacles that change its path or scatter it to several other different directions. It also forms a right angle with the inclined surface. If is the angle of incidence of the beam radiation on the tilted surface, it is simple to show that the instantaneous beam radiation on the surface per unit area is [2] :

$$I_{b,c} = I_{b,N} \cos i \qquad \textbf{(1.4)}$$

Diffuse radiation (Scattered) :

It is the radiation that has different, unspecified directions, due to its exposure to obstacles that change its path from the sun to the surface of the earth, such as clouds, air, water ... and it can be calculated by the following equation:

$$I_{d,c} = I_{d,h}(1 + \cos Q)/2 = I_{d,h} \cos^2\left(\frac{Q}{2}\right) \qquad (1.5)$$

b. Reflected radiation:

It is radiation similar to scattered radiation, except that it has one direction, unlike scattered radiation, it can be calculated by the following equation:

$$I_{r,c} = I_h \, \rho \qquad \textbf{(1.6)}$$

c. Global radiation

The global radiation of the sun on a surface inclined at an angle of inclination and azimuth is the sum of the scattered rays and the reflected rays:

$$I_G(\mathbf{B}) = I_r(\mathbf{B}) + I_d(\mathbf{B}) + I_b(\mathbf{B}) \qquad (1.7)$$

1.2.5. Solar radiation measurement technology

The Radiometric Sun-tracker: It is possible to rely on a device to measure sunlight in its three forms, equipped with a tracking system consisting of two main parts:

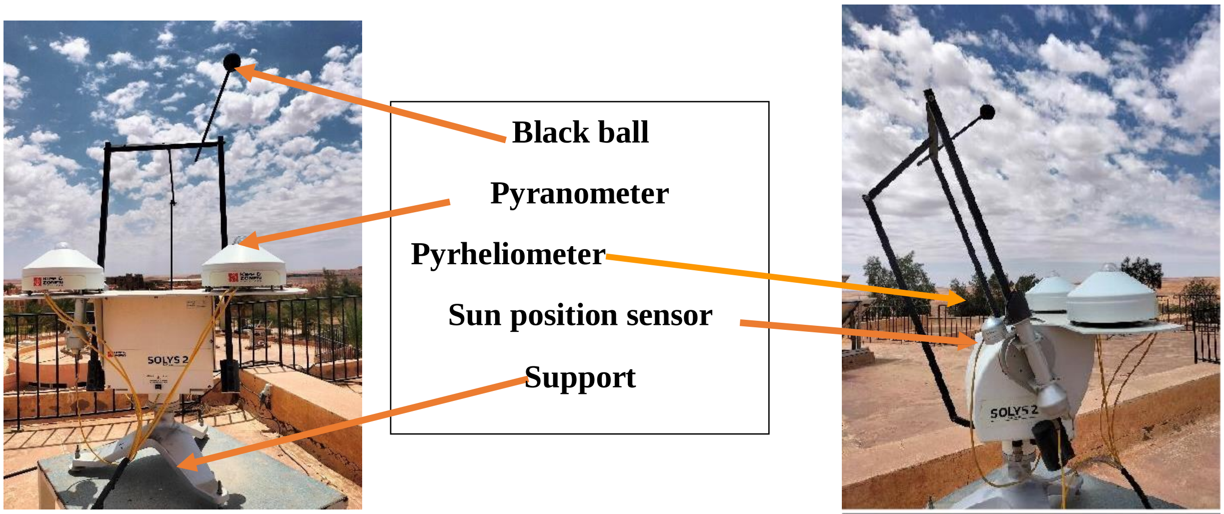


Figure 1.4: Radiometric Sun-tracker, installed at URAER, Ghardaia.

a) The pyranometer:

The pyranometer measures the reflected and scattered sunlight on the horizontal surface, as the hemisphere on the top of the device gives it a greater breadth to receive the rays (works to collect sunlight from different sides) and it is also equipped with another ball that blocks the sun's rays to measure the scattered rays.

b) The pyrheliometer:

where it is directed directly towards the sun to measure direct rays with a length of about 0.2 to 0.4 micrometers.

1.2.6. Coordinates of a location on the Earth's surface

To determine a location on the Earth's surface, we rely on coordinates to help us achieve this:

- **Longitude:**

The angle between the Greenwich line and the site line. The rotation of the Earth in an estimated extension of 24 hours also constitutes a 360° rotation, and thus every hour corresponds to 15° formed from the longitude, denoted by **G.**

- **The latitude:**

it is the angle between the equator and zenith which is perpendicular to the surface, denoted by **L** .

- **Zenith:**

is the angle between the site to sun line and the vertical at the site?

1.2.7. Sun coordinates

As it is known, due to the movement of the earth around the sun, the position of the sun changes during the day, and this results in other changes that occur on the surface, the most important of which are:

a) Sun declination:

As the earth revolves around the sun for a whole year, the sun forms an angle with the surface of the earth, or if you will, with respect to the equator, where it is estimated at +23.45° in relation to the north of the equator and -23.45° in relation to the south of the equator (as shown the figure 1.5), and this is what is called the declination of the sun **δ.**

It is calculated by using equation:

$$\boldsymbol{\delta = 23.45 \sin\left[\frac{360}{365}(d - 81)\right]} \qquad \textbf{(1.8)}$$

Where n is the day number in the year (i.e., d=1 for January 1, d=32 for February 1…etc.).

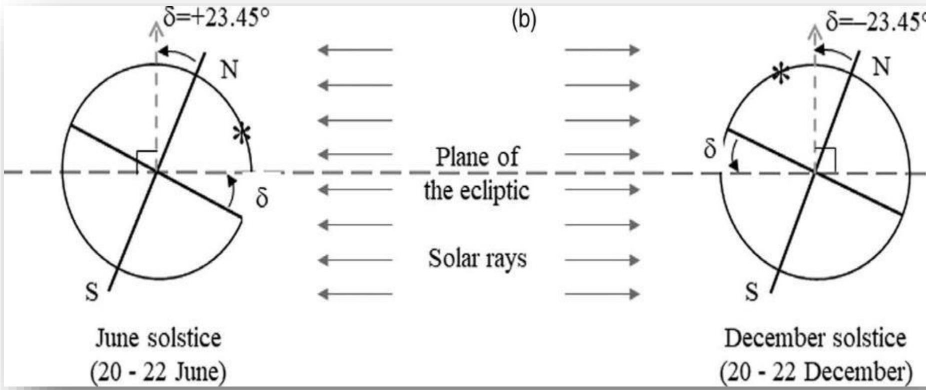


Figure 1.5: Declination angel.

It is also followed by the reversal of the seasons, and in each season, we encounter a special day, either in which the tide of the night is longer than the day, or vice versa, or it is equal, and these cases enable the study of the deflection of the sun in an easier and faster way.

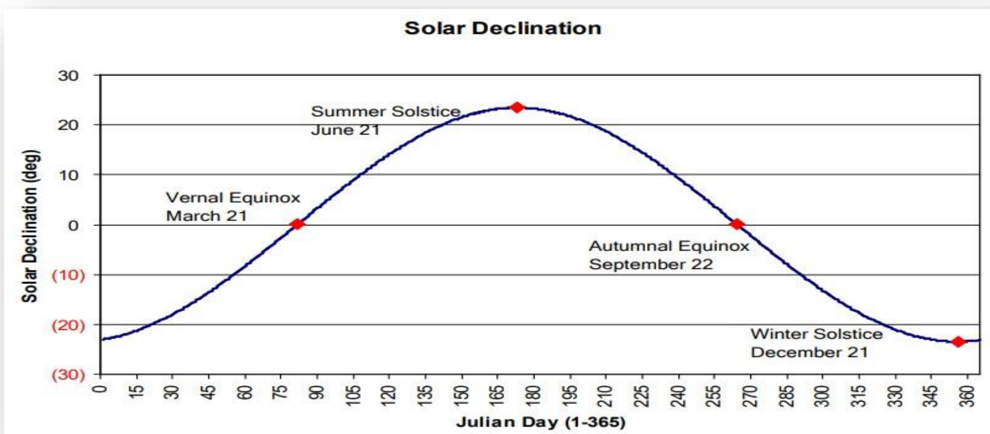


Figure 1.6: Annual variation solar declination.

- The position of the sun can be described at any time by two angles, the altitude and azimuth angles:

b) The altitude:

The solar altitude angle, also called the solar elevation angle. This angle is formed by the ray emanating from the sun and the surface reaching it, denoted by **β**, is calculated by the following relationship:

$$\beta_{N} = 90° - L + \delta \qquad (1.9)$$

c) The azimuth:

The azimuth (a) is the angle between the meridian of the place and the vertical plane passing through the sun a (Figure 1.7) . It is given by the following relationship:[5]

$$\sin \emptyset_s = \frac{\cos \delta * \sin H}{\cos \beta} \qquad (1.10)$$

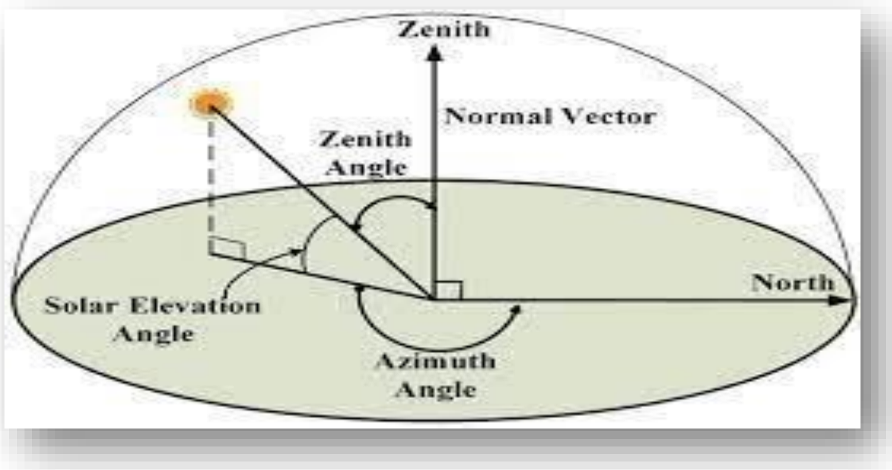


Figure 1.7: Azimuth angle**.**

d) Hour angle:

The hour angle is the number of degrees that the earth must rotate before the sun will be directly over your local meridian.

As the hourly rotation of the earth to rotate 360◦ in 24 h, or 15◦/h, the hour angle can be described as follows: .[1]

$$\mathrm{H} = \left(\frac{15°}{\mathrm{hour}}\right).(\boldsymbol{hours\ before\ solar\ noon}) \qquad (1.11)$$

1.2.8. The sun Coordinate in the clear Sky:

Example:

Find the altitude angle and azimuth angle for the sun at 10:00 AM solar time in **Ghardaïa** Latitude 32° on 7 April.

Solution:

Firstly, calculate the declination solar by using equation: $\delta = 23.45 \sin\left[\frac{360}{365}(n-81)\right]$,7 April is the ninety-seven day on the year so:

$$\text{A.N: } \delta = 23.45 \sin\left[\frac{360}{365}(97-81)\right] = \boldsymbol{6.38°}$$

Then, since 10:00 AM is hours before solar noon so we can calculate hour angle using equation below:

$$H = \left(\frac{15°}{\text{hour}}\right) \Rightarrow \text{A.N: } H = \frac{15}{h} \cdot (10\, h) = \boldsymbol{150°}$$

- The altitude angle is :

$$\sin(\beta) = \cos(L)\cos(\delta)\cos(H) + \sin(L)\sin(\delta)$$

$$\sin(\beta) = \cos(32°)\cos(6.38°)\cos(150°) + \sin(32°)\sin(6.38)$$

$$\sin(\beta) = -0.6709$$

$$\beta = \sin^{-1}(-0.6709) = \boldsymbol{-42.1}°$$

- The azimuth angle is :

$$\sin \emptyset_s = \frac{\cos\delta\ \sin H}{\cos\beta}$$

$$\sin \emptyset_s = \frac{\cos(6.38°)\sin(150°)}{\cos(-42.1)} = 0.6697$$

So the arcsine is : $\emptyset_s = \sin^{-1}(0.6697) = \boldsymbol{42}\ °$

1.3. Water potential

1.3.1. Basic concept

a) Water resource:

The Earth is geologically divided into:

- Atmosphere.
- Hydrosphere.
- Stone cover.

The blue color appears on most of the Earth's surface with small areas of land, so it was called the blue planet. Water occupies a large area of the Earth's surface, estimated at 71%. The water on the surface of the earth is divided into salt water that we find in oceans and lakes, and fresh water at the level of rivers, ponds and some oceans.

As it is known that the earth consists of several layers of different composition and characteristics that allow water to pass through it and others do not allow it to pass through and this is the reason for the formation of groundwater that is in the water-bearing layer.

The sources of water on the surface of the earth vary, and their forms and nature vary, due to the large area they occupy on the surface of the earth. Among these sources are:

Ocean and sea water, rain water, river water, lake water, ground water, mineral and hot water.

b) The Groundwater:

Groundwater is found inside reservoirs in the ground (which is a bedrock or sedimentary layer that is able to contain an amount of water and consists of non-incorporated materials such as sand and gravel or compact rocks such as sandstone or gravel limestone) or in the voids and cracks between the soil grains.[7]

c) The aquifer:

From the standpoint of ground-water occurrence, all rocks that underlie the Earth's surface can be classified either as aquifers or as confining beds. An aquifer is a rock unit that will yield water in a usable quantity to a well or spring. (In geologic usage, "rock" includes unconsolidated sediments.) A confining bed is a rock unit having very low hydraulic conductivity that restricts the movement of ground water either into or out of adjacent aquifers.[8]

1.3.2. Study area

a) Geographic location of M’zab valley, Ghardaia

As it is known that Algeria is a country with a large area, which led to the diversity of its terrain and climate, and the desert side covers the largest proportion of its area. Therefore, we find that the population suffers from a lack of water due to the remoteness of the main source of water.

Ghardaia is one of the states of Algeria, located north of the Great South and considered the center of the south. Its area is estimated at 86,560 m. It is located between longitudes 7 and 8 and latitudes 35 and 36. It is bounded to the north by Laghouat, to the east by Ouargla, to the south by Tamanrasset, and to the west by El Bayadh and Adrar.

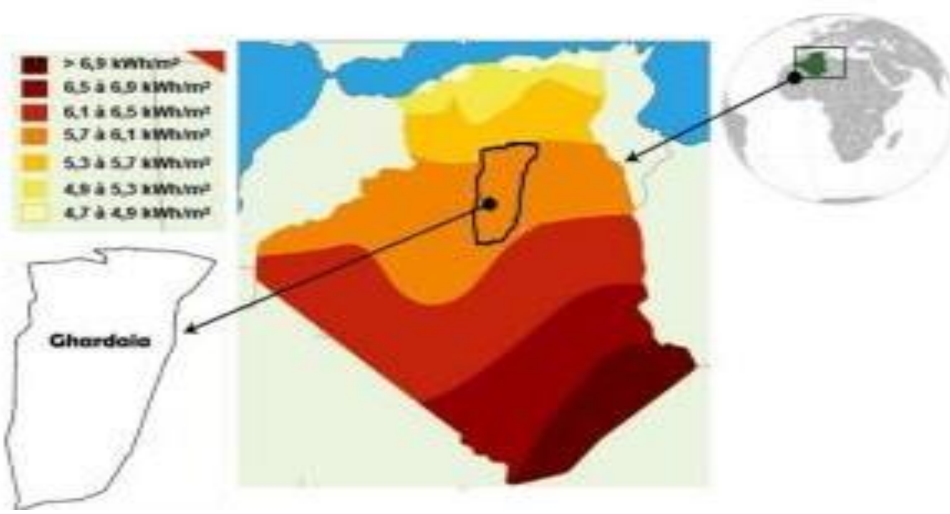
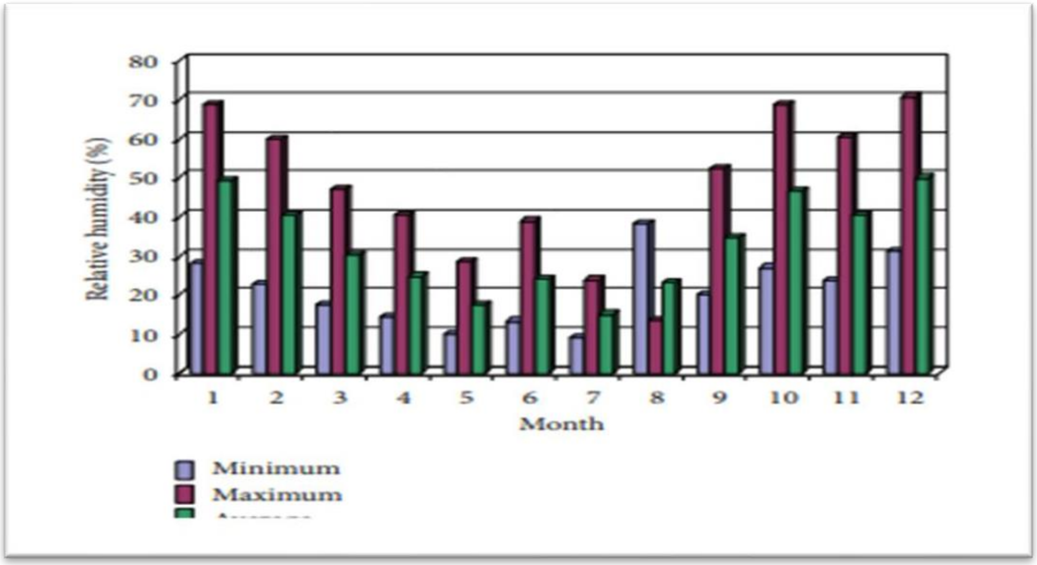


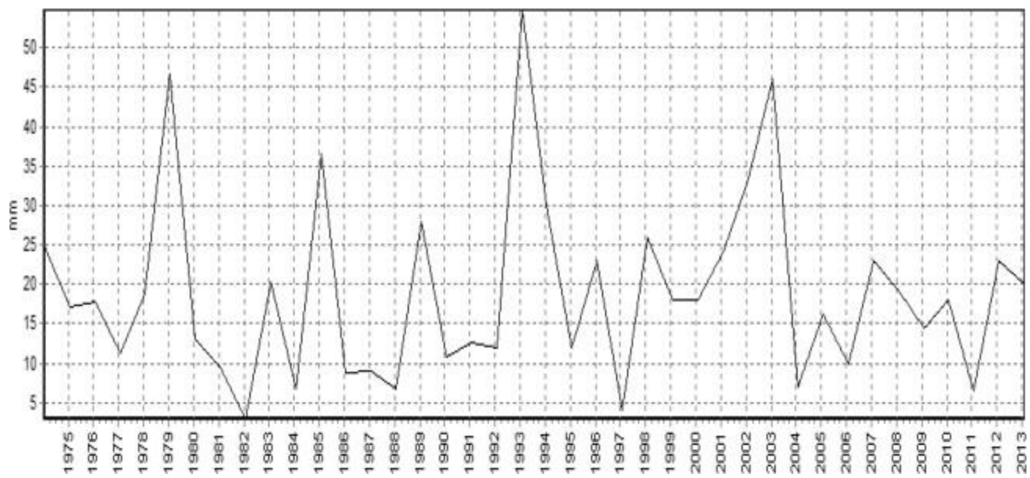
Figure 1.8: Location map of M’zab valley, Ghardaia.

b) Desert climate :

which is the sea and the state of Ghardaia from the desert areas that It is characterized by a hot weather, where the average value of the temperature during the year is 25 ° and the humidity is estimated at 200 mm per year. As for the droplets, the rainfall during the year is about 60 mm per year represented by figure 1.9 .



(a)



(b)

Figure 1.9: (a) The various humidity[35] and (b) Rainfall of Ghardaia[36].

c) Traditional wells in the region

Due to the nature of the terrain of the region, groundwater has become a major resource in the region, where we find a large number of residents who rely heavily on traditional wells. The layer of water in the area was called the aquifer in the M'zab area (AAMR), which consisted of sand, sandstone and sandy clay. It is exploited by more than 750 water wells with a volume of 531.76 Hm^3 [9].

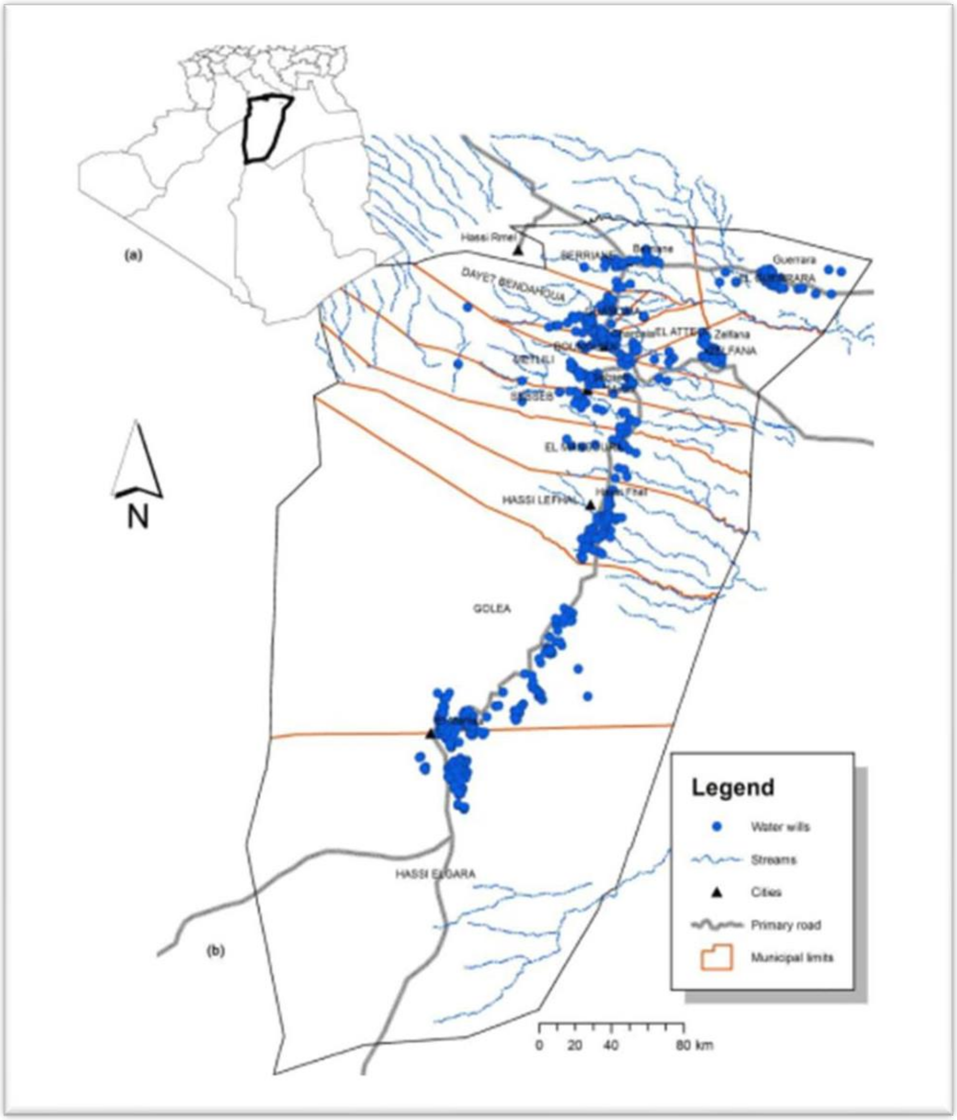


Figure 1.10: Distribution of wells in the region of Ghardaia.

Chapter 02

Photovoltaic conversion

2.1. Introduction

With the increasing demand for electricity in the world, by relying on roads that are environmentally threatening and dangerous to human life, as they are from non-renewable sources, which means the possibility of their demise, it has become necessary to find alternative solutions that negate the harm caused by traditional methods and facilitate their availability and ensure sustainability among these The solutions found solar energy, or what is also known as clean energy, that can provide electricity through photovoltaic technology, and this is what the second chapter contains.

2.2. History of Photovoltaics

The **timeline** of **solar cells** begins in the 1800s when it is observed that the presence of sunlight is capable of generating usable electrical energy. [12]

In 1839, the French physicist Alexandre-Edmond Becquerel, discovered the photovoltaic effect at an age of only 19 years, possibly working with his father, the physicist Antoine César [13]. He observed this effect in an electrolytic cell, which was made out of two platinum electrodes, placed in an electrolyte. An electrolyte is an electrically conducting solution; Becquerel used silver chloride dissolved in an acidic solution. Becquerel observed that the current of the cell was enhanced when his setup was irradiated with sunlight. [14]

Willoughby Smith and his helper Joseph May found **in 1873** that when the semiconductor selenium was exposed to light, its resistance altered. They saw for the first time the internal photo effect pertinent to photovoltaics, in which light rips electrons from their bonds in the semiconductor and makes them available as free charge carriers in the solid-state body. **Three years later**, Englishmen William Adams and Richard Day discovered that when a selenium rod with platinum electrodes is exposed to light, it may produce electrical energy. For the first time, a solid body was shown to be capable of directly converting light energy into electrical energy.[15]

Heinrich Hertz, a German physicist, developed the photoelectric phenomenon **in 1887.** Electrons are emitted from a substance that has absorbed light with a wavelength shorter than a material-dependent threshold frequency in this phenomenon. Albert Einstein presented a paper **in 1905** in which he explained the photoelectric effect by proposing that light energy is conveyed in quantized bundles of energy called photons. research continued until **1954** Solar cells as we know them now were first developed at Bell Laboratories in the United States, their researchers Daryl M. Chapin, Calvin S. Fuller, and Gerald L. Pearson developed a silicon-based solar cell with a 6 % efficiency. Reynolds et al. published a paper in the same year on the photovoltaic effect of cadmium sulfide (CdS), an II-VI semiconductor.[14]

As research continues on the photovoltaic effect to this day, it indicates the need for solar energy in our life.

2.3. What Is the Meaning of "Photovoltaics"?

Based on the photovoltaic effect, photovoltaics (abbreviated PV) is the most direct approach to convert solar energy into electricity [16], The word ‘photovoltaic’ comes from the Greek word photos meaning light and ‘Volta’, the name of the Italian physicist who discovered the electric battery in 1800 [17].

The basic component of every photovoltaic plant is the solar **cell**, A photovoltaic solar cell is a silicon wafer (semiconductor) that converts light into electricity directly. This effect is called the photovoltaic effect. The voltage obtained is in the order of 0.5 V, and the current obtained is a direct current.

A photovoltaic system's individual cell produces relatively low electrical power, typically between 1 and 3 W with a voltage of less than one volt. The cells are integrated into a module to create greater power (or panel). Numerous cells connected in series increase the voltage for the same current, but multiple cells connected in parallel increase the current while retaining the voltage. Under maximum illumination, the peak power obtained will be proportional to the module's surface.

The concept of a solar generator is defined by the interconnection of modules in series or parallel to obtain more electricity. The solar generator is made up of multiple modules and a collection of components that convert the electricity generated by the modules to the receivers' specifications. [20]

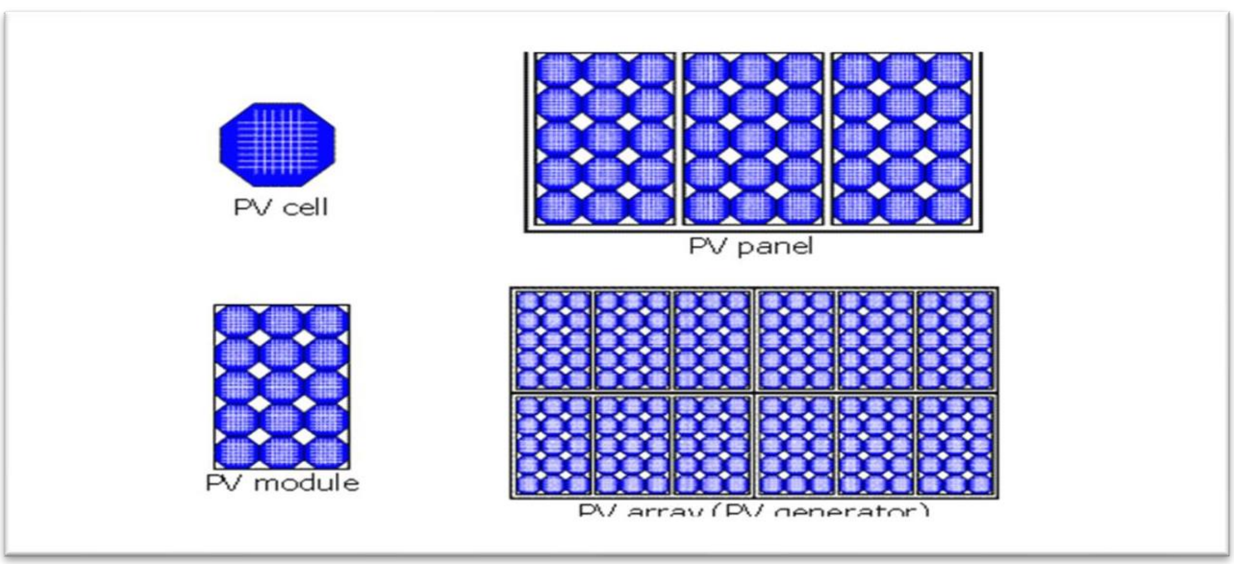


Figure 2.1 provides an illustration of the PV system, from cell to array.

- Photovoltaic cells are semi-conductor junction devices. So, in order to study photovoltaic cells, we should have a basic understanding of semiconductors.

2.4. Semiconductor

First, let's go through the following points:

- Under lighting, the charges that form the electric current are electrons, which are elementary negative charges found in semiconductor materials. All solids are made up of atoms, which have a nucleus (which is made up of protons and neutrons) and a ring of electrons circling around it.

- The absorbed photons merely transmit their energy to the atom's periphery electrons (those farthest from the nucleus), allowing them to escape the nucleus's attraction. If these released electrons are drawn to the outside, they form an electric current.

- The freed electron creates a 'hole,' which translates to a positive charge in the process. If this electron is drawn outside the atom, an electron from a nearby atom will travel to fill the hole, leaving another hole to be filled by a neighboring electron, and so on. This creates a circulation of elementary charges, with electrons moving in one direction and holes moving in the other, resulting in an electric current. [17]

2.4.1. Definition:

Semiconductors are elements found in nature. They are sensitive to visible and invisible light (ultraviolet, infrared beam, etc.) and conduct current poorly compared to metals, but better as the temperature rises (Typical examples: silicon Si, germanium Ge) The existence of electrons free of the electronic gas that flow throughout the metal network is responsible for the metals' high electrical conductivity. [21]

2.4.2. Doping:

A pure semiconductor can be doped to allow it to receive higher charges, increasing its conductivity. Figure 2.2 depicts a two-dimensional schematic of silicon atoms coupled to four other silicon atoms (with four electrons in the exterior layer).

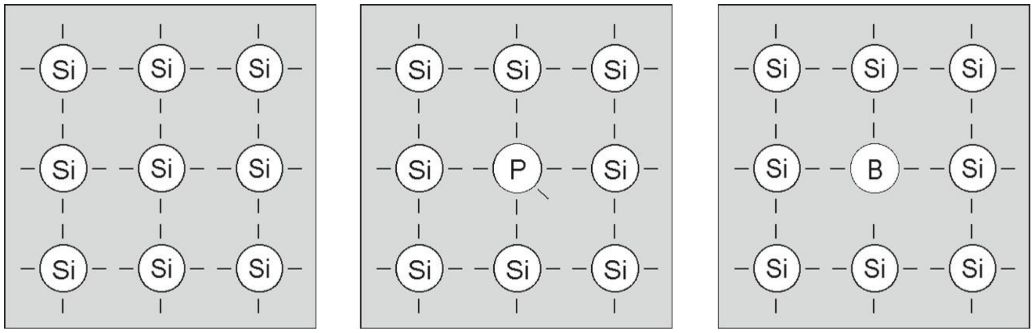


Figure 2.2: (a) Pure silicon; (b) n-type silicon; (c) p-type silicon [18]

When phosphorus atoms with five electrons in their exterior layer are doped into silicon, one electron in each phosphorus atom is unable to interact with its silicon counterpart, resulting in an excess of negative charge in the crystal (Figure 2.2b). The material subsequently becomes a potential 'donor' of electrons, which can be used to conduct electricity, and type n silicon is the result.

Silicon, on the other side, can be doped with boron, which has a valence band with just three electrons per atom. Because each boron atom lacks one electron to match the four silicon electrons, the result is the appearance of extra holes, or positive charges (Figure 2.3c). The substance becomes a 'acceptor' of electrons, in contrast to the previous example. Type **P** silicon is a material that has been doped in this fashion.[17]

2.4.3. Junction P-N:

when two regions of a semiconductor that are doped in opposite directions come into close contact, the result is a diode. A so-called depletion region appears at the interface where extraneous atom concentrations create a junction between p-type and n-type silicon, arising from the tendency of excess electrons from region n to try to pass to region p, where they are attracted by the excess holes, and the tendency of the holes to try to pass to region n by reciprocity (Figure 2.4). This charge carrier exchange in the spatial charge region produces an electric field that balances the charge exchange and restores equilibrium.[17]

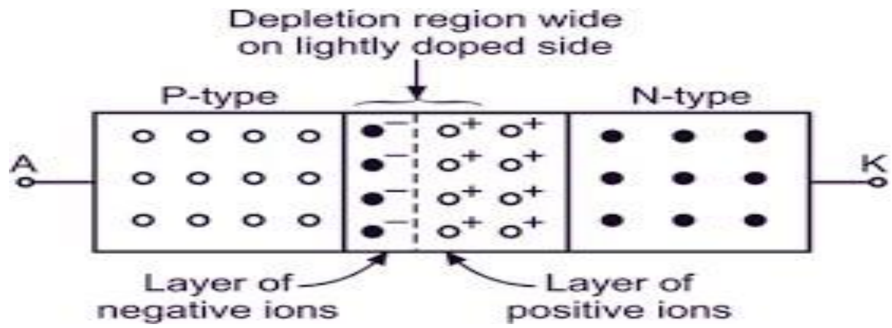


Figure 2.3: Schematic representation of a p-n junction.

2.4.4. Deference between insulation, conductors, semiconductors:

Insulation, **semiconductors**, and **conductors** are the three types of solid materials, the difference is found in :

2.4.4.1. The electrons in an electrical insulator are bonded to atoms and cannot migrate.

2.4.4.2. The electrons in an electric conductor are free to circulate, allowing a current to flow.

2.4.4.3. The situation is intermediate in a semiconductor: matter's electrons can only circulate if they aregiven energy to free them from their atoms.

When photons from light enter a semiconductor, they provide energy that allows electrons to release and travel in matter, resulting in an electrical current. [22].

2.5. Photovoltaic effect

Based on the photovoltaic effect, photovoltaics is the most direct approach to convert solar energy into electricity.

PV cell is depicted in Figure (2.4). It explains its structure in great detail. A PV cell consists of two layers of silicon, one of which is P-doped (boron-doped) and the other of which is N-doped (phosphorus-doped), resulting in a PN junction with a potential barrier. When photons are absorbed by the semiconductor, their energy is transferred to the atoms of the PN junction, causing their electrons to be liberated, resulting in electrons (N charges) and holes (P charges). As a result, a possible disparity between the two layers emerges. Between the connections of the cell's positive and negative terminals, there is a difference in potential that can be measured. [20]

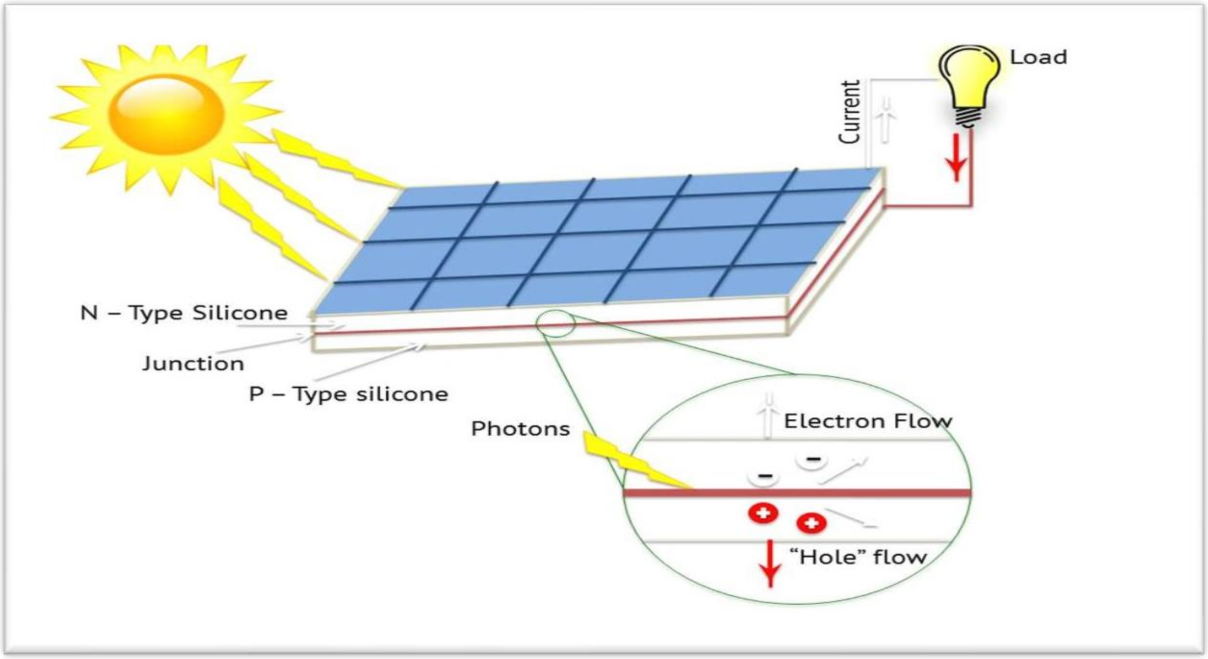
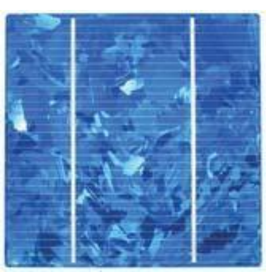


Figure 2.4: Showing functional of solar cell system.

2.6. Different technology of photovoltaic

Solar panels come in a variety of shapes and sizes, including monocrystalline, polycrystalline, Cadmium Telluride (CdTe), CIGS, CIGSS, Amorphous Silicon (a-SI), thin-film, etc. Each has its own set of benefits and drawbacks, as well as varied prices and returns.

Two types of panels are available as shown in Figure (2.5), both of which are relatively similar and can be put in a variety of ways: The Polycrystalline is slightly less expensive than the Monocrystalline, but its efficiency is lower. To achieve the same level of power, you'll need to install a greater area of Polycrystalline, which will offset its cheaper cost.[18]



Poly-Crystalline Silicon PV Cell

Mono-Crystalline Silicon PV Cell

Figure 2.5: Mono-and Poly-Crystalline Silicon PV Cell [19].

Apart from aesthetic changes, the most noticeable distinction between PV cell technologies is their conversion efficiency, as seen in Table 1.[19]

Technology	Module efficiency
Mono-crystalline Silicon	12.5-15%
Poly-crystalline Silicon	11-14%
Copper Indium Gallium Selenide (CIGS)	10-13%
Cadmium Telluride (CdTe)	9-12%
Amorphous Silicon (a-Si)	5-7%
Thin film	12-20%

Table 2.1: Conversion efficiencies of various PV module technologies.

2.7. Electric characteristics of PV cell

2.7.1. Equivalent circuit case ideal of a PV cell

The ideal equivalent circuit of a PV cell is a current source in parallel with a single diode [23]. Figure (2.6) represents the equivalent circuit of a photovoltaic cell under the influence of light, as it contains a generator, which is the source of current passing through the circuit, symbolized by I_{pv} connected in parallel with the diode.

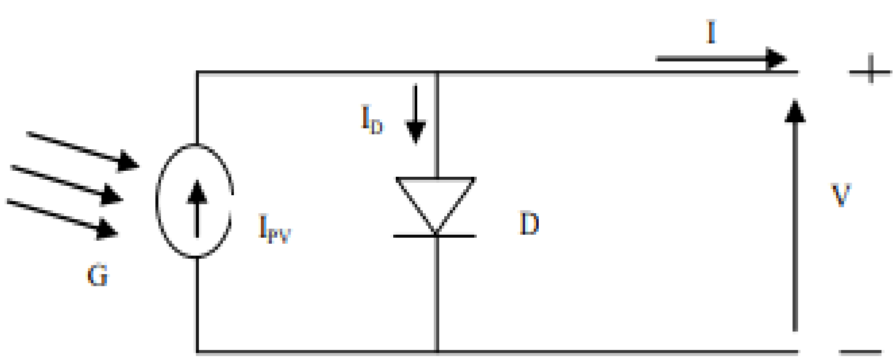


Figure 2.6 : Equivalent circuit of an ideal PV cell.

Applying Kirchhoff's law, we get the output I of the PV cell based on the equivalent electrical circuit in the figure (2.6) .

$$\boldsymbol{I = I_{PV} - I_D} \quad \textbf{(2.1)}$$

I_{PV} : it's the current generate by PV cell.

Where

$$\boldsymbol{I_D = I_0 \, [\exp(\frac{V}{AV_T}) - 1]} \quad \textbf{(2.2)}$$

I_0 : it’s the diode saturation current.

its can become

$$\boldsymbol{I = I_{PV} - I_0 \, [\exp(\frac{V}{AV_T}) - 1]} \quad \textbf{(2.3)}$$

Where,

V : is the voltage of diode (V).

$V_T = \frac{N_S * K * T}{q}$: is the thermal voltage of a PV module.

Ns cells connected in series.

q the electron charge (1.6 ×10-19 C).

k the Boltzmann constant (1.3 ×10-23 J/K).

T the temperature of the p-n junction in kelvin (k).

The diode ideality factor.

can the PV cell characterized by the short circuit current (I_{SC}) and the open circuit voltage (V_{OC}) so it can put: $\mathbf{I = I_{SC} = I_{PV}}$.

Substituting the above into equation (2.3) it becomes the following form:

$$I_0 = \frac{I_{SC}}{(\exp(\frac{V}{AV_T}) - 1)} \quad (2.4)$$

At the same conditions of temperature and p-n junction the open circuit V_{OC} and for I=0 it can be written as following equation :

$$V = V_{OC} = A * V_T \ln\left[1 + \frac{I_{SC}}{I_0}\right] \quad (2.5)$$

2.7.2. Characteristic I-V of PV cell

The characteristics of the PV cell's voltage and current are represented in what is known as the I-V curve, which shows the relationship between PV cell voltage and PV cell current, which constitute the PV cell's output.

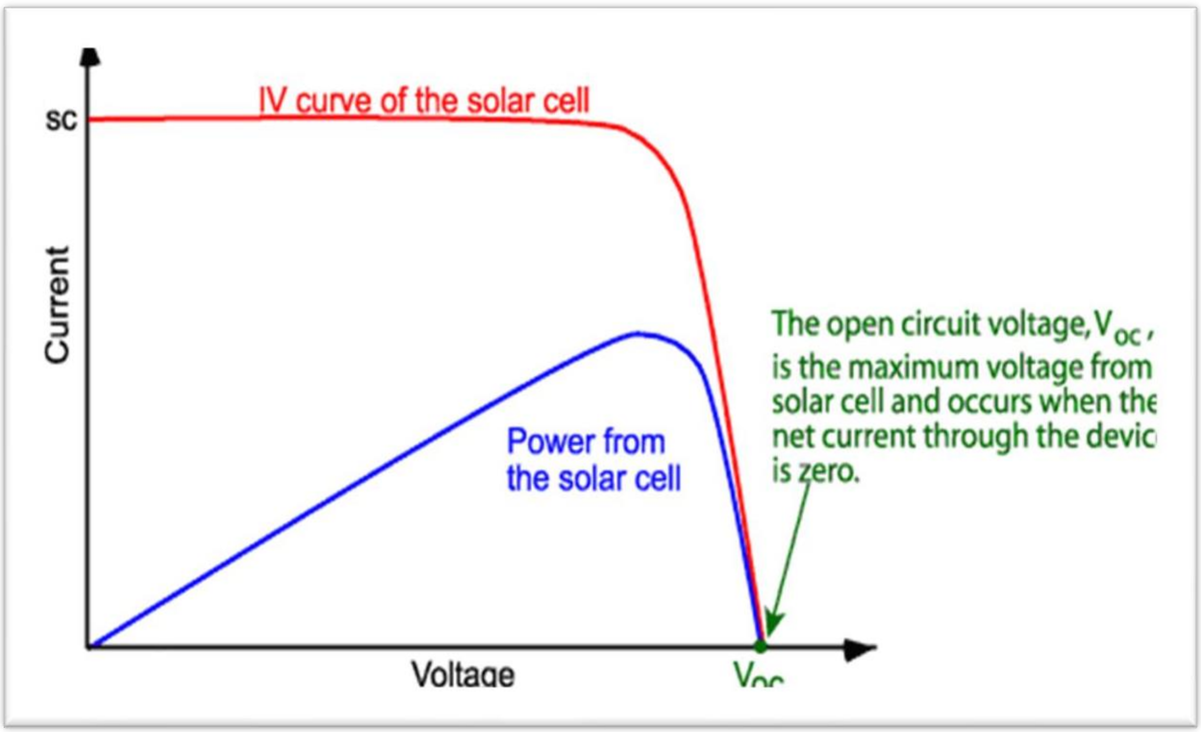


Figure 2.7: I-V characteristics of PV cell.

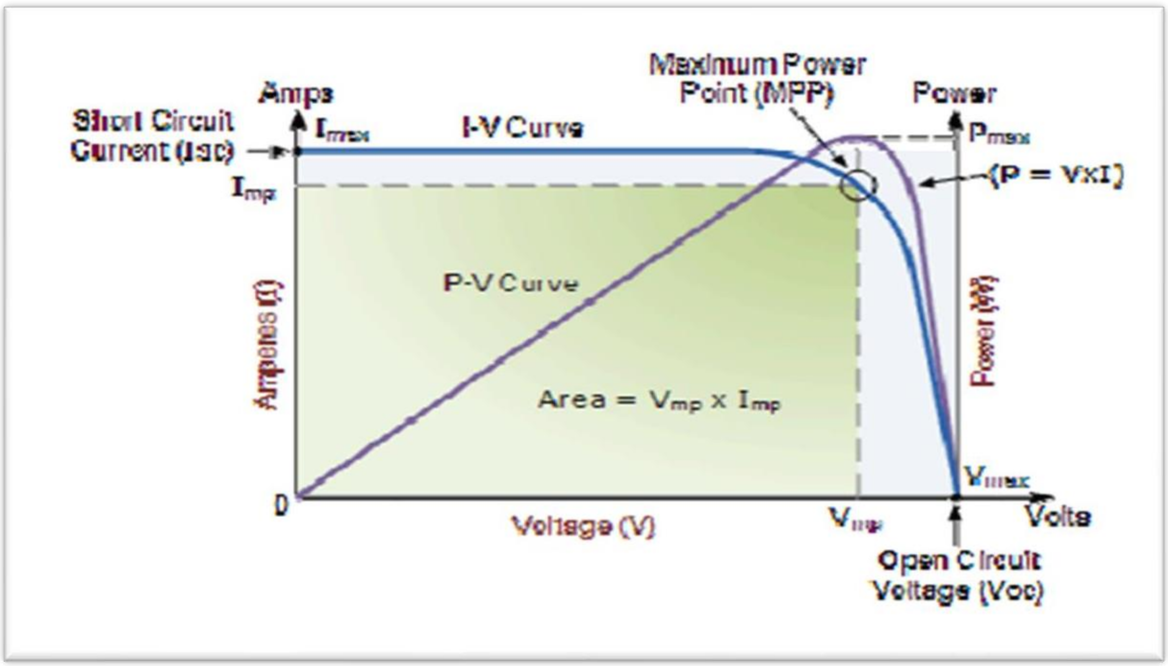
2.7.3. PV generator performance

2.7.3.1. The maximum power point (MPP/T)

The maximum power point is the largest value that a photovoltaic generator can produce so that it can be graphically represented by the point of intersection of the voltage line and the current line on the I-V characteristic curve. In this case, the voltage at that point will become the highest value of the voltage, and this also applies to the current, so it is called I_{max} and the voltage is V_{max}, and the product between them gives the maximum value of the power and is called P_{max} ,[24] It can be expressed by the following equation:

$$P_{max} = V_{max} \times I_{max} \tag{2.6}$$

The figure (2.7) shows the



location of the maximum power point on the I-V curve

Figure 2.8: The maximum power point in I-V current.

2.7.3.2. Fill factor (FF) :

The fill factor, and it can be obtained from the ratio of the maximum power point (P_{max}) to the voltage (V_{sc}) and current (I_{oc}) [25], so that the shaded area A in the figure (2.8) is graphically displayed.

$$FF = \frac{P_{max}}{V_{sc} \times I_{oc}} = \frac{V_m \times I_m}{V_{sc} \times I_{oc}} \tag{2.7}$$

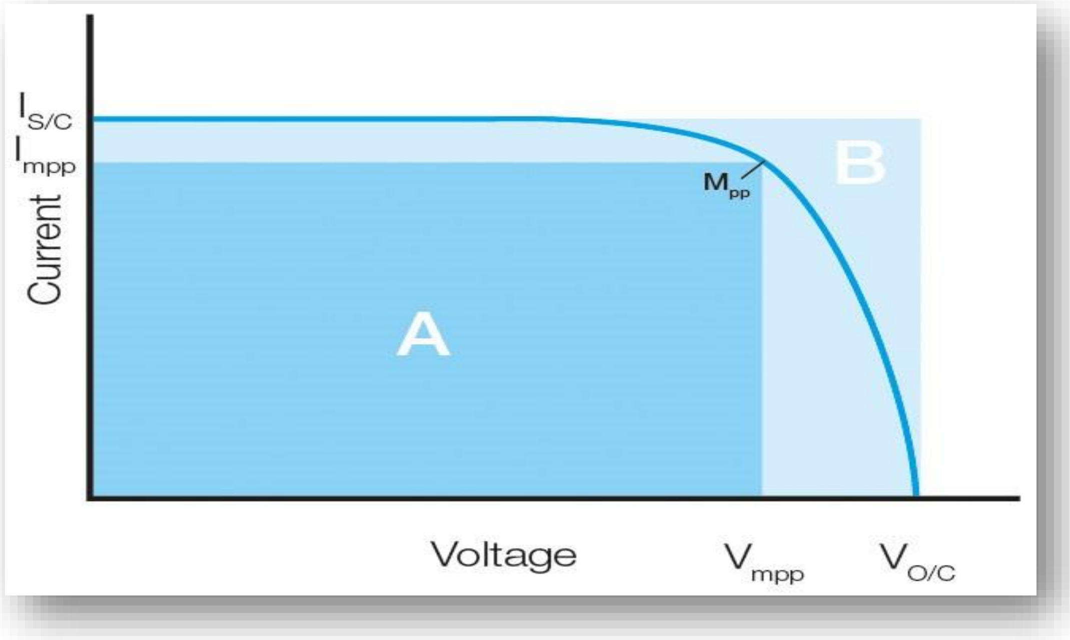


Figure 2.9: Presentation of fill factor in I-V current.

2.7.3.3. Power conversion efficiency

the power conversion efficiency of PV array or PV generator is defined as the ration between the solar cell output power and the solar power hitting the solar cell total surface [24]. It is calculated by the following equation:

$$\eta = \frac{P_{max}}{E \times S} \qquad (2.8)$$

Where,

E : Flux incident.

S : Surface de cellule solaire.

2.8. Temperature effect on PV cell performance

Solar panels are tested in the laboratory under nominal conditions where the temperature is 25°, the amount of radiation is 1000W/m^2, the wind speed is 0, and the air mass is 1.5, but in the conditions usually it is not possible to achieve these conditions because the external factors affect the solar panel

One of the external factors that affect the solar cell is temperature, which makes a difference in the level of solar cell properties so that the voltage is highly dependent on the temperature and an increase in temperature will decrease the voltage [26] As shown in the figure (2.10).

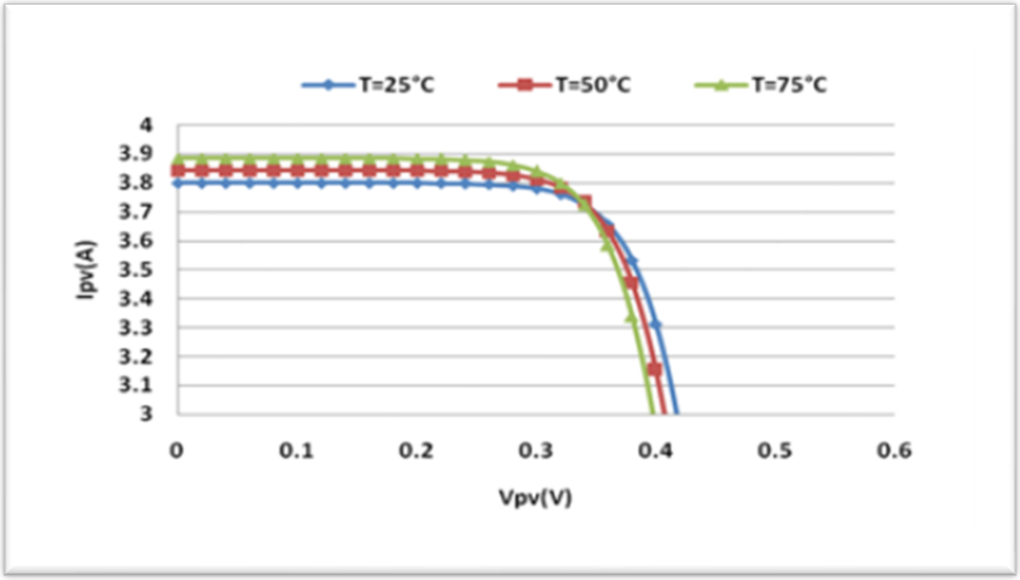


Figure 2.10: The effect of temperature on the I-V characteristic curve.[27]

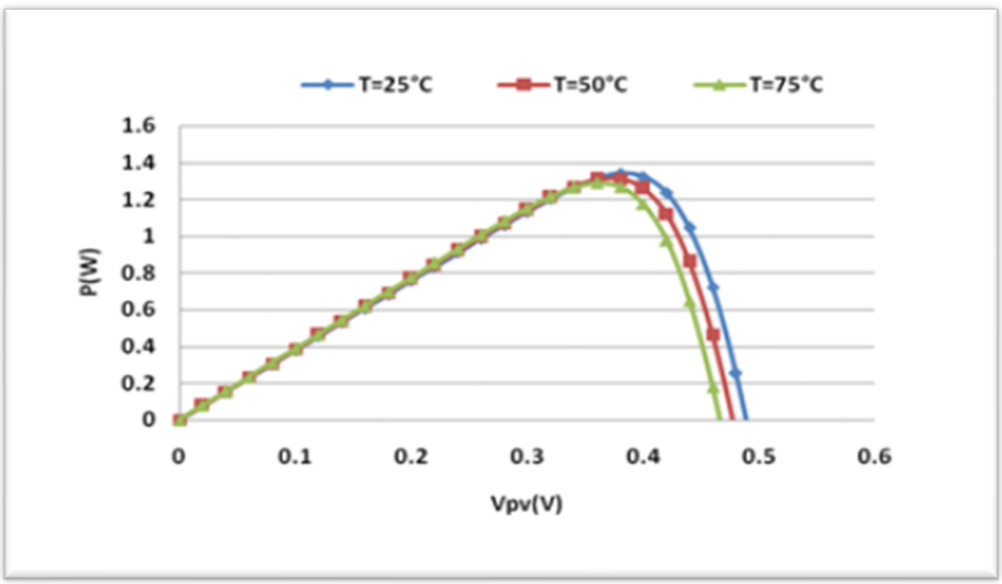


Figure 2.11: The effect of temperature on the power characteristic curve.[27]

The figure (2.11) shows the direct relationship between temperature and the output power of PV solar. The higher the temperature, the lower the power, and vice versa.

2.9. Radiation effect on PV cell performance

As it is known that solar panels are the main source of their work is sunlight, that is, sunlight has a noticeable effect on the work of solar panels, so it is directly related to sunlight as shown. in shape. Current, voltage, and power, the higher the radiation, the higher the tension, current, and power.

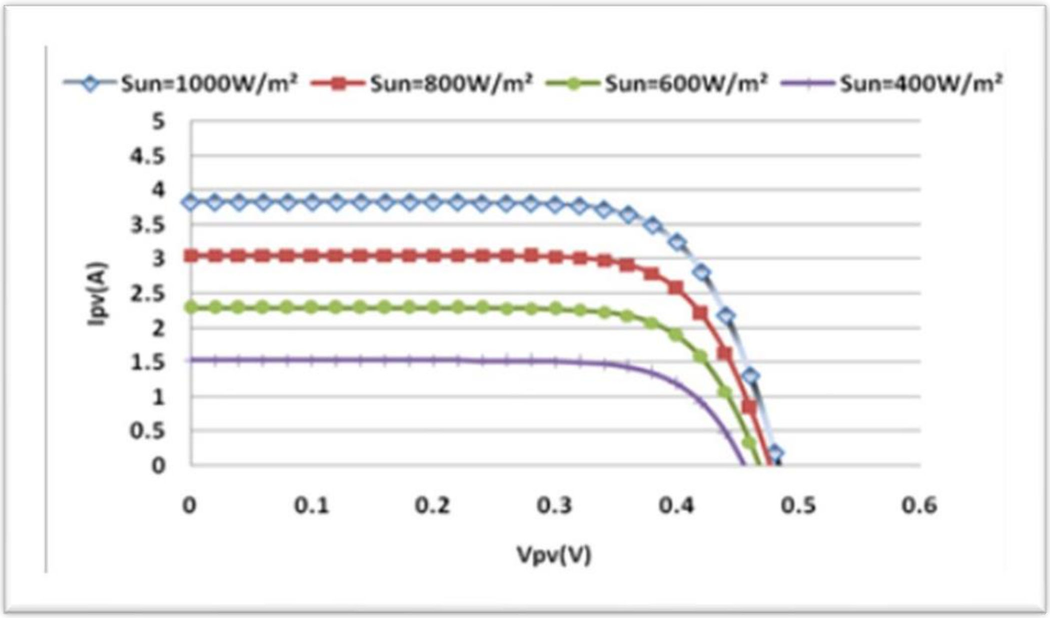


Figure 2.12: The effect of radiation on the I-V characteristic curve.[27]

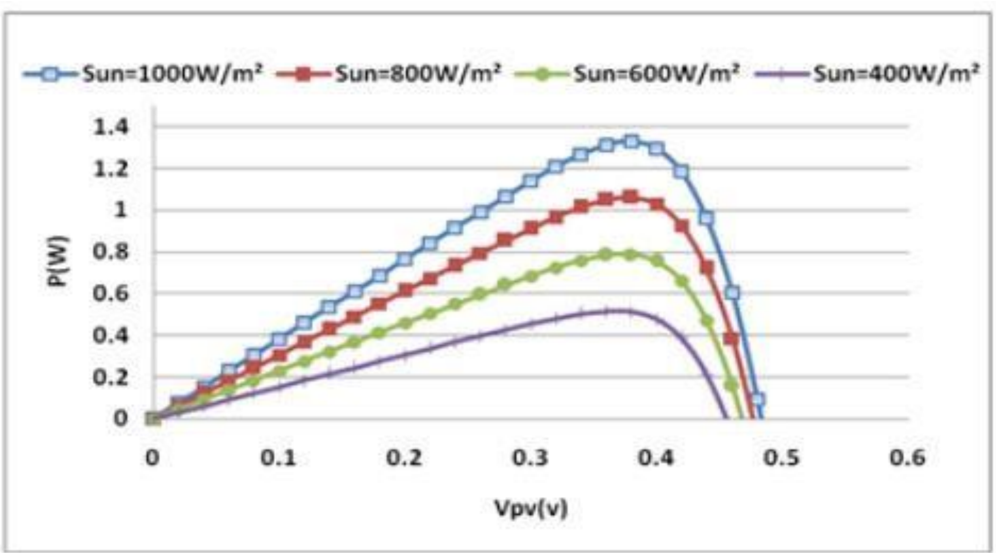


Figure 2.13 : The effect of radiation on the power characteristic curve.[27]

2.10. Configuration of PV

Solar cells are connected to each other in different forms to form a complete solar panel, and these panels are connected together to form a photoelectric generator that generates electricity for us with higher values than one panel alone. The two basic forms of connection are serial and parallel.

a) Connection on serial:

The goal of connecting the number of solar panels in series is to increase the voltage. As for the current, its value remains constant, as the voltage is collected according to the number of solar panels.

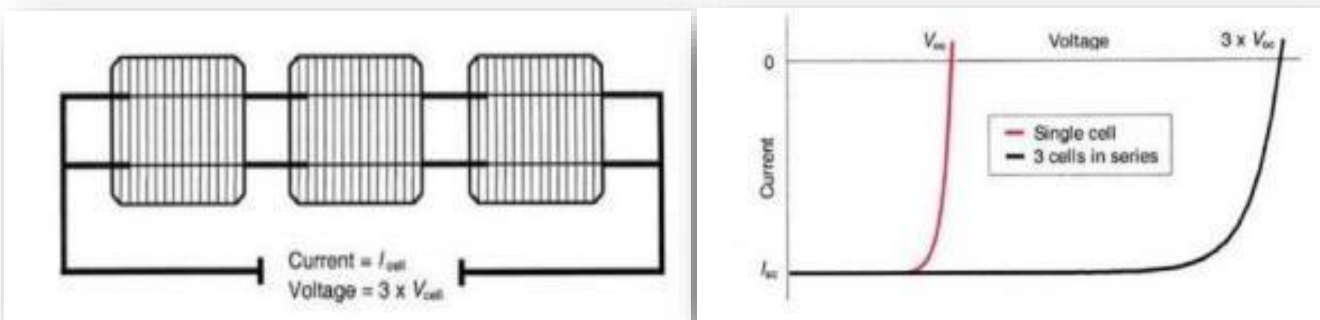


Figure (2.14): The serial connection of PV cell.

$$\boldsymbol{V_{oc} = N_s * V_{pv} \qquad (I = 0)} \tag{2.9}$$

Where

N_s: number of PV model.

$$\boldsymbol{V_{oc} = \sum_{1}^{n} V_n = V_1 + V_2 + V_3 + \cdots + V_n \; (0 < I)} \tag{2.10}$$

b) **Connection on parallel:**

The goal of connecting the number of solar panels in parallel is to increase the current. As for the voltage, its value remains constant as the current is collected according to the number of solar panels.

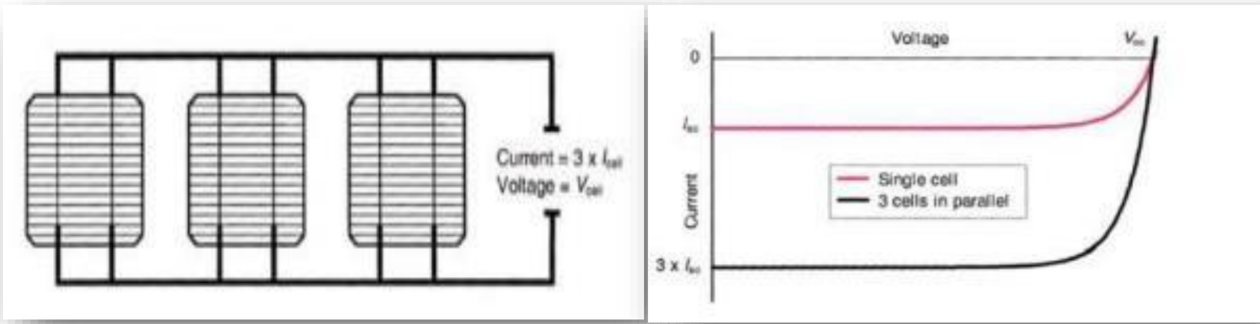


Figure 2.15: the parallel connection of PV cell.

$$I_{sc} = N_s * I_{pv} \tag{2.11}$$

Where

N_s : number of PV model .

$$I_{sc} = \sum_{1}^{n} I_n = I_1 + I_2 + I_3 + \cdots + I_n \tag{2.12}$$

2.11 Photovoltaic Generator Applications

- **For low voltage**

Such as street lights that are relied upon at night by relying on it to charge the battery in the morning and then the battery works to operate the lamp at night.

- **Standalone installation**

As feeding the electrical facade in the morning directly from solar panels, and at night, it is possible to rely on the electric network or batteries, and this is one of the appropriate solutions for economic saving for the person.

- **Smart grid**

With the development of technology, it has become possible to control remotely and work flexibly thanks to the presence of automatic work of things. Among the problems that burden the world is the sudden power cut, so solar energy has become an alternative solution to it, by automatically transferring from the electricity network to another feeding such as solar energy, and this is the origin of existence smart grid.

- **Irrigation and Agriculture**

Solar energy has become the ideal solution for owners of agricultural land and areas where drinking water is not available to feed the means that provide this.

Chapter 03

Sizing steps of a photovoltaic water pumping system

3.1. Introduction

Demand for water has become a key and growing thing, especially in rural areas and isolated locations. Many farmers suffer from water crisis in their farms, as water delivery in arid and semi-arid areas is difficult. As a result, the need for a dependable pumping system is critical. As a result, more people are interested in using solar generators as a new source of energy. Developing a self-contained, dependable, and efficient solar system is a viable and cost-effective solution to the problem of water scarcity, especially in desert settings. In reality, a solar system becomes appealing when it is simple to install, has a reasonable level of autonomy, and provides outstanding service reliability.

In this work, we will compare the performance of a PV water pumping system installed on a true well in the desert area (URAER, Lab. Ghardaia). The major goal of this research is to find the best photovoltaic (PV) array layout for supplying optimal energy to a pump under various environmental conditions. Where We Choose two different PV array configurations (**2S × 1P, 2S × 2P**) after measuring the voltage and current to make sure the connection is correct and we picked the pump. The tests have been carried out for different heads between 10 m and 20 m in sunny days. This PV water pumping system consist a PV powered by Isofoton (110/24) module configurations with nominal electrical characteristics (Open circuit voltage Voc = 40V, Short circuit current Isc=3.5A, maximum power Pmax= 110W) and a submersible DC Shurflo pump with nominal electrical characteristic (DC maximum voltage V_m=24 V, maximum current I_m = 4A, maximum power P_m=120 W).

The following steps should be followed when sizing a PV pumping system:

- Characteristics of the site
- Technical data of the well
- Photovoltaic field peak power.

3.2. Photovoltaic water pumping system theory

Solar pumping is a technique that has lately been utilized to provide water from sources such as artificial ponds, water wells, boreholes, and rivers. Solar pumping is frequently the most obvious answer in regions where there is no power grid since renewable energy solutions are easier to build and operate than other systems. This is because they may be put together in pieces on-site and do not require the transportation of running fuel. A photovoltaic (PV) pumping system can assist agriculture areas in becoming more sustainable, as these systems can reduce over irrigation.

A PV pumping system consists of five major components, which are PV array, a power conditioning unit, pump-motor load, water tank storage, and pipe distribution system. PV pumping systems can be directly or battery-coupled. PV panels, charge regulators, batteries, pump controllers, tanks, and DC pumps are all part of the battery-coupled system. The directly connected type, on the other hand, has no batteries, therefore water must be stored in the tank to be utilized at night or on overcast days.[28]

Figure 3.1 schematically shows the main components of a PV pumping system. There are three components to a solar PV pumping system:

- The PV array which converts solar energy to DC electricity.
- The motor-pump subsystem comprising the components which convert the electrical output of the PV array into hydraulic power.
- The storage tank or storage battery.[29]

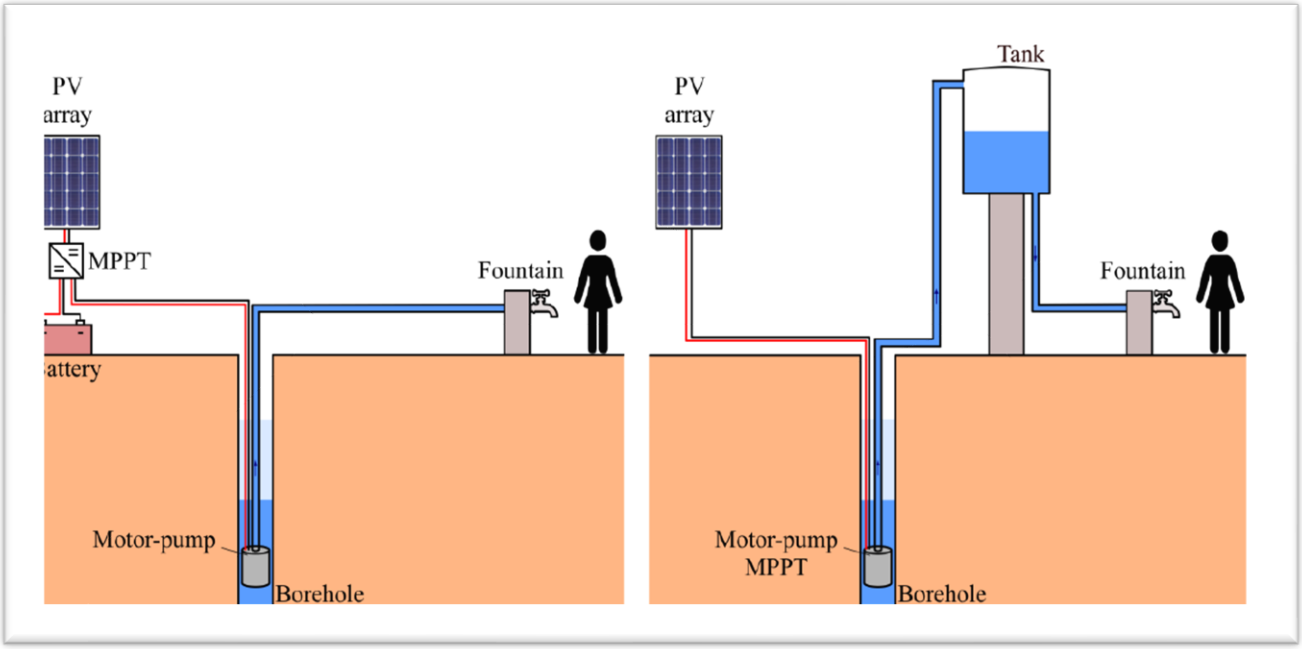


Figure 3.1: Schematic layout of PVWPS with battery storage (left) and water tank storage (right) – adapted from [33], MPPT: maximum power point tracker. .

3.2.1. Different pumping methods

There are many methods that can be relied upon in the process of pumping water, each of which has its negatives and positives, as well as its work for which it was made, including:

3 Hand pumps Link.

4 Animal driven pumps.

5 Hydraulic pumps (e.g., rams) Link.

6 Wind pumps Link.

7 Solar PV.

8 Diesel and gasoline pumps.

3.2.2. The PV Generator

In bright sunlight, each solar cell produces an average 0.5 volts. To build a module and generate the needed voltage, solar cells are connected in series. To provide the power levels required for the application, solar modules are connected in series and parallel. 12 volt and 24-volt, 48-volt, 110 volts, and 180 volt DC are common system voltages. The linked modules, known as an array, are commonly put on the ground, on a roof, or on a trailer and are usually fixed to a light aluminum structure. [34]

3.2.3. The pump

A machine used to transport liquids of different natures by snatching and shoving using the pressure force provided by the pump walls. And the pumps varied in shapes from manual, electric and hydraulic.

Pumps are classified into two main categories: centrifugal pumps and volumetric pumps, and their classification depends on their properties in terms of pressure strength, engine quality, and others.

a) Classification of pumps

There are two main pump types: rotodynamic and positive-displacement. In a rotodynamic pump, a rotating impeller imparts energy to the fluid. The most common type of rotodynamic pump is the centrifugal pump.

A positive-displacement (PD) pump, a discrete amount of fluid is trapped, forced through the pump, and discharged.[30]

The figure (3.2) shows the classification of pumps sequentially and in detail:

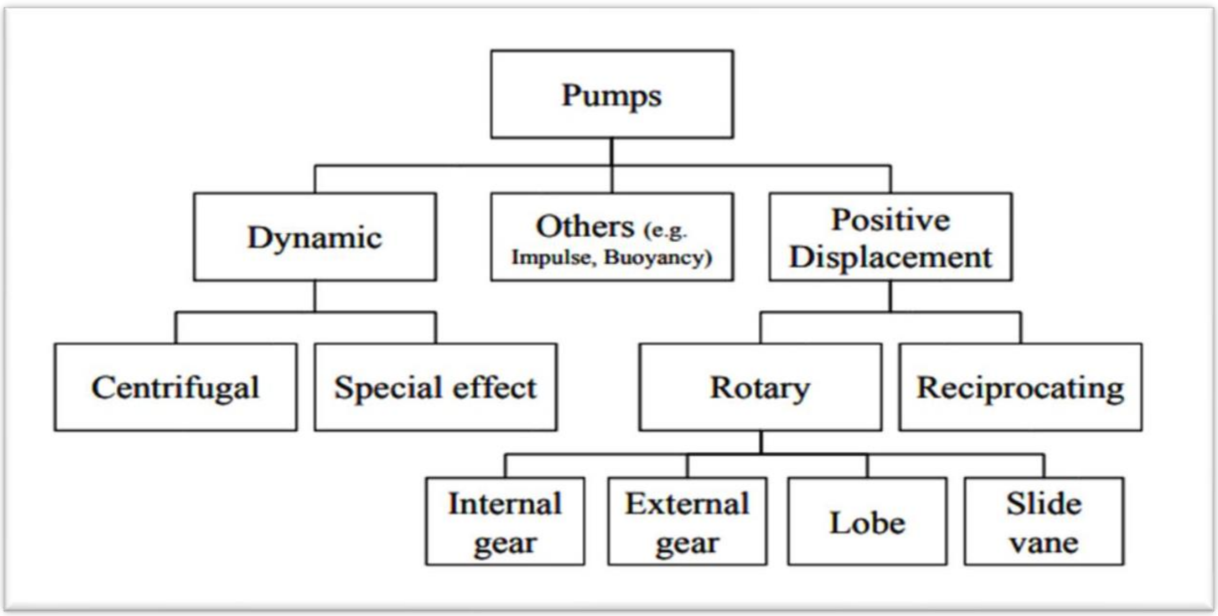


Figure 3.2: classification of pumps.

b) Type of a submerged centrifugal motor-pump

<u>Shurflo 9300 series submersible pump [29]</u>

a) Characteristic of pump:

- Strong Construction, yet lightweight (2.7 kg, 6 lbs)
- Corrosion-proof housing with stainless-steel fasteners.
- Dry Running capability without pump damage.
- Internal Bypass Feature for pump protection.
- Long-life, 24 VDC Operation .
- Easily repaired in the field.
- State of the art solid diaphragm.
- Voltage 24 VDC Nominal.
- Amps 4.0 Maximum.

Figure 3.3 : the shurflo pump model .

b) Application of shurflo pump:

- Drinking water supply.
- Water supply for remote domestic usage.
- Water supply for solar thermal installation.
- Water supply for animals.
- Game parks and game farms.
- Solar micro irrigation (small family's garden, small rural areas or green roof system) .
- Irrigation of fields and greenhouses.
- Pond management.

3.2.4. Motors:

To work, the pump requires mechanical input energy. In most cases, a motor provides this mechanical energy. PV pumping systems typically use two types of motors.[30]

- DC motors.
- AC motors (asynchronous).

The following are the criteria that can be used to determine the most prudent motor choice:

- Good performance.
- Flexibility of operation.
- Robustness of the equipment in order to limit maintenance and the risk of breakdowns as much as possible.
- Reliability and autonomy of the installation.
- Low starting power.

The principle of operation of the motors is the electromagnetic induction according to which a turn traversed by an electric current, placed in a magnetic field is subjected to a force of displacement.

a) <u>AC motors:</u>

Asynchronous AC motors are applied. The advantages of these motors are their resilience, easy maintenance, and low-cost availability on the market. However, an inverter is required.

b) <u>DC motors:</u>

Brush or electrically commutated DC motors can be used. Brushed motors demand a lot of upkeep (change of brush).

Electronically commutated motors, on the other hand, have the advantage of requiring less maintenance than brushed motors. Electronically commutated motors, in general, outperform asynchronous motors in terms of reliability and efficiency throughout a wide range of pump heads.

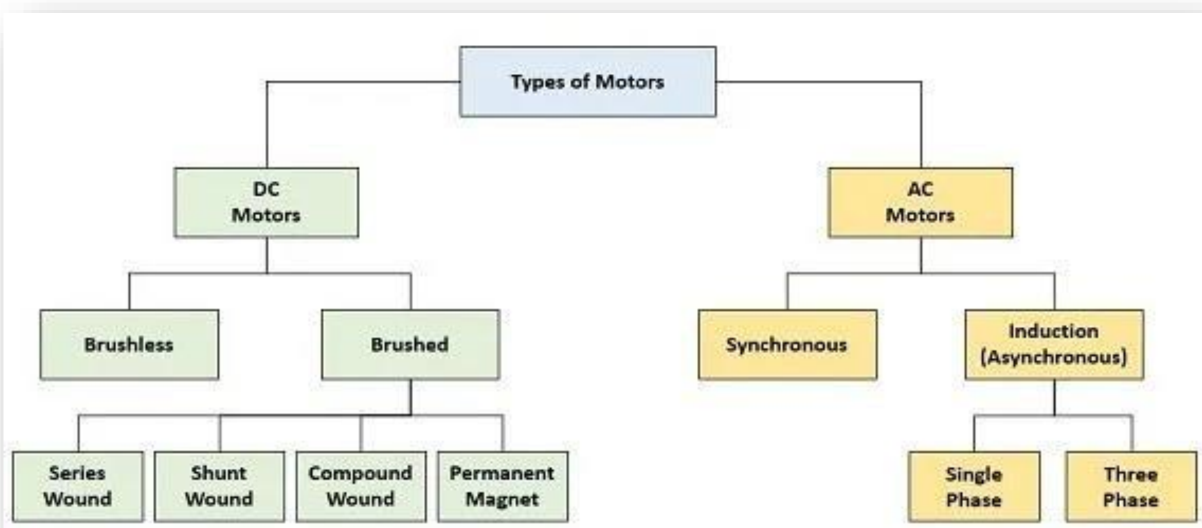


Figure (3.4): Motors classifications.

3.2.5. The storage

There are different forms of energy storage, which is the heating of electric energy in batteries, and hydraulics, by collecting water in a tank, the latter being one of the best ways to use Because it is practical, simple to install and use, and does not pollute the environment and has few faults, meaning it does not require much maintenance. and does not require a high budget.

3.3. Basic hydraulic concept

3.3.1. Flow rate:

Because it is difficult to obtain an accurate value of the flow, different methods are used to obtain it, and among this method is to divide the volume of the tank by the time it takes for the pump to fill the tank [30], and this is the closest meaning to the flow. It is expressed in (m^3 / h) or ($Lmin^{-1}$) or (Lh^{-1}).

3.3.2. Total Mano-metric head:

Total Mano-metric head is the difference in distance or length between two different points , It can be said that is the difference in pressure (in meters) between the pump's inlet and outlet points [31]. denoted by TMH.

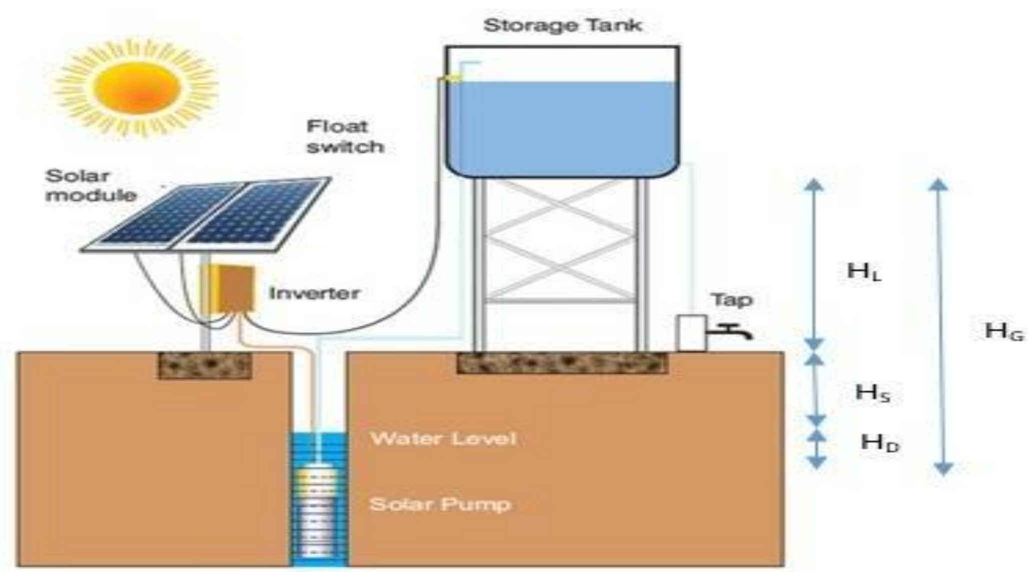


Figure 3.5: presentation of the TMH .

The total Mano-metric height is a set of lengths for different points of the system, which consists of:

Static height (H_S) : It is the length between the ground level and the water level.

Dynamic height (H_D) : It is the length between the water level and the pump level.

Level of tank (H_L) : It is the length between the tank level and the ground level .

Geometric height (H_G) : It is the total length of the system from the tank level to the pump level.

$$H_G = H_S + H_D + H_L \qquad (3.1)$$

It can be calculated with the following expression:

$$TMH = H_G + 10\% * H_G \qquad (3.2)$$

Where

H_G : geometric height .

3.3.3. Hydraulic energy

We also know that when the water movement produces energy and this is called hydraulic energy (in some cases it is called water energy) it is by (Wh/day) ,and this is what applies to the pump in this case it is calculated by the following relationship :

$$E_H = C_h \times Q \times TMH \qquad (3.3)$$

Where

TMH : The total Mano-metric height (m) .

Q: the amount of water pumped per day (m3/day) [31] .

C_h : $C_h = \frac{\rho \cdot g}{3600}$ end it is constant (2.725).[31]

3.3.4. Electric energy

It is the energy produced by the photovoltaic generator to operate the pump it is by (Wh) , The necessary electric energy is related to the hydraulic energy by the following expression [32] :

$$E_e = \frac{E_h}{\varepsilon_p} \qquad (3.4)$$

Where

E_h : the hydraulic energy (Wh/day).

ε_p : the pump efficiency .

3.3.5. maximum peak power

It is a value produced by the photovoltaic generator to operate the pump, and therefore it is called the peak maximum power to operate the pumping system. It is calculated by the following expression:

$$P = \frac{E_e}{D_h[1 - losses]} \qquad (3.5)$$

Equations should be in non-visible cases, as:

$$P = \frac{E_e}{D_h[1 - losses]} \qquad (3.6)$$

Where

E_e : electric energy (Wh) .

D_h : daylight pre hours .

3.4. Methods and Materials:

A basic configuration consisting of a photovoltaic generator, a collection box, a test well, a pump, a data collector, a data analysis computer, a display panel as shown in the figure has been relied

In this study, two different methods were used to achieve different conditions during the testing process, which are:

a) Method 1 : (1P × 2S)

That two panels were installed in series, and the purpose of this is to obtain a higher voltage value while maintaining the value of the current.

b) Method 2 : (2P × 2S)

That two branches were installed, each branch consists of two plates in series, and the purpose of this is to obtain a higher current value while maintaining a voltage value.

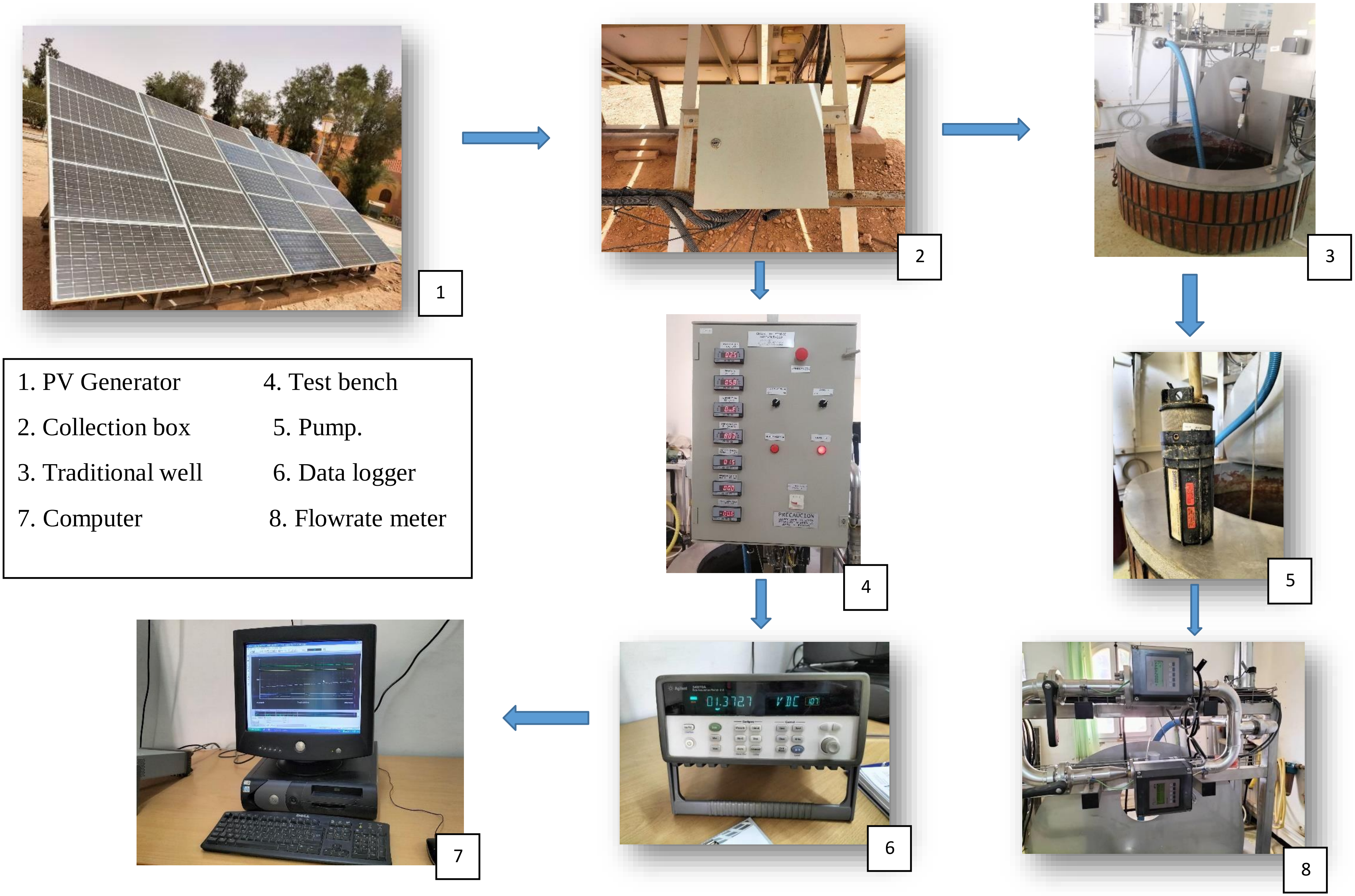


Figure (3.6): The process of characterization of solar pumping system.

3.4.1. Material selection

a) Outside the lab

- PV Generator:
- The source of the electrical supply for the system is the photovoltaic generator ISFOTON 110W/40V about 40 m away from the laboratory, and all the panels are tilted at an angle of inclination of 30°.

Figure3.7 : PV Generator of ISOFOTON (110W/24V) type.

- Collection box.

b) Inside the lab

- **Test bench:**

It consists of an artificial well and a stainless tank that includes a hydraulic circuit system consisting of two flowmeters, the first C1 for 10000 l / h and the second C2 for 2000 l / h, a valve to control the water pumping pressure, two high pressure sensors 0-160 m and low 0-10 m, as well as several Manual control sockets.

Figure 3.8: Test bench of photovoltaic pumping system

- **Display panel:**

Digital display panel to display the main parameter of solar pumping system:

I_{TB}: Test pump direct current.

V : the supply voltage of the test pump.

E: Irradiation at the level of solar panels per square meter.

T: plate temperature.

P1: simulated well depth deep well.

P2: simulated well depth of shallow well.

P3: The water level in the tank.

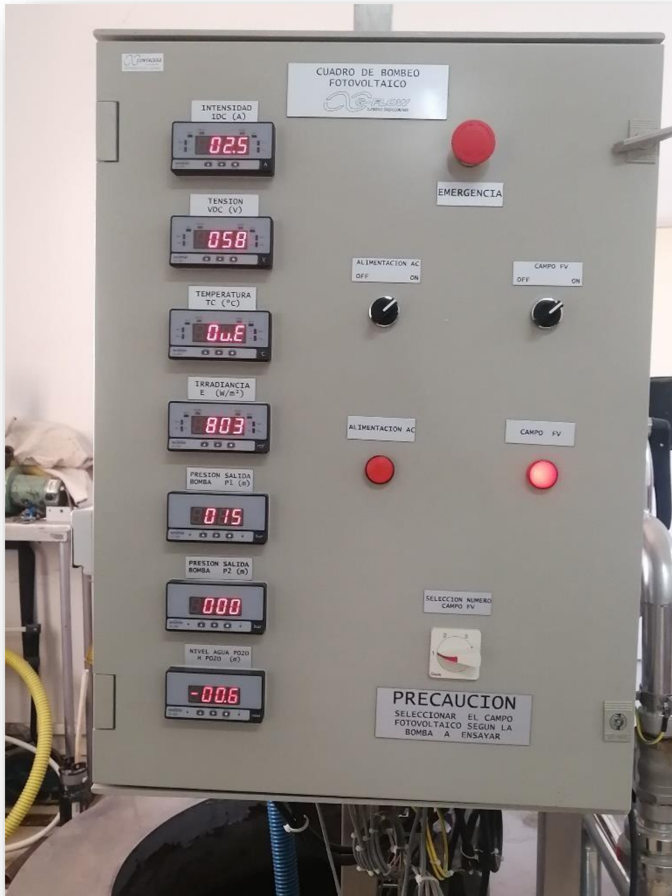


Figure 3.9: Display panel.

- **Data logger:**

The data logger Agilent, model 34970A Its task is to collect data and record it in a period of time estimated every 10 seconds, it records a value containing 250 display channels and 50 thousand readings of non-volatile memory and inputs shown by measurements such as current, tension and temperature ... and it is connected to pc.

Figure 3.10 : Data logger Agilent, model 34970A.

- **<u>Computer:</u>**

To analyze, process and save the measured data, save it using a program that connects it to a data logger.

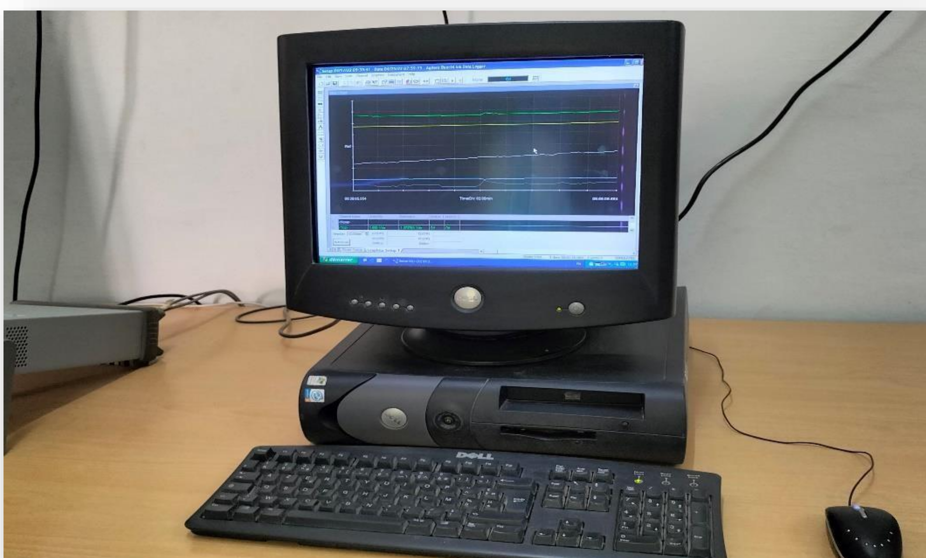


Figure 3.11 : Computer of data saving .

- **Pump :**

Among the pumps designed and dedicated to working with solar energy and batteries for wells whose diameter does not exceed 100 mm and whose working depth does not exceed 70 m, we chose a pump of 24 volts (DC) and 4 AMPS (Max).

Figure 3.12 : Sharflo9325 pump .

Chapter 04

Tests results

4.1. Introduction

After performing the measurement and installation steps and experimenting with different methods, we obtained, based on the coordinates of the site attached in this chapter, the results we obtained and what we noticed through them and what was deduced from this experiment.

4.2. Characteristics of the site

<u>Location of site:</u>

Latitude: 32°,36'N.

Longitude: 3°,1'S.

Sea level rise: 450m

<u>Location characterization</u>

the following figures represent the variation of sun rays and temperature per month in year .

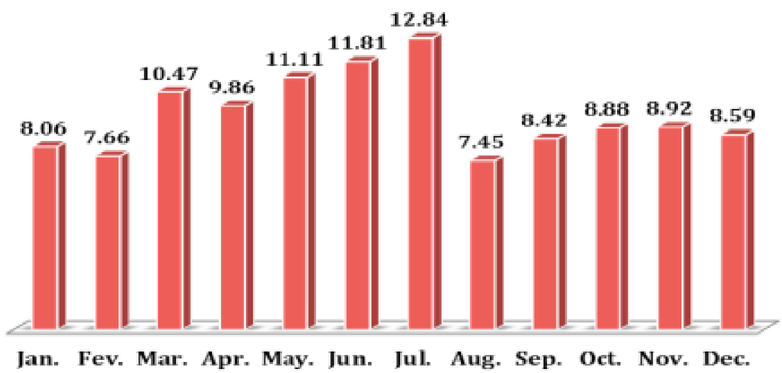


Figure 4.1: Annual monthly Sun shining

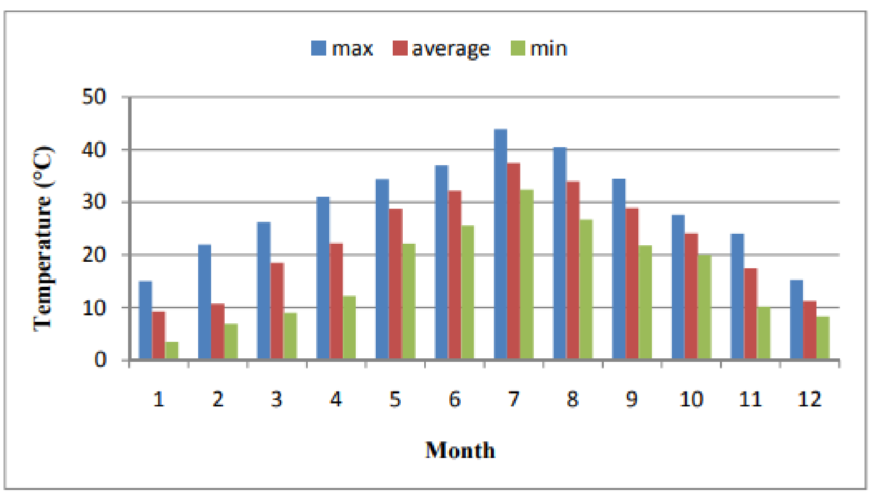


Figure 4.: Annual monthly temperature of Ghardaia.

4.3. Characteristics of the PV array configurations:

The suggested PV array designs include two distinct configurations, both of which are based on mono-crystalline silicon Isofoton (110/24) PV modules. The two different PV array configurations are: PVG1(2 modules connected in serial), PVG2 (4 modules connected in two parallel with two serial modules). The Tables 1 show the experimental results:

PV array design	**Electrical Nominal rates**		
PVG (P × S)	**Isc (A)**	**Voc (V)**	**Pm (W)**
PVG1: **1P × 2S**	3.5	80	220
PVG2: **2P × 2S**	7.0	80	220

Table 4.1: Characteristics of the different PV array.

4.4. Measurement protocol

- Check panel connection and installation (serial or parallel) of each configuration
- Release the current and power the pump from the bench electrical cabinet test
- Set the desired height of the surface pump manually
- Perform the 9:30 AM to 14:30 PM test
- Record measurements every 5 min
- Repeat previous steps each day of measurement and each configuration
- Draw the variation curves

The pump's depth varies between 10 meters, 15 meters, and 20 meters. We kept track of data for seven hours each day. Water flow, current, tension, sun radiation, and TMH were all recorded. Then, using the equations correspondence, we calculated the exact values for each of the following:

- Radiation.
- Flowrate.
- Voltage.
- Current.
- TMH.

This data enabled us to calculate of Hydraulic energy, power and water volumetric.

4.5. Results and discussions:

The results of the various PV pumping system (PVPS) configurations that were tested:

<u>4.5.1. Configuration 1:</u>

Recorded data on 04/18/202, for TMH= 10m

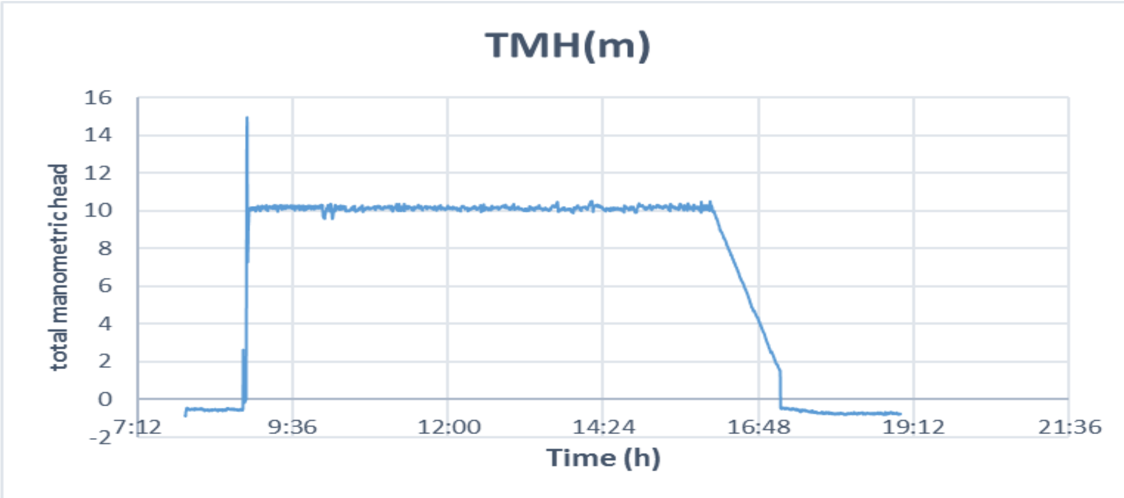


Figure 4.3: Variable TMH for a TMH of 10m.

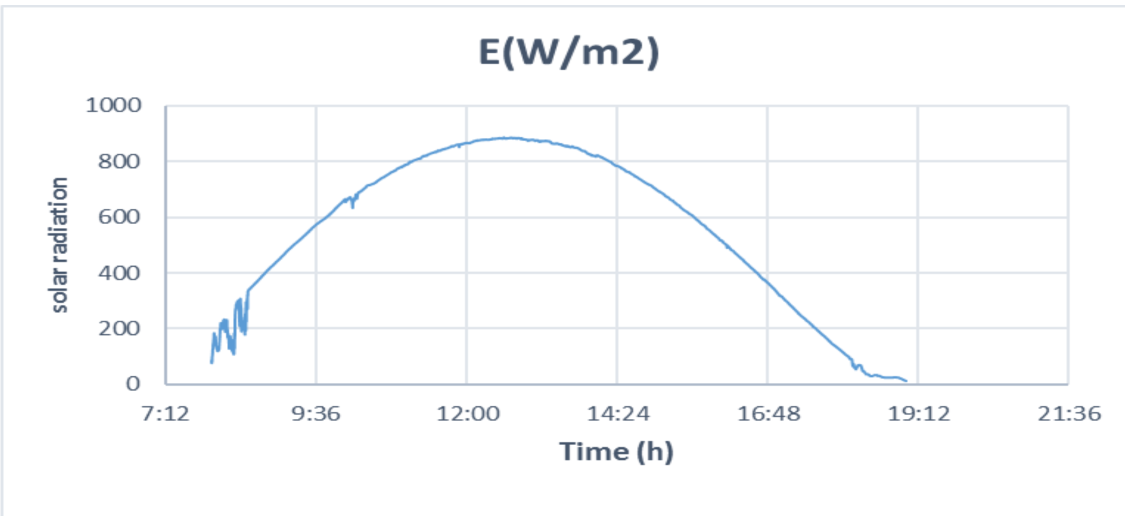


Figure 4.4 : Variable radiation for a TMH of 10.

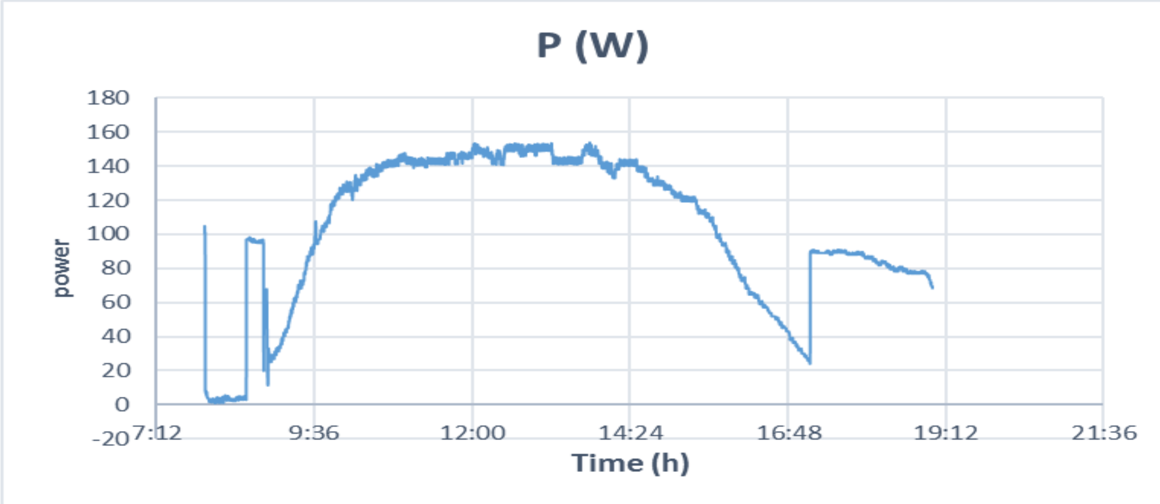


Figure 4.5: Variable power for a TMH of 10m.

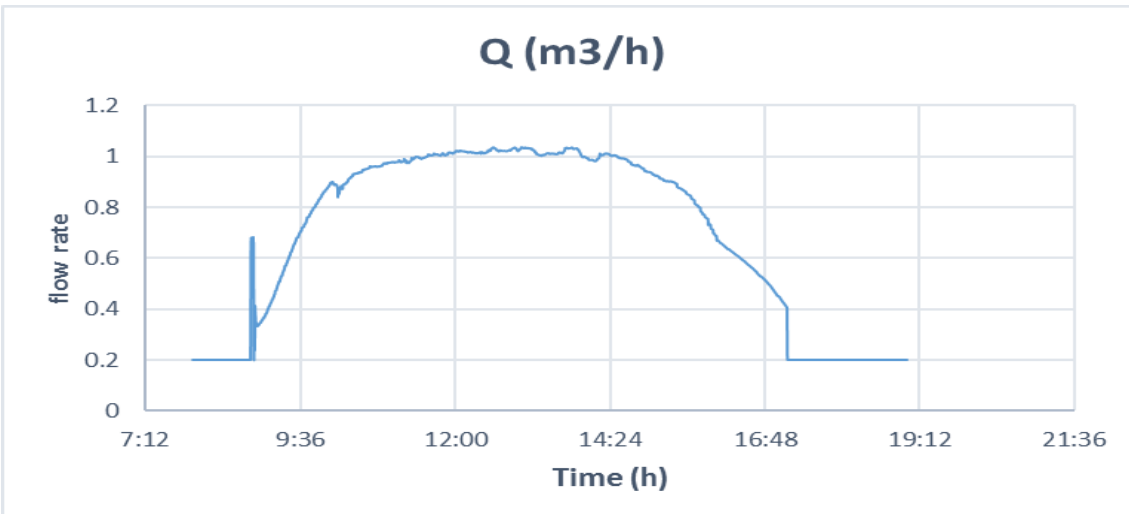


Figure 4.6 : Variable flow rate for a TMH of 10m.

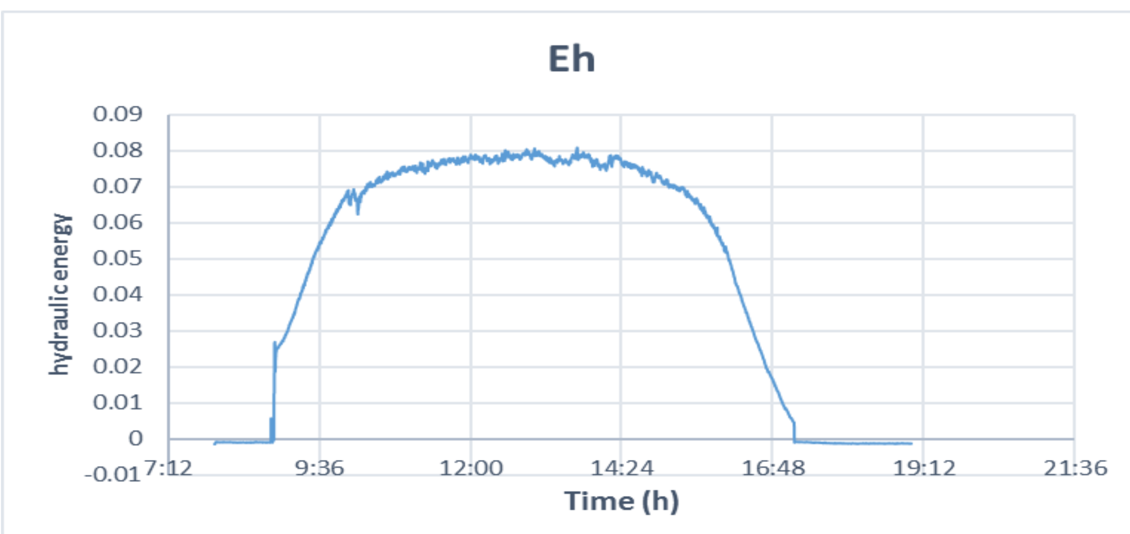


Figure 4.7: Variable hydraulic energy for a TMH of 10m.

Comment 1:

The daily variation of TMH, irradiance, flow rate, power, and hydraulic energy are depicted in Figures **4.3, 4.4, 4.5, 4.6** and **4.7**, where we note:

The beginning of the sunrise curve is unstable between the time period 7:55h until 8:30 h. At 10:10 h , we notice that there is instability due to a clouding passing and then return to normal. The highest energy value was 887 W/m2 at 12:41 h.

The beginning of the flow rate curve is unstable, as at 8:55 h a peak occurred and then returned to normal. We note that there is a fluctuation in the curve where there are also maximum values found in several times. The highest value reached 1.034 m3/h at 12:55h. It appears that the greatest value that the pump can provide is in the period around midday, from the beginning of 10:00h until 15:00h. The energy hydraulic curve is relatively stable with the presence of some peak as it reached the highest value of 0.080 J at 13:00 and it is in a direct relationship with the flow rate curve.

Recorded data on 04/19/202, for TMH= 15m

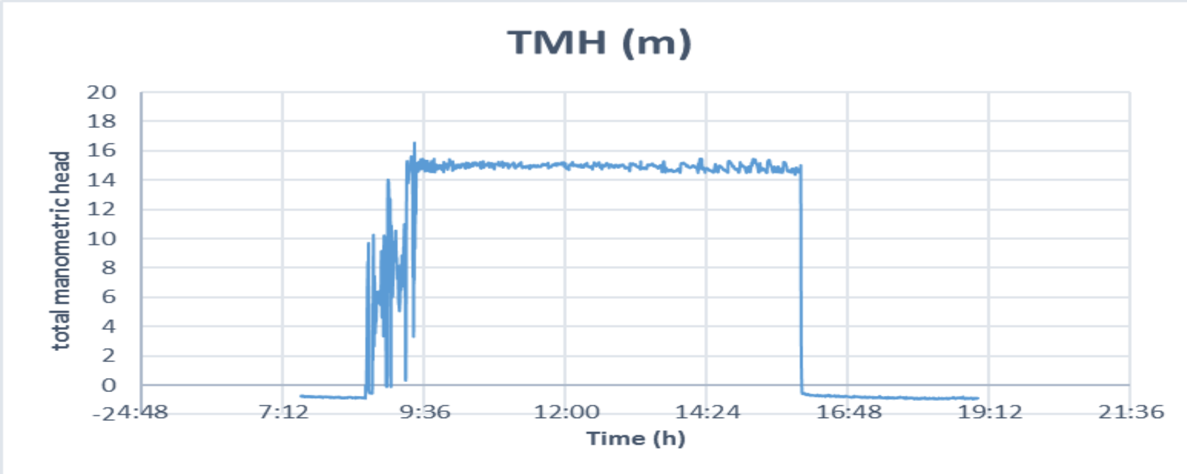


Figure 4.8 : Variable TMH for a TMH of 15m.

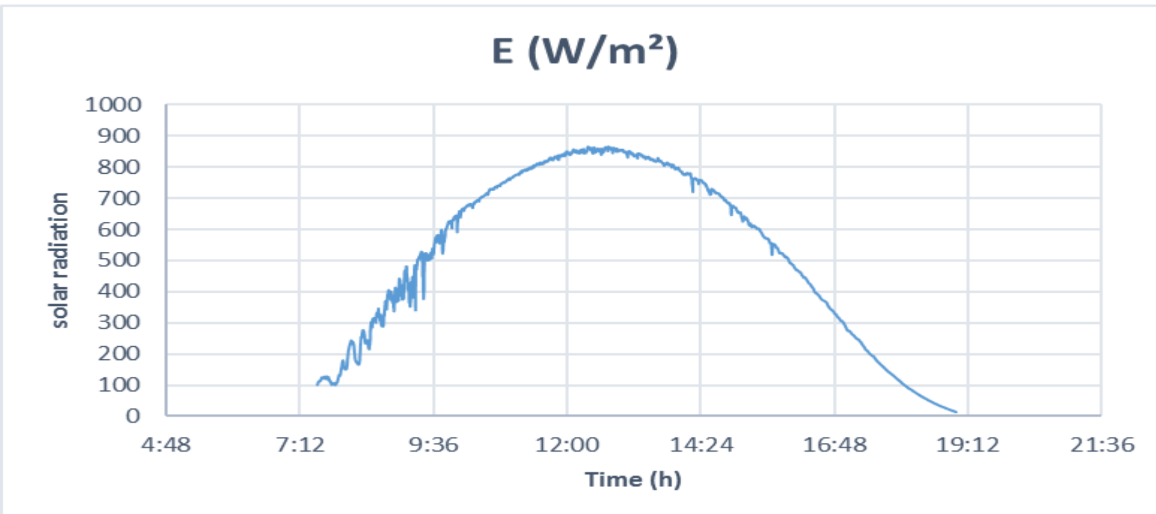


Figure 4.9 : Variable radiation for a TMH of 15m

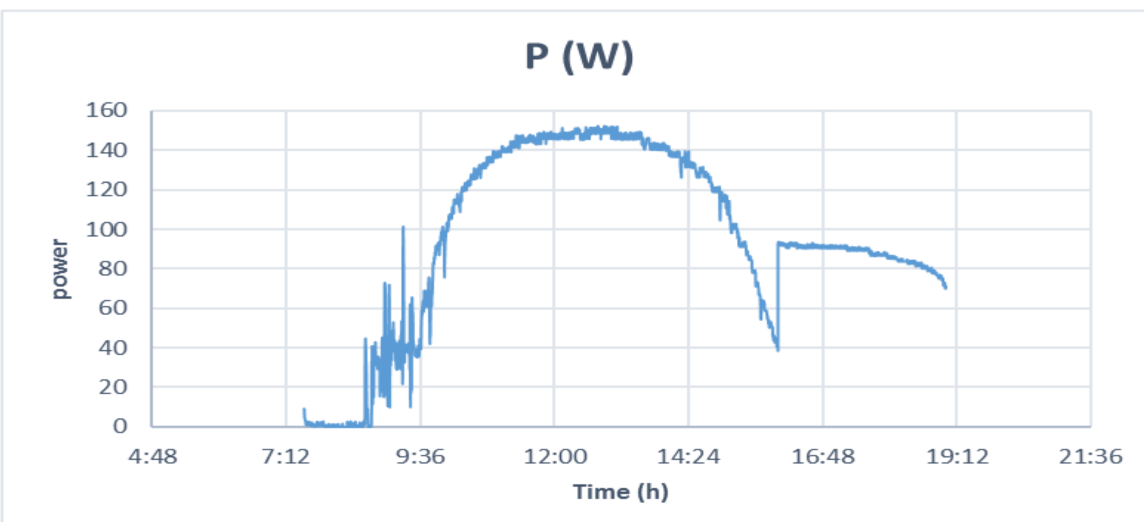


Figure 4.10 : Variable power for a TMH of 15m.

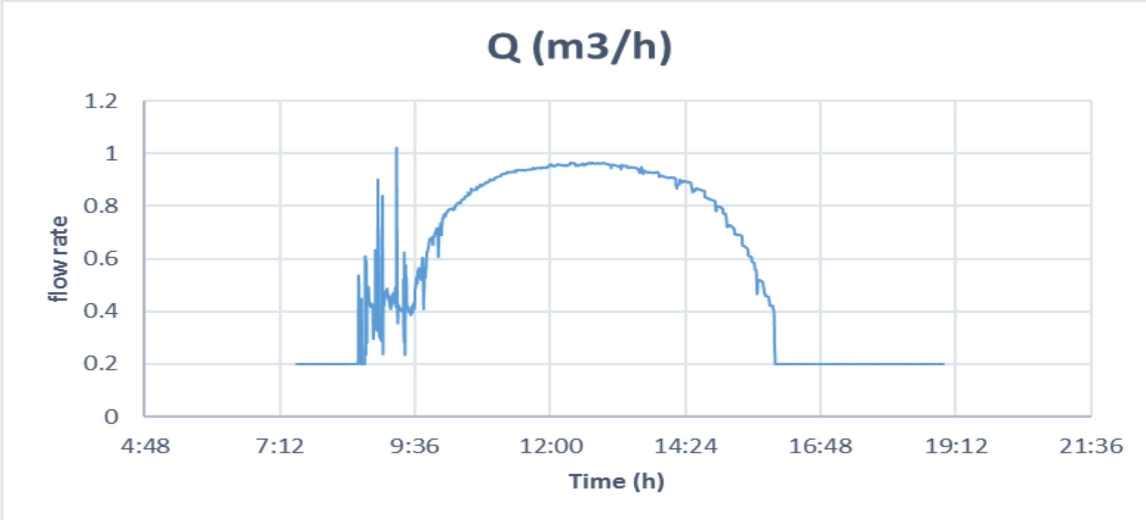


Figure 4.11 : Variable flow rate for a TMH of 15m.

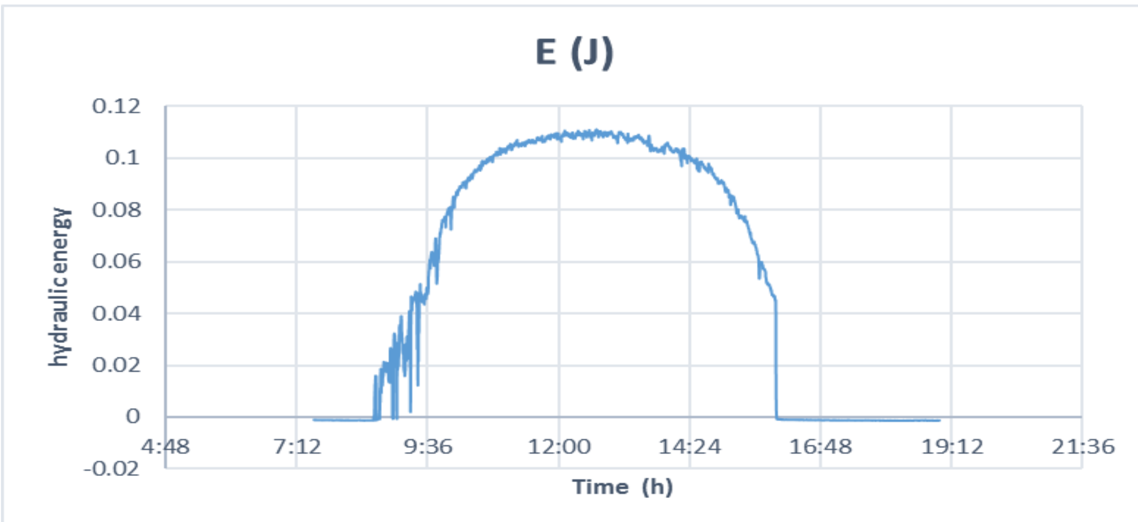


Figure 4.12: Variable hydraulic energy for a TMH of 15m.

Comment 2 :

Figures 4.8,4.9,4.10,4.11 and 4.12 show the daily variation of TMH, irradiance, flow rate, power, and hydraulic energy, with the following observations:

The turbulent sunrise resulted in an unstable radiation curve. Maximum power values of 861 W/m2 are reached at 12:22.

The peak occurred at the beginning of the flow rate curve due to radiation because it is in a positive relationship. The maximum value was estimated at 0.962m3/h at 12:25h, and it appears that the largest value the pump can provide is around midday.

In terms of power, hydraulic energy, and TMH, the curve starts unstable due to unstable radiation and then returns to relatively stable with peak power occurring over time intervals.

Recorded data on 05/09/2022, for TMH= 20 m

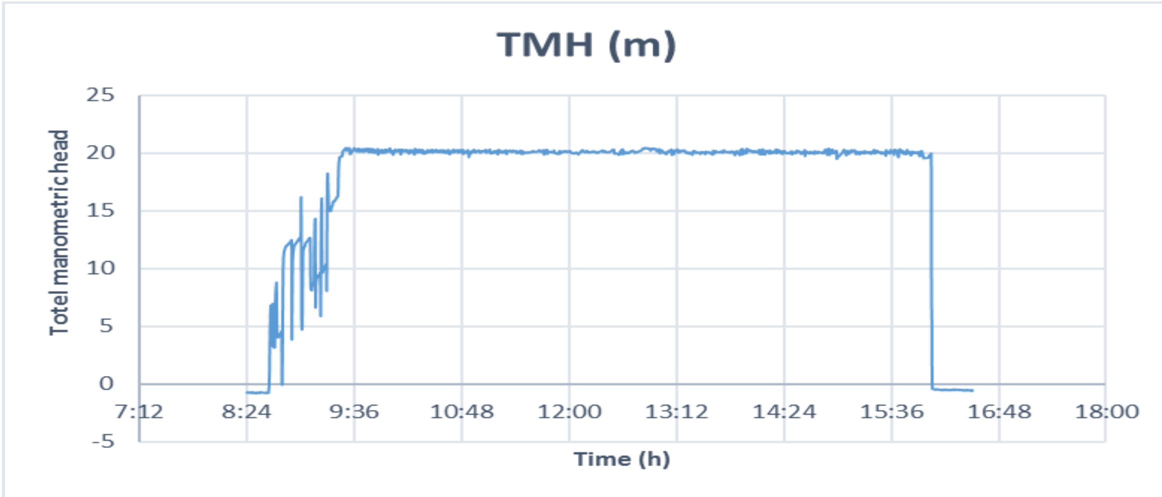


Figure 4.13: Variable TMH for a TMH of 20m.

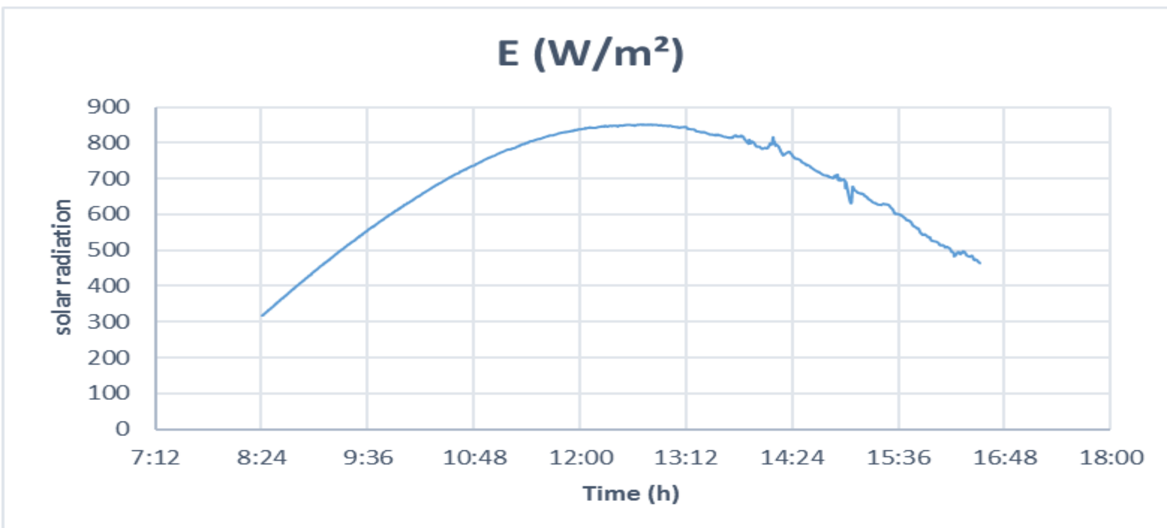


Figure 4.14 : Variable radiation for a TMH of 20m.

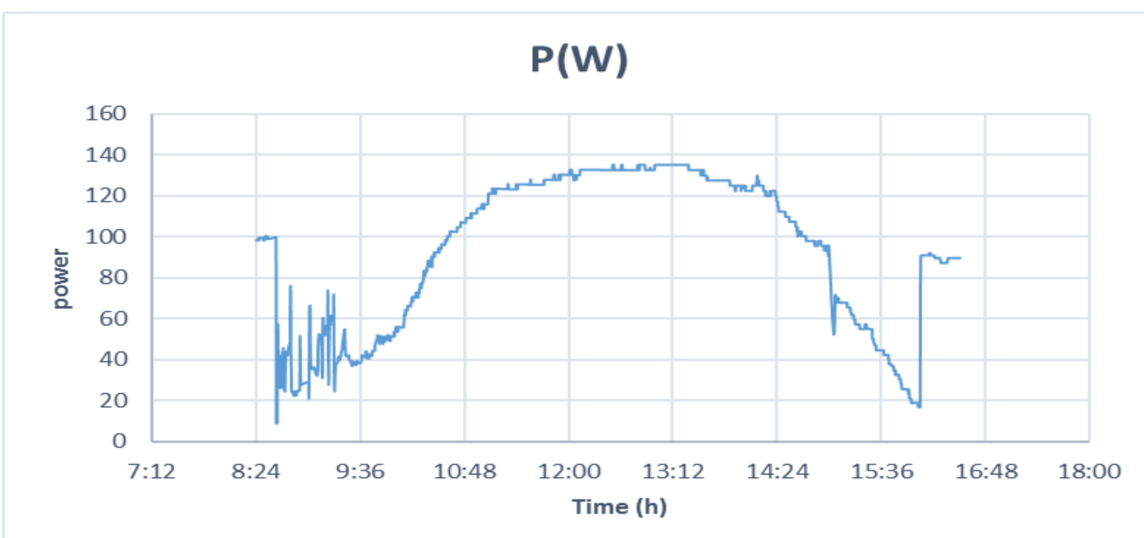


Figure 4.15: Variable power for a TMH of 20m.

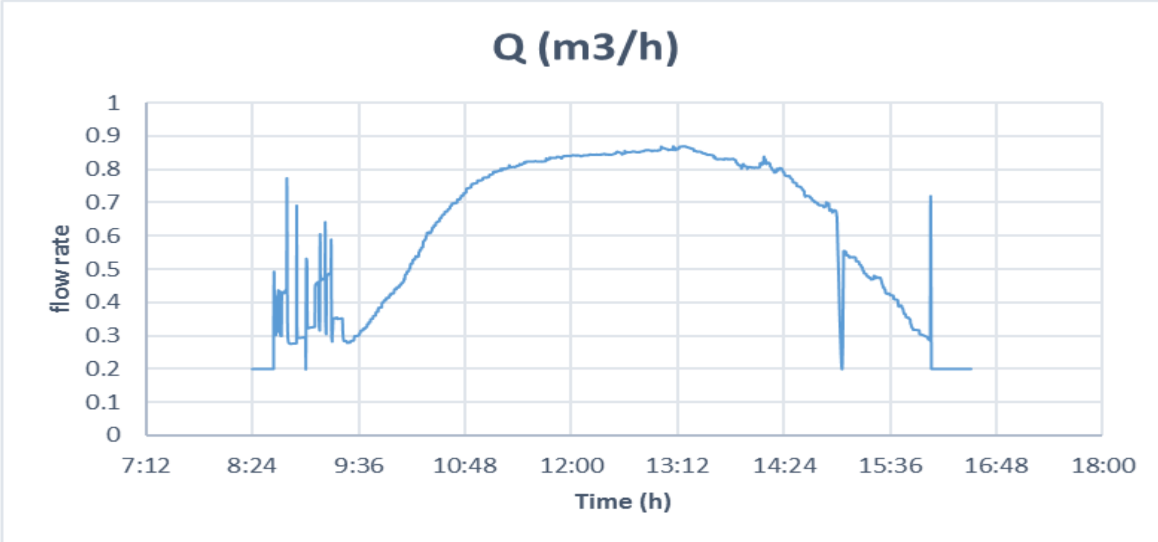


Figure 4.16 : Variable flow rate for a TMH of 20m.

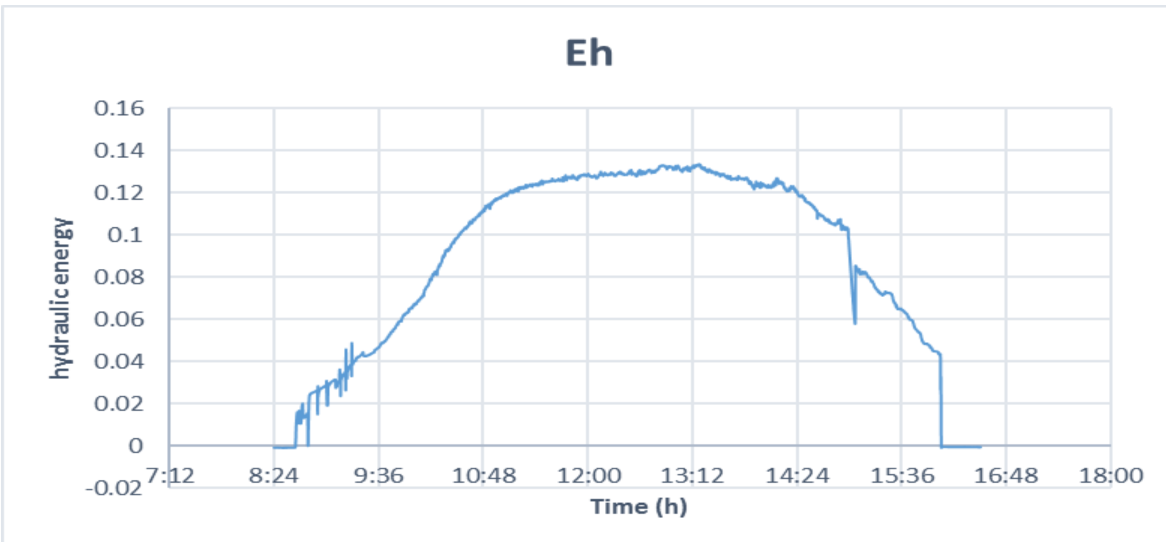


Figure 4.17: Variable hydraulic energy for a TMH of 20m

Comment 3:

The daily variations of TMH, irradiance, flow rate, power, and hydraulic energy are shown in Figures 4.13,4.14,4.15,4.16 and 4.17, with the following observations:

A stable sunrise resulted in a stable radiation curve. Reaching peak power values of 852 W/m2 at 12:48 is a lower value compared to the previous two curves because the weather conditions on that day were partly cloudy.

The peak occurred at the beginning of the flow rate curve due to radiation because it is in a positive relationship. The estimated maximum value was 0.868 m3/h at 13:16, and the largest value the pump could provide seemed to be around midday.

Relative to power, hydraulic energy, and TMH, the beginning of the curve is unstable due to unstable radiation and then returns to relatively stable with peak energy occurring over time intervals.

Discussion:

We note that the TMH radiation curve of 10 m was better than the TMH curves of 15 and 20 m. For the 15m TMH curve, it was a semi-cloudy day, so we note that the curve is unstable with peak energy occurring multiple times.

For the 10 m flow rate curve is the best and highest value, the 15 m flow rate curve is the average value, while the 20 m flow rate curve has the lowest value, noting that the amount of radiation was not significantly different. The greatest value a pump can provide appears to be around midday.

In contrast to the flow rate, we note that the hydraulic power is the largest value of TMH 20 m The lowest value for TMH is 10m, while TMH is 15m. Thus, we conclude that the pump is optimal at a TMH of 20 m.

We note that the power curve of TMH 10 and 15 m is close to each other and the highest value is from the TMH curve of 20 m and this affects the work of the pump and this is the reason for the difference in the flow rate.

4.5.2. Configuration 2:

Recorded data on 11/05/2022, for TMH= 10 m

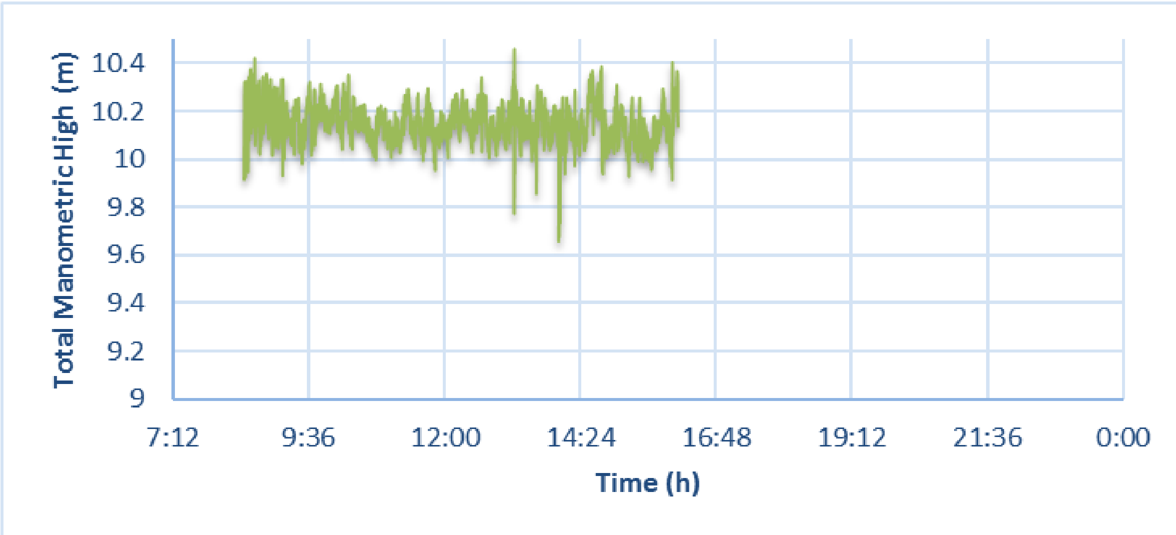


Figure 4.18: Daily Total Manometric high at 10m.

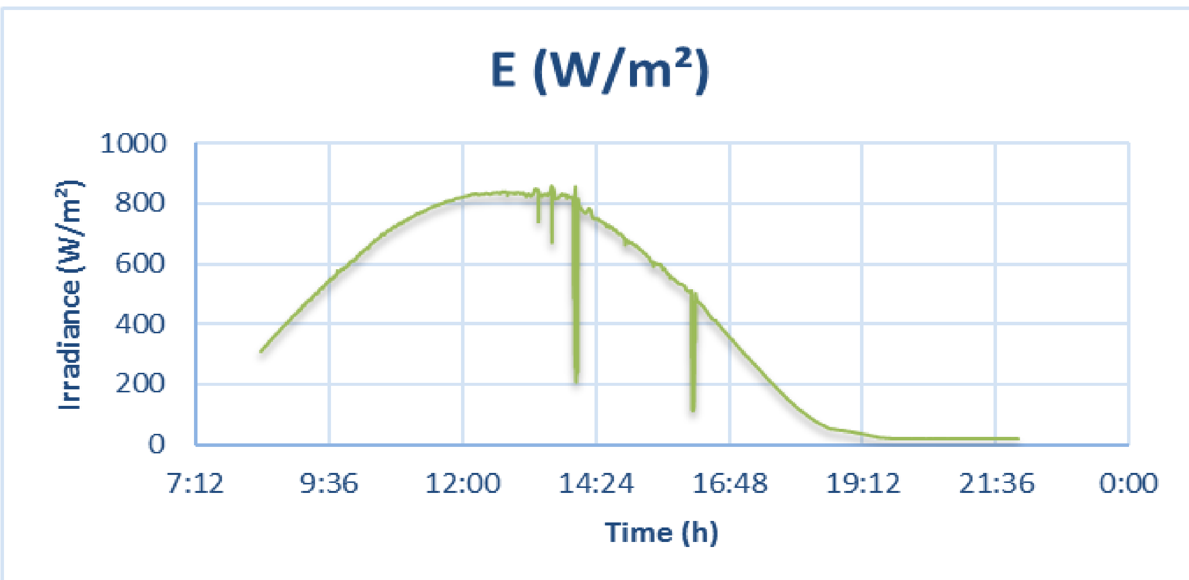


Figure 4.19: Insolation variation.

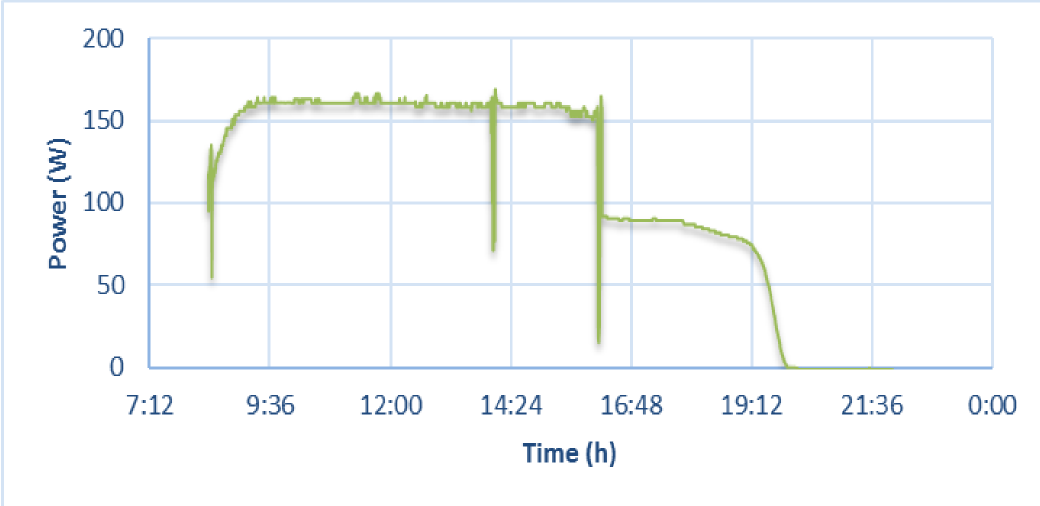


Figure 4.20: Daily variation Power.

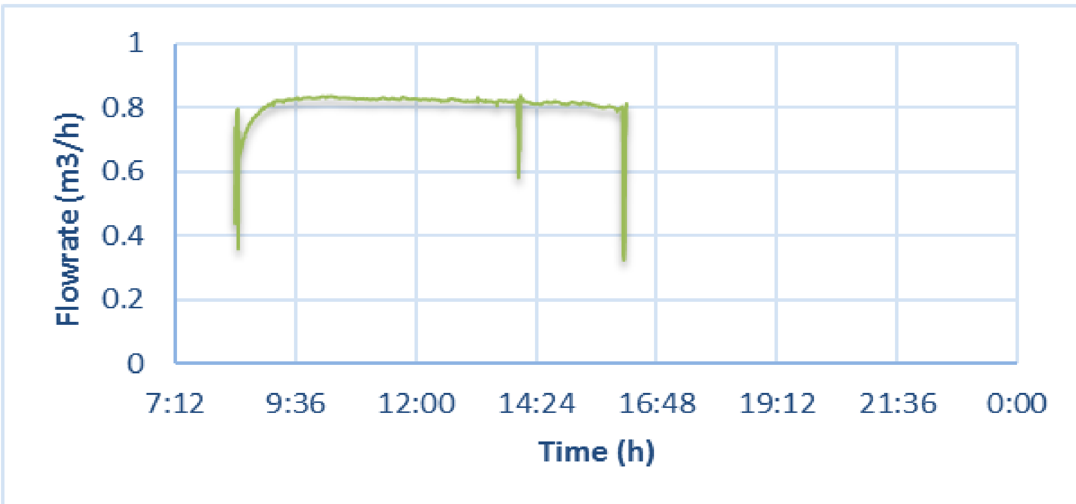


Figure 4.21: Daily variation Flow rate.

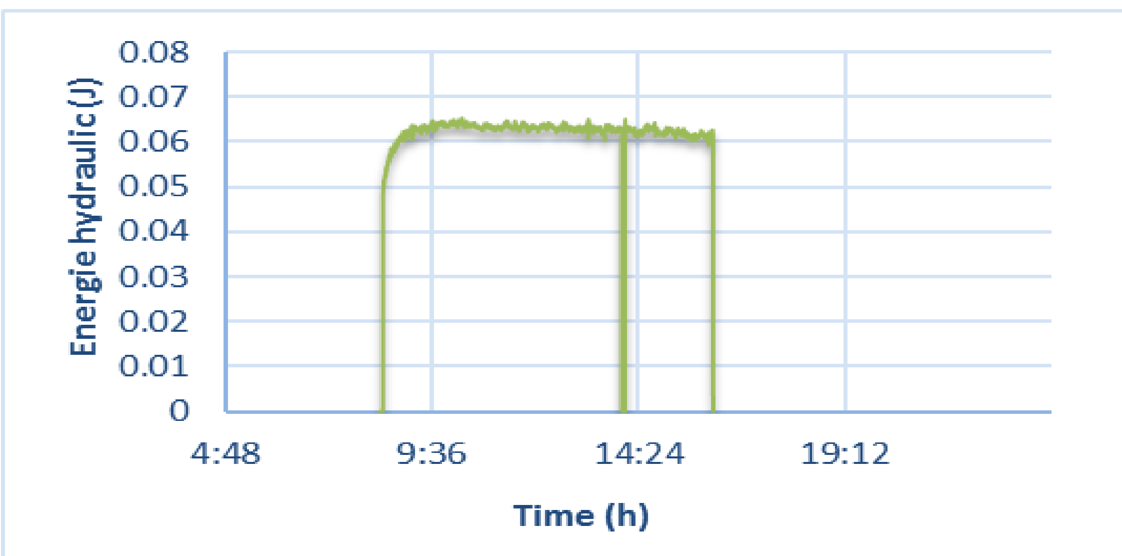


Figure 4.22: Hydraulic energy.

Comment 1:

The daily variation of TMH, irradiance, Power, Flowrate and energy hydraulic is represented by the curves in figs. 4.18, 4.19, 4.20, 4.21 and 4.22. As shown in the curve. The variation in radiation from sunrise to sunset was depicted in **figure 4.19**. Cloudy passage was indicated by declines in the curve at 13:22h, 13:56h, 14:13h, and 16:14h. Also, at 12:55h, we score the highest point is 833 W/m2. **Figure 4.20** shows the daily variance in flow; The flow was constant, as shown in the chart. At 14:04 the curve dropped to 0.5788 m3/h. On the other hand, **Figure 4.21** depicts a change in power, with a decrease at 14:04 h 16:07h. **Figure 4.22** shows that the hydraulic energy was steady until 14:04 h, when it began to decline. Because each of Flowrate, Energy hydraulic, and Power is affected when the amount of irradiation coming in is too low, we conclude that there is a direct relationship between Flowrate, Energy hydraulic, and Power and the amount of irradiation coming in.

Recorded data on 12/05/2022, for TMH=15 m

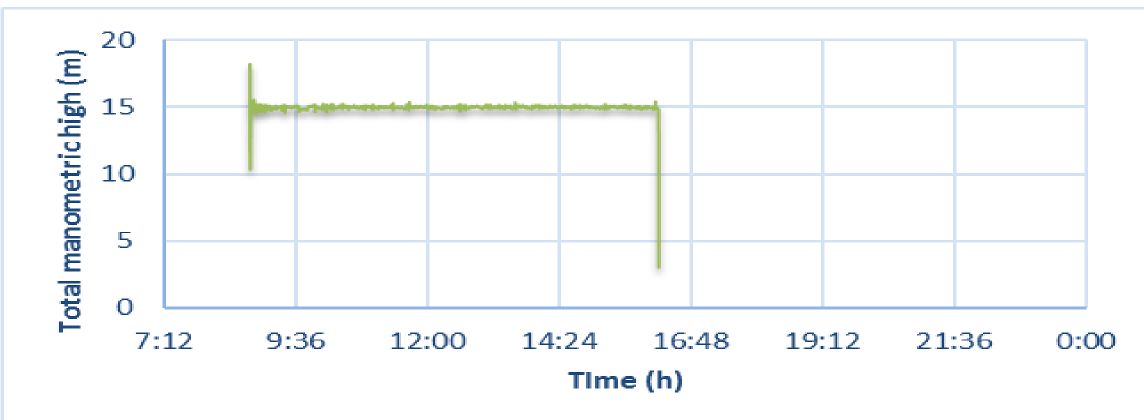


Figure 4.23: Daily Manometric high at 15m

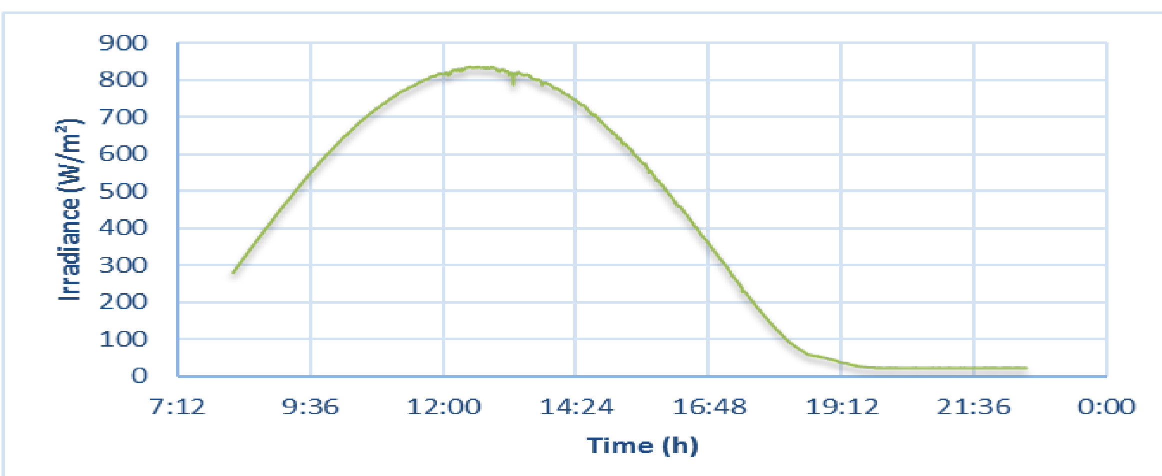


Figure 4.24: Insolation variation

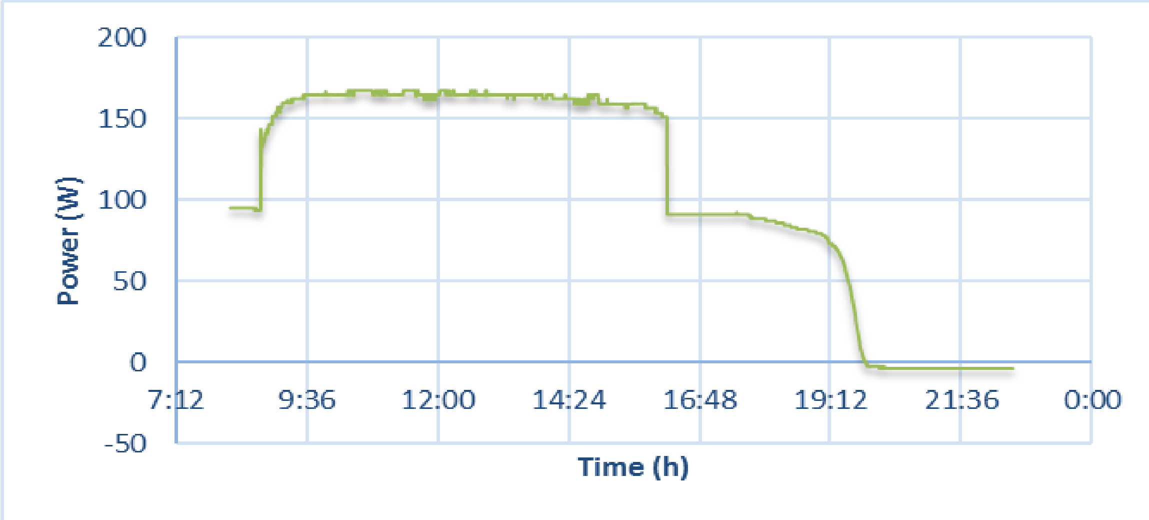


Figure 4.25: Daily variation Power

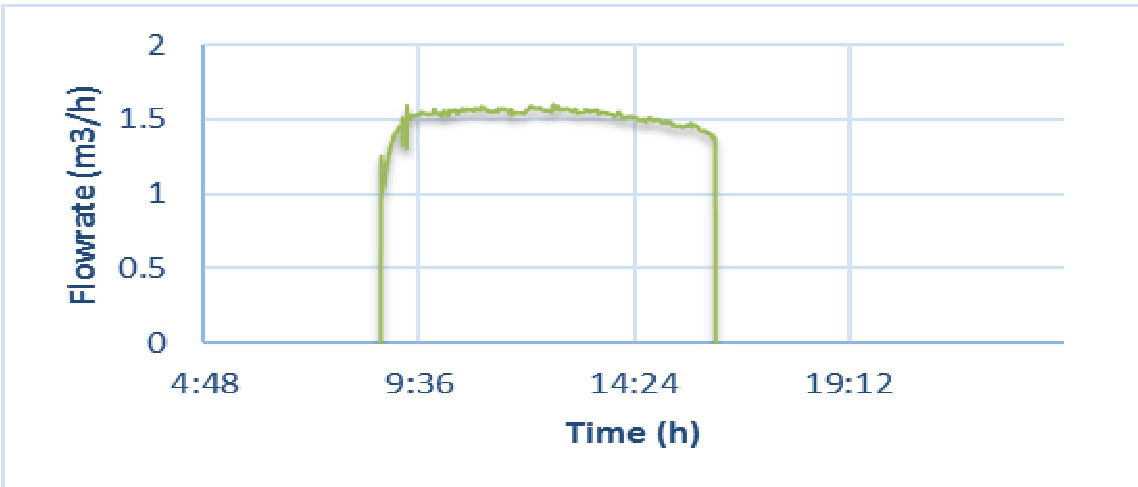


Figure 4.26: Daily variation Flow rate

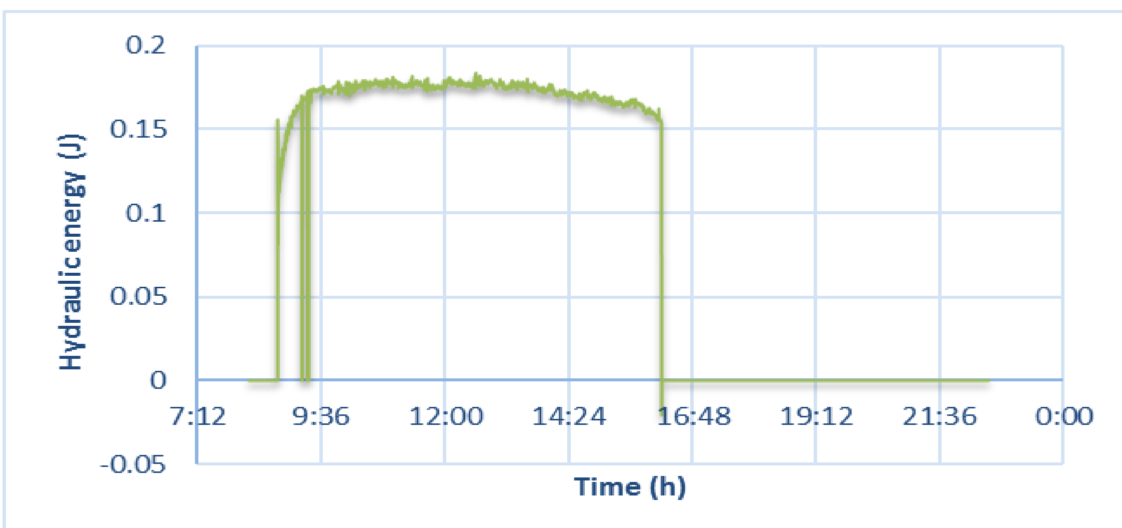


Figure 4.27: Hydraulic energy.

Comment 2:

Figs 4.23, 4.24, 4.25, 4.26 and 4.27 represents the daily variation of TMH, irradiance, flow rate, power and hydraulic energy. As illustrated in **fig. 4.24**, a large amount of radiation is emitted during a sunny day from sunrise to sunset. The variation power in **fig.4.25** remained consistent throughout the day. Furthermore, in **fig. 4.26**, the flow was shaky at first until 9:18 h, then settled down until the conclusion of the day. **Fig 4.27** shows the hydraulic energy curve presented at the beginning of the scan declined to 0 J around 9:20 h, indicating that flowrate and hydraulic energy have a direct relationship.

Recorded data on 16/05/2022, for TMH= 20 m

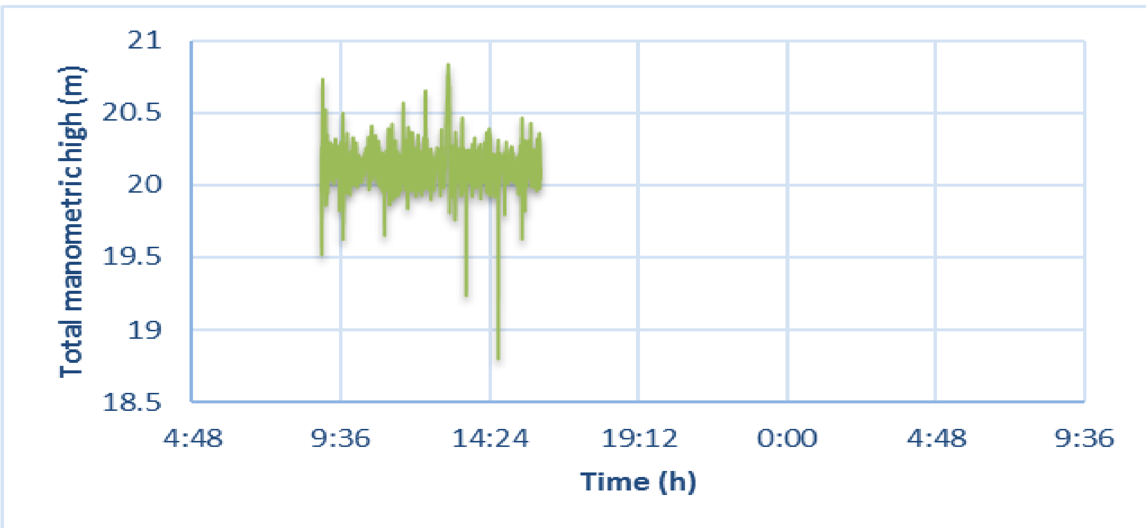


Figure 4.28: Daily Manometric high at 20m

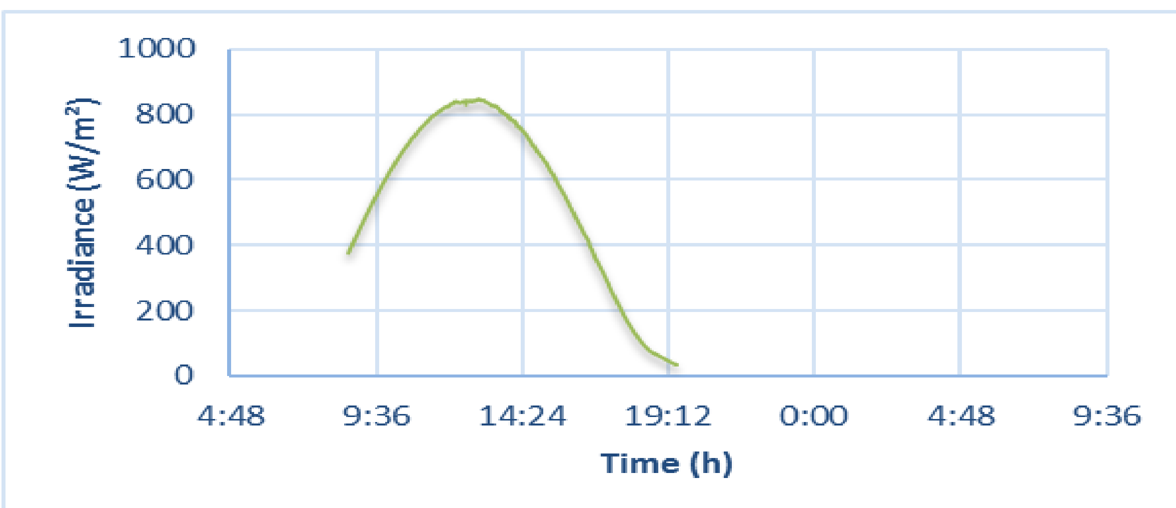


Figure 4.29: Insolation variation

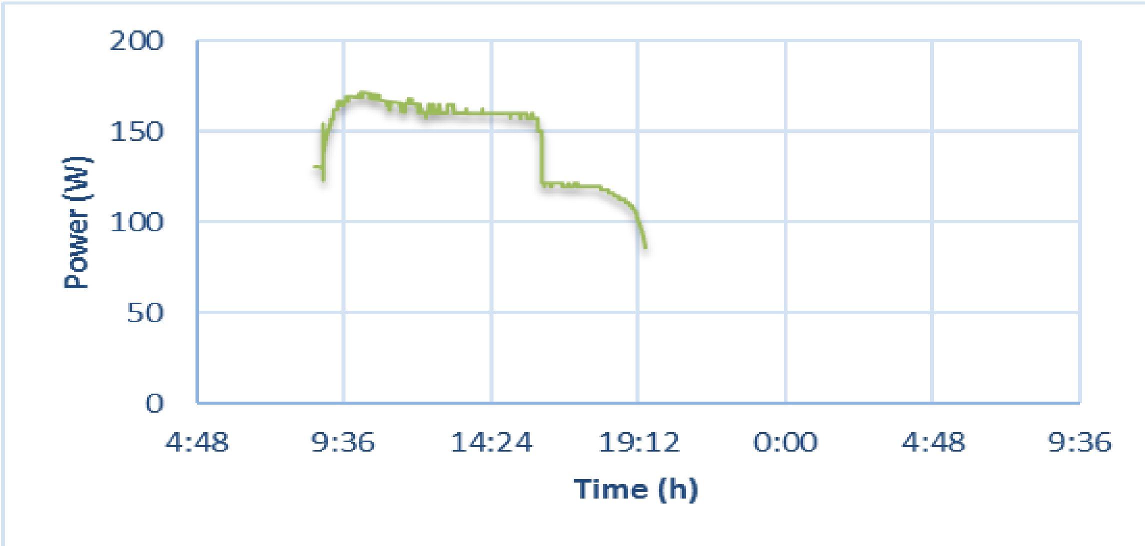


Figure 4.30: Daily variation Power

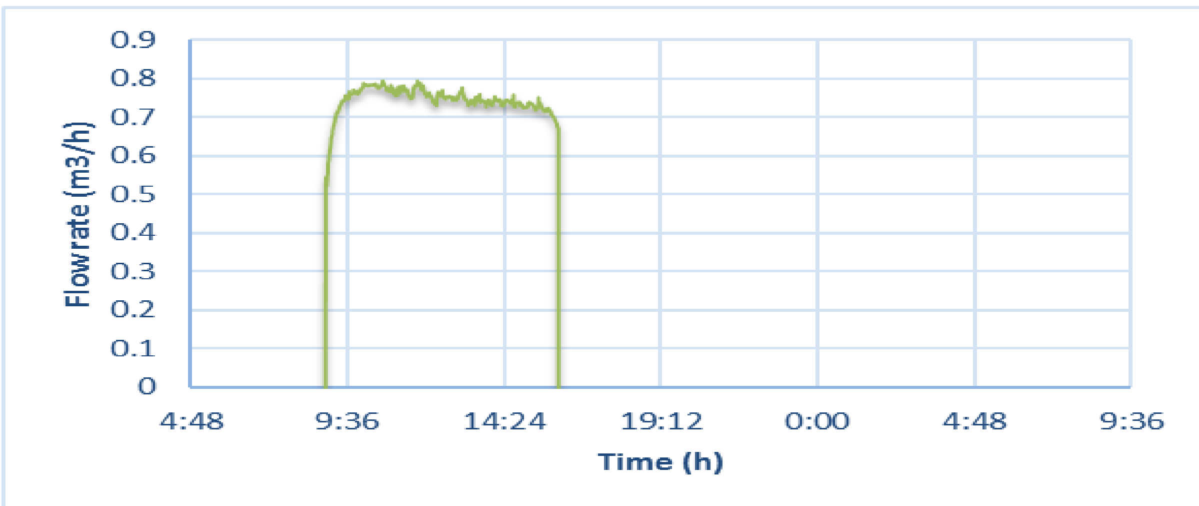


Figure 4.31: Daily variation Flow rate

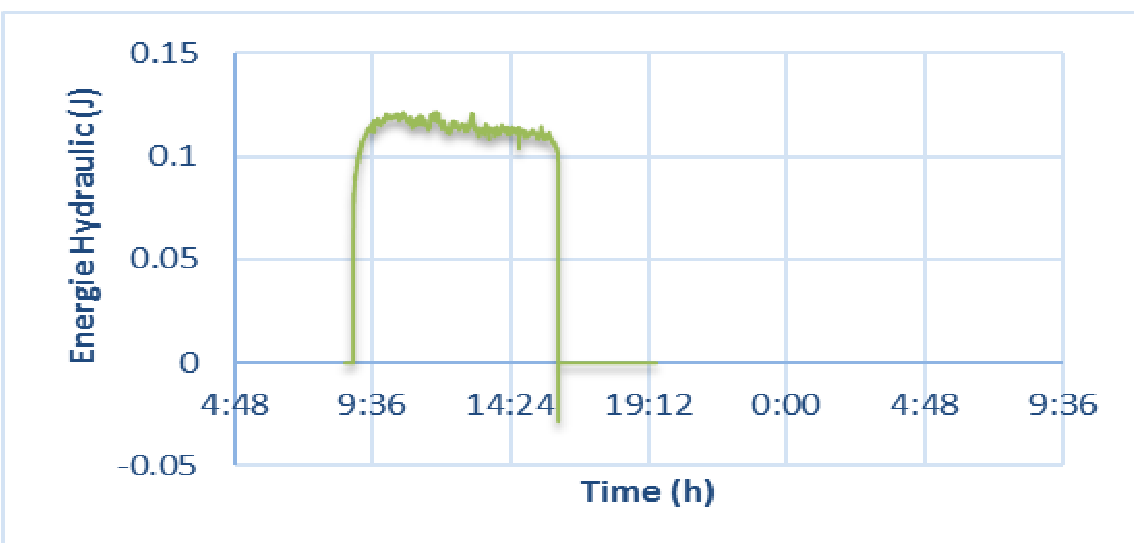


Figure 4.32: Hydraulic energy

Comment 3:

Figures 4.28, 4.29, 4.30, 4.31 and 4.32 represents the daily variation of TMH, irradiance, power, flowrate and hydraulic energy. **Figure 4.29** shows that the irradiance was steady from morning till night, with the greatest value of 838 W/m2 recorded at 12:46 h. The variation of power in **figure 4.30** was constant. In **fig. 4.31**, the flow rate seemed to increase at first, reaching a value of 0.7659 m3/h at 11:58 h, until decreasing to a value of 0.6968 m3/h at 15:56 h. In **figure 4.32**, we can observe that hydraulic energy increased at first, but subsequently looked to decline.

Discussion:

In the different days and at the different depths of the well (10,15,20 m), We note that at TMH =15 m was better than the TMH 10 and 20 m, where we deduced this from the given results.

The best and highest value is for the 15 m flow rate curve, whereas the 20 m and 10 m flow rate curves have nearly identical values, indicating that the amount of radiation was not considerably different. Around noon, it looks that a pump can deliver the most value.

In contrast to the flow rate, the hydraulic power of TMH 15 m is the highest value. The lowest value for TMH is 10m, and average is 20m. Thus, as a result, we conclude that a TMH of 15 m is optimal for the pump.

We can see that the power curves of TMH 10 m, 15 m, and 20 m are very similar. This has an impact on the pump's performance, which is why the flow rate is different.

Comparison between the two configuration performances

After studying the results and analyzing them, we found that for the first installation is sufficient to provide the pump with energy at a depth of 20m where it provides optimal hydrolytic energy. The second installation is capable of providing a higher power to the pump than the first, allowing it to reach the same hydroelectric energy at a depth of 15 meters. Furthermore, the first installation is less costly than the second installation.

In addition, we observe that hydraulic energy is is the lowest output in the first configuration, unlike the second configuration, where it reached the highest value 0.1742 J at the 15m.

GENERAL CONCLUSION

The work presented in this thesis relates to the scaling of the various steps of testing a solar pumping system. Where the real experiment was carried out with real data in the photovoltaic pumping laboratory in the Applied Research Unit for Renewable Energies in GHARDAIA.

The experimental study of the solar pumping system in two different ways made it possible for two different configurations to know the behavior of each of them in terms of external influences and the characteristics of each installation to reach the best efficiency for each system and to compare between them.

Through this study, we were able to reach that sunlight has a significant impact on the production of electrical energy from the photovoltaic generator that feeds the pump motor, thus the entire system work and its efficiency.

With the different types of pumping engines available in the market, we have a great opportunity to choose the appropriate type that meets the needs in terms of the amount of load to be pushed, the amount of flow that determines the hydraulic power, and also in terms of the maximum depth point

Thus, photovoltaic pumping is an ideal solution in these cases because it is a multi-choice and according to the cost, as it encourages farmers and residents of remote areas to use it.

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الملخص: في هذا العمل، تم إجراء دراسة الحجم لنظام ضخ المياه الكهروضوئي المستقل. من خلال اعتماد خطوات التحجيم، تم إخضاع نظامين على بيانات لبئر تقليدي حقيقي. يتم الحصول على التصميم الامثل لنظام ضخ المياه الكهروضوئي، بناًمختلفين من نظام الضخ الكهروضوئي الاختبارات التوصيف، في مختبر أنظمة ضخ المياه الكهروضوئية، بوحدة البحث التطبيقي في الطاقات المتجددة/غرداية. النظام الأول (نظام 1) ؛ يتكون من مضخة شمسية من نوع Shurflo (120واط)، مقترنة مباشرة بلوحتين شمسيتين (110 واط / 24 فولت) من نوع Isofoton مربوطة على التسلسل (2s*1p) النظام الثاني (نظام 2)؛ يتكون من مضخة شمسية من نوع Shurflo (120واط)، مقترنة مباشرة بأربع لوحات شمسية (110 واط / 24 فولت) من نوع Isofoton، مربوطة على فرعين متوازيين يتكون كل فرع من لوحتين شمسيتين مربوطة على التسلسل (2s*2p).أجريت اختبارات ضخ تجريبية على ارتفاعات ضخ مختلفة في ظروف مناخية حقيقية. تمت معالجة البيانات التي تم الحصول عليها، لكل نظام، بينما تم إجراء تحليل مقارنة لتحديد نظام ضخ المياه الكهروضوئي الامثل.

الكلمات المفتاحية: اختبارات التحجيم، الامثل، التوصيف، المضخة الشمسية.

Abstract: In this memory sheet, the dimensioning study of an autonomous Photovoltaic Water Pumping System, has been carried out. Through the sizing steps, the optimal design of a PVWPS is achieved**,** based on the data of a real traditional well. Accordingly, two different PVWPS configurations were put into characterization tests, at the PV water pumping system laboratory, URAER, Ghardaia. The first configuration (Config.1); consists of a submersible solar pump of Shurflo (120W) type, directly coupled to two Isofoton PV modules (110W/24V), connected in serial (2Sx1P). The second configuration (Config.2); consists of a submersible solar pump of Shurflo (120W) type, directly coupled to four Isofoton PV modules (110W/24V), connected in two parallel branches of two PV modules serial, each (2SX2P). The pumping tests were carried out for different pumping heads, under the real outdoor conditions. The obtained data were treated, for each configuration, whereas, a comparison analysis has been undertaken to determine the optimal PVWPS configuration.

Keywords: Sizing, optimal, characterization tests, solar pump

Résumé : Dans cette travail, l'étude de dimensionnement d'un Système de Pompage d'Eau Photovoltaïque autonome, a été réalisée. En adoptant les étapes de dimensionnement, la conception optimale d'un PVWPS est obtenue, sur la base des données d'un puits traditionnel réel. Deux configurations différentes de PVWPS ont été soumises à des tests de caractérisation, au laboratoire de systèmes de pompage d'eau Photovoltaïque, URAER, Ghardaia. La première configuration (Config.1); se compose d'une pompe solaire submersible de type Shurflo (120W), couplée directement à deux modules PV Isofoton (110W/24V), connectés en série (2Sx1P). La deuxième configuration (Config.2); se compose d'une pompe solaire submersible de type Shurflo (120W), couplée directement à quatre modules PV Isofoton (110W/24V), connectés en deux branches parallèles de deux modules PV en série, chacune (2SX2P). Les tests expérimentaux de pompage ont été réalisés pour différentes hauteurs de pompage, dans les conditions climatiques réelles. Les données obtenues ont été traitées, pour chaque configuration, alors qu'une analyse de comparaison a été entreprise pour déterminer la configuration PVWPS optimale.

Mots clés : Dimensionnement, optimal, tests de caractérisation, pompe solaire.