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Theme

Standalone PV water pumping system for Durum Wheat irrigation in Ghardaia region: Technique and economic study

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I dedicate this work to: My parents without reverence

It can live up to the love they keep giving me

to fill up. May God grant them wellness and long life.

To my brothers and sisters, to all my family and friends. And to everyone who contributed from near or far to this project,

I say thank you

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To dear parents, the inexhaustible source of giving, of patience

and sacrifice. Whatever I say and write, no dedication

I can express my deep dissatisfaction and appreciation

love. May God protect you and provide you with health and happiness.

For my brothers and sisters

To all my family and friends

thank you

KAMEL

Abstract

The Ghardaia region is one of the large southern parts of Algeria which has great solar potential and huge groundwater that can be exploited in agriculture, considered as one of the main sector in the local development. The annual production of Durum Wheat has reached about a half million quantal in the last years which attracted the care of the sector. However, the supply with water is considered as the main problem, due to the far of the majority of the farms from the main grid. In other hand the supply with fuel is very exhaustive for the using diesel pumps due to the remote of the fuel stations. In this work, an attempt of techno-economic study of photovoltaic water pumping system (PVWPS) has been adopted to see the feasibility level in integrating this new system in irrigation. Accordingly, a technical study has been conducted to determine the optimal power needed by dimensioning examination and then making economic evaluations to estimate the total cost of the investment. In other hand, experimental tests were carried out both in photovoltaic laboratory, technically, whereas an economic test was carried out on sample of a Durum wheat area production, in one farm of Hassi Lefhel, Ghardaia, Therefore, a techno-economic comparison between the water supply by electricity and a PV water pumping system has been done and the result show that the two investments can be linked after three years, which confirms the medium investment of the PVWPS.

Keywords: Ghardaia. Solar energy, PV water pumping system, durum wheat, electricity. Sprinkling water

Résumé

La région de Ghardaia est l'une des grandes régions du sud de l'Algérie qui possède un grand potentiel solaire et d'immenses nappes phréatiques, exploitables en agriculture, considérée comme l'un des principaux secteurs du développement local. La production annuelle de blé dur a atteint environ un demi-million de quantaux au cours des dernières années, ce qui a attiré l'attention du secteur. Cependant, l'approvisionnement en eau est considéré comme le problème principal, en raison de l'éloignement de la majorité des fermes du réseau principal. Par contre l'approvisionnement en carburant est très exhaustif pour ceux qui utilisent des pompes diesel en raison de l'éloignement des stations-service. Dans ce travail, une tentative d'étude technico-économique du système de pompage d'eau photovoltaïque (PVWPS) a été adoptée pour voir le niveau de faisabilité de l'intégration de ce nouveau système dans l'irrigation. Ainsi, une étude technique a été menée pour déterminer la puissance optimale nécessaire par une étude de dimensionnement puis une étude économique a été réalisée en estimant le coût total de l'investissement. D'autre part, Des tests expérimentaux ont été réalisés à la fois dans le laboratoire photovoltaïque de l'Institut des énergies renouvelables de Ghardaia (URAER), tandis qu'un test économique a été réalisé sur un échantillon de la zone de production de blé dur, dans une ferme à Hassi Lfhel, Ghardaia. Par conséquent, une comparaison technique économique a été faite entre l'approvisionnement en eau électrique et le système de pompage d'eau photovoltaïque et le résultat a montré que les deux investissements peuvent être liés après 3 ans, ce qui confirme l'investissement moyen du système de pompage solaire.

Mots-clés : Ghardaia. Énergie solaire, système de pompage solaire, blé dur, électricité. Eau arrosage

ملخص

تعتبر منطقة غرداية من المناطق الجنوبية الكبيرة في الجزائر التي تتمتع بإمكانيات كبيرة من الطاقة الشمسية ومياه جوفية ضخمة يمكن استغلالها في الزراعة باعتبارها أحد القطاعات الرئيسية في التنمية المحلية. حيث بلغ الإنتاج السنوي من القمح القاسي حوالي نصف مليون قنطار في السنوات الماضية مما جذب اهتمام القطاع. ومع ذلك، تعتبر مشكلة الإمداد بالمياه هي المشكلة الرئيسية، نظرًا لبعد غالبية المزارع عن الشبكة الرئيسية. من ناحية أخرى ، فإن الإمداد بالوقود شديد الاستنزاف لأولئك الذين يستخدمون مضخات الديزل بسبب البعد عن محطات الوقود. في هذا العمل ، تم اعتماد محاولة لدراسة تقنية اقتصادية لنظام ضخ المياه الكهروضوئية (PVWPS) لمعرفة مستوى الجدوى في دمج هذا النظام الجديد في الري. وعليه تم عمل دراسة فنية لتحديد كمية الماء لازمة لسقي, باضافة الى طاقة الكهربائية التي نحتاجها من اجل ضخ الماء ومن ثم عمل دراسة اقتصادية بتقدير التكلفة الإجمالية للاستثمار. من ناحية أخرى تم إجراء اختبارات تجريبية في معهد طاقات المتجددة بغرداية (URAER) ، بينما تم إجراء اختبار اقتصادي على عينة من منطقة إنتاج قمح الصلب في مزرعة حاسي لفحل ، غرداية ،بعدها تم إجراء مقارنة تقنية اقتصادية بين تزويد المياه بالكهرباء ونظام ضخ المياه الكهروضوئية ، وأظهرت النتيجة أنه يمكن ربط الاستثمارين بعد ثلاث سنوات ، مما يؤكد الاستثمار المتوسط ل لنظام الضخ بطاقة الشمسية

الكلمات المفتاحية: غرداية. طاقة الشمسية، نظام الضخ الشمسي، قمح صلب، كهرباء. الماء .السقي

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Nomenclature

PV	Photovoltaic panels.	
°C	Degré Celsius.	
IB	Direct radiation	
ID	Diffuse radiation & Reflected	
IG	Global radiation	
δ	declination angle	[°]
β	Altitude angle	[°]
H	Hour angle	[°]
L	Latitude angle	[°]
φ	azimuth angle	[°]
SASS	The Northern Sahara Aquifer System	
CI	Continental Intercalaire	
CT	Complexe Terminal	
eV	Electronvolt	
Iout	Current supplied by cell	[A]
Id	Diode Current	[A]
Iph	Current produced by the solar cell	[A]
Isc	The short-circuit current	[A]
Ki	The temperature coefficient	[%/K]
Tc	module temperature	[K]
G	the irradiation	[W/m^2]
Tref	298 K	[K]
Gref	1000 W/m^2.	[W/m^2]
q	Electron charge = $1,602.\ 10^{-19}$	[C]
K	Constante de Boltzmann = $1,38.\ 10^{-23}$	[J/K]
T	Effective cell temperature	[K]
Rs	Series Resistance	[Ω]
Rsh	Shunt Resistance	[Ω]
Icc	Short Circuit Current	[A]
Voc	Open-circuit voltage	[V]
FF	Form factor	

η	Conversion efficiency	
Pi	the incident power of solar radiation on the ground	[W]
Pm	maximum electrical power of a solar panel	[W]
Noct	Nominal operating temperature	[K]
Ta	Ambient temperature	[K]
HMT	total manometric height	[m]
Hg	geometric height is between the dynamic level and the high level	[m]
Pch	pressure drop caused by the friction of the water against the walls pipes	[m]
Hs	The static level	[m]
Hd	Dynamic height	[m]
Vb	Basin volume	[m^3]
Vdm	The maximum volume of water requested by user	[m^3]
Ch	The hydraulic constant	
g	The constant of gravity	[$m^3 \cdot kg^{-1} . s^{-2}$]
ρ	The density of water	[Kg/m^3]
η_p	The efficiency of the electric pump	
Dh	The number of hours of sunshine	
Losse	losses of energy produced due to temperature and dust	[%]
Pp	Pump Power	[W]
Pc	Peak Power	[W]
Nt	module number	
NS	Number of the PV module in series	
Vpvg	Nominal voltage of each PV module	[V]
NP	Number of the PV module in parallel	
Ipvg	Nominal current of each PV module	[A]
CDER	Renewable Energy Development Center- ALGER	
URAER	Unit Research Applied in Renewable Energies Ghardaia	
DC	Direct current	
DA	Algerian dinar	

General Introduction

General introduction

Conflicts between countries over water and energy resources have intensified. After the climatic changes that have occurred on the globe in recent decades and the huge population increase, countries have pushed to secure their energy and water sources to meet their future needs, which made the world, agree that these climate changes may affect human life. Energy strategies must be changed and shifted from non-renewable and polluting fossil energy to clean and renewable energy such as solar energy, wind energy and others. Algeria, like other countries, is trying to get rid of its heavy dependence on fossil energies And changing it with clean energy, Algeria is a vast country and is characterized by a diversity of renewable energy sources, for example We can take advantage of the vast desert areas and the solar potential that they have to make it a pole of solar energy in the world

In this note, are going to dimensions to exploit this potential in the agricultural field (cultivating hard wheat) in one of the southern states, Ghardaia, in addition to carrying out a technical and economic study to determine the advantages of alternative energy. The one we depend on is also renewable

In the first chapter, we learn about the solar potential that Algeria has and study some solar angles that allow us to make optimal use of solar energy and the types of solar rays, and any of these rays we can use then we close To the diversity of water sources that the country does not have, in general, in the province Ghardaia, in particular, given that Algeria is located in the largest water basin called the Groundwater System in the North of the Sahara (SASS).

In Chapter Two, we will learn about Photovoltaic conversion and the most important element in the work of photovoltaic cells, which are semiconductors and their types. Then we discuss the history of photovoltaic cells and the way they were discovered, also the way the photovoltaic cell works, and the most important characteristics of photovoltaic cells and the effect of temperature on their work. At the end of this section, we talk about some solar cell technologies and their types, and the most prominent differences between cells, in addition to a comparison between them.

In a third chapter, we're going to discuss the method of studying the dimensions of a solar pumping system, and the most important data and the important conditions to study the dimensions such as the well and manometric height data. Then we mention the types of pumping systems and their most prominent components like solar panels and types of pumps, at the end, we learn the steps of a study Dimensions as calculating daily hydraulic energy and electrical energy needed in addition to the method of installing solar panels to obtain the electrical requirements of the pump

We focus on the last chapter to make a technical and economic study for the cultivation of durum wheat in the province Ghardaia, in addition to a comparison between the solar pumping system and the traditional pumping system and determining the extent of the impact of each system on the economic situation of the investor

Chapter 1:

Solar potential and water sources

Chapter 1

Solar potential and water sources

1.1 Introduction

Solar energy is the major renewable energy source of all existing renewable energies. It is the source of almost all sources of energy that humans use. Moreover, they are abundant, cover the whole world, and are free source. Algeria is a vast country with an area of 2,381,740 km^2, where the annual average irradiation value, registered varies between 2300-2200 kWh/m^2 per year. In addition the brightness duration can achieve about 14 hours during the summer, particularly in southern regions. Algeria is distinguished by that it has a clear sky and less pollution in the far south, such as Tamanrasset, and this means that the sun's rays fall directly without dust, clouds, etc.

The good use of solar energy in the country provides its production with the equivalent of 60 times the need of European countries for electric energy, and 4 times the need of the world. When we compare solar energy with natural gas, the potential of solar energy is in Algeria is worth the equivalent of 37,000 billion m^3 [1]. More than 8 times its Natural gas reserves in the country. This makes Algeria the sleeping giant in the field of solar energy, since; it contains one of the largest solar energy fields in the world.

The distribution of solar energy in Algeria varies from one region to another. For example, in the coastal provinces, we find that the amount of solar energy is very little, and the latter increases whenever we go to the south.

We find in Ghardaia that it reaches 1421 kw/h until it reaches the maximum value in Illizi and Tamanrasset from 2136kw/h to 2250 kw/h The distribution of the Photovoltaic solar power potential, in Algeria is presented by the figure 1.1 [2].

Chapter 1 Solar potential and water sources

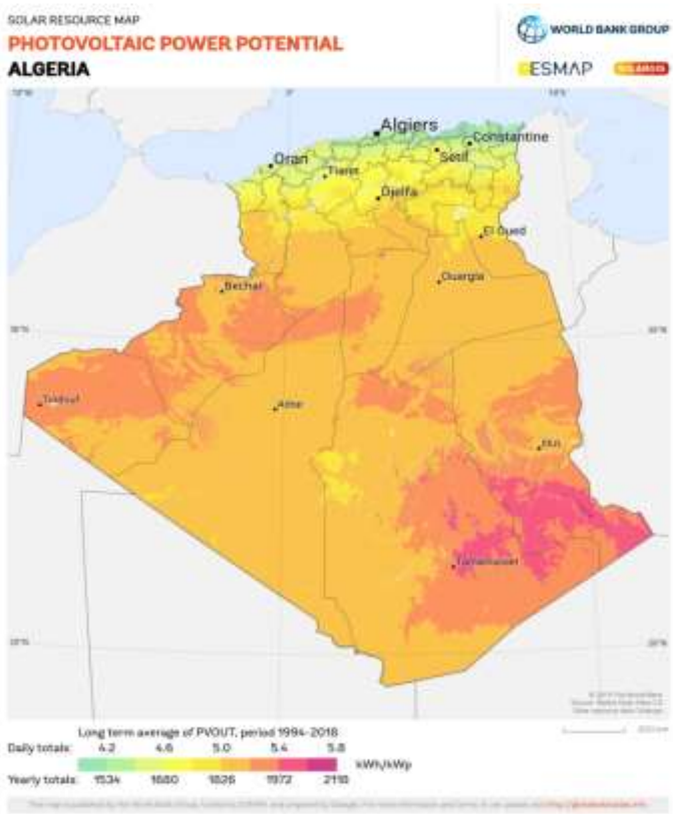

Figure 1 : The Photovoltaic Electricity Potential in Algeria

1.2 Solar energy potential

1.2.1 The Sun:

The Sun is the star at the center of the Solar System. It is a nearly perfect sphere of hot plasma, heated to incandescence by nuclear fusion reactions in its core, radiating the energy mainly as visible light and infrared radiation. It is by far the most important source of energy for life on Earth. Its diameter is about 1.39 million kilometers (864,000 miles), or 109 times that of Earth. Its mass is about 330,000 times that of Earth, and accounts for about 99.86% of the total mass of the Solar System. Roughly three quarters of the Sun's mass consists of hydrogen (~ 73%); the rest is mostly helium (~ 25%), with much smaller quantities of heavier elements, including oxygen, carbon, neon, and iron.) [3]. The Fig. 1.3 presents the Sun's atmosphere [4].

Chapter 1 Solar potential and water sources

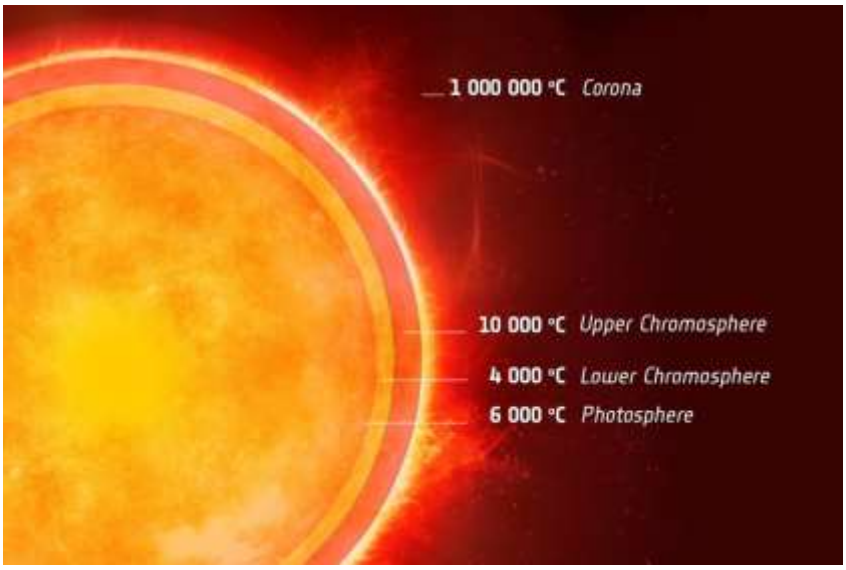

Figure 2 : The Sun's atmosphere

The atmosphere of the sun is also made of three basic layers.

The Photosphere — this is the innermost part of the sun's atmosphere and the only part that we can see that is about 100 to 400 km (62.1 Milles to 248.5 Milles) thick. This is the "physical" boundary of the sun that we are unable to see beyond and is less dense, about 0.01%, than the Earth's atmosphere. This part of the sun reaches temperatures between 5000 to 8000 °C, which is cooler than the other layers of the sun's atmosphere [5].

The Chromosphere — though further than the photosphere from the sun's mass, it is much hotter than the photosphere. It is about 1500 km (932 Milles) thick and reaches temperatures of 4000 °C to as high as 25000 °C as it moves into the Corona. The Chromosphere is even less dense than the photosphere by 0.01% and is visible only during total solar eclipses. It is the red ring around the moon during the eclipse [5].

The Corona — the hottest (at between 1 to 2 million °C) and furthest point of the sun is the Corona which stretches several million kilometers around the sun and is also visible during solar eclipses. It is the white light that surrounds the moon during the eclipse and is even less dense than the Chromosphere by 0.01% [5].

1.2.2 The movement of the earth around the sun:

In its movement around the sun, the earth describes an ellipse of which the sun is one of its homes. The complete revolution takes place in a period of 365.25 days. The plan of this ellipse is called the ecliptic. It is at the winter solstice (December 21) that the earth is closest to the sun with 147 million km. As of June 22,

Chapter 1 Solar potential and water sources

The earth-sun distance is 152 million km. It's the day where the earth is furthest away, it is the summer solstice. March 21 and September 21 are called the spring equinox and the autumn equinox, respectively; where day and night are equal. In addition to its rotation around the sun, the earth also rotates around itself. Of an axis called the pole axis. This rotation takes place in one day. The plane perpendicular to the axis of the poles and passing through the center of the earth is called the equator. The pole axis is not perpendicular to the ecliptic. They make an angle between them called inclination equal to 23.45 ° .The Fig. 1.4 presents the revolution of the earth and seasons. [6].

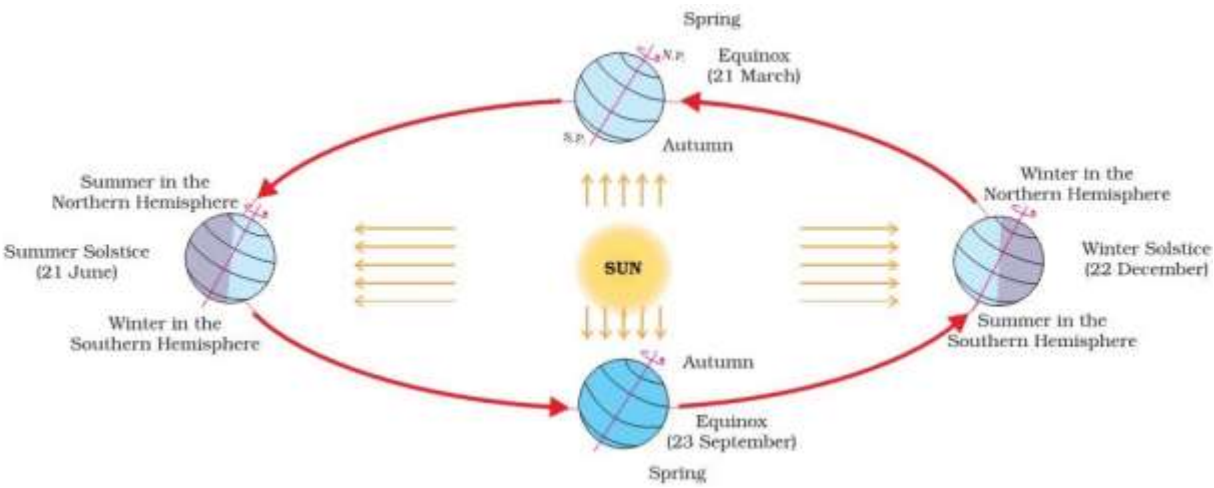

Figure 3 : The revolution of the earth and seasons

1.2.3 Solar radiation:

Solar radiation, often called the solar resource or just sunlight, is a general term for the electromagnetic radiation emitted by the sun. Solar radiation can be captured and turned into useful forms of energy, such as heat and electricity, using a variety of technologies. However, the technical feasibility and economical operation of these technologies at a specific location depends on the available solar resource.

Every location on Earth receives sunlight at least part of the year. The amount of solar radiation that reaches any one spot on the Earth's surface varies according to:

- Geographic location
- Time of day
- Season
- Local landscape
- Local weather.

Because the Earth is round, the sun strikes the surface at different angles, ranging from 0° (just above the horizon) to 90° (directly overhead). When the sun's rays are vertical, the Earth's surface gets all the energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse. Because the Earth is round, the frigid Polar Regions never get a high sun, and because of the tilted axis of rotation, these areas receive no sun at all during part of the year.

1.2.3. A Spectrum solar:

The energy in solar irradiation comes in the form of electromagnetic waves of a wide spectrum. Longer wavelengths have less energy (for instance infrared) than shorter ones such as visible light or UV. The solar spectrum covers wavelengths ranging from gamma rays to radio waves the solar spectrum is divided into three bands. These are:

- Ultra-violet light (UV) – 290nm–380nm
- Visible light – 380nm–780nm
- Infra-red light – 780nm–2500nm

The energy distribution within the solar spectrum is approximately 2% UV, 47% visible and 51% infra-red. Only the visible light band is seen by the human eye.

Important to know that shorter Wavelength (i.e., nanometer drop), the more energy associated with radiation. This is highlighted by the fact that it is the ultraviolet rays of shorter wavelength and of higher energy Light that causes sunburn to humans, fabrics to fade and plastic to deteriorate. The longer wavelength and the lower-energy radiation produced by the ranges of visible and infrared light are lower Harmful. The Fig. 1.5 presents the solar spectrum

Chapter 1 Solar potential and water sources

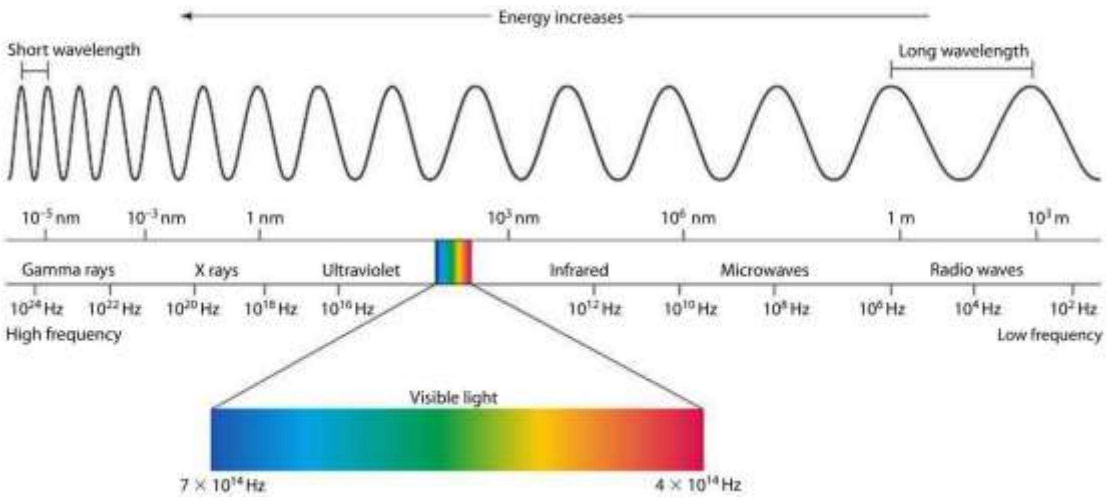

Figure 4 : The solar spectrum

1.2.3. B Types of solar radiation:

Solar radiation consists of two types of radiation, direct, diffused, or reflected radiation. The Fig. 1.7 presents the Types of solar radiation

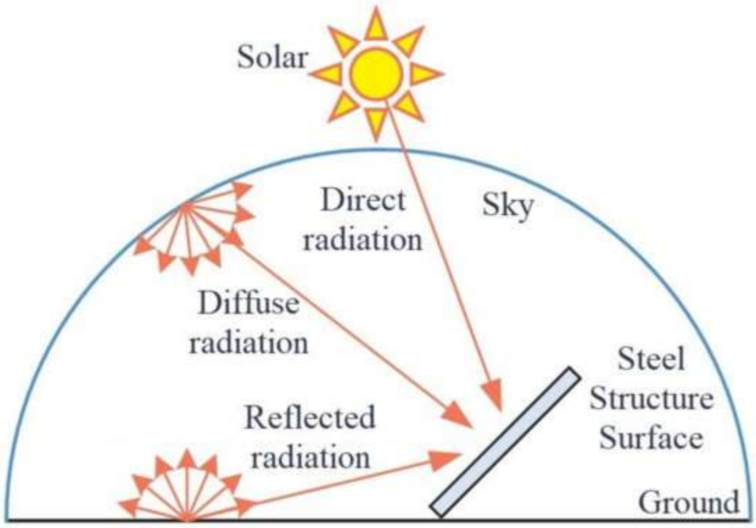

Figure 5 : The Types of solar radiation

❖ **Direct radiation IB:**

Direct radiation or beam radiation is solar radiation that directly reaches the surface of the earth from the sun. It depends on the thickness of the atmosphere through which the solar radiation must pass and the inclination of the rays to the ground. The pyrheliometer is the instrument that measures the intensity of direct radiation. The Fig. 1.6 presents the pyrheliometer

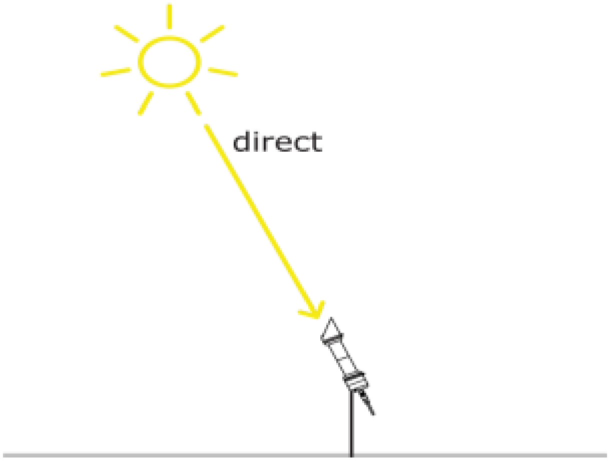

Figure 6 : The pyrheliometer

- **Diffuse radiation & Reflected ID:**

Atmospheric conditions such as clouds and pollution also increase the proportion of diffuse radiation. On a very cloudy day, almost 100% of the solar radiations are diffuse radiation.

- **Global radiation IG:**

Global radiation is the sum of direct sunlight and diffuse radiation produced by the reflection and scattering of sunlight.

$$IG = ID + IB \quad \textbf{(1.1)}$$

ID: Diffuse radiation & Reflected

IB: Direct radiation

The solar radiation measures are completed by mean of Sun-tracker The Fig. 1.8 presents the Sun-Trackuer

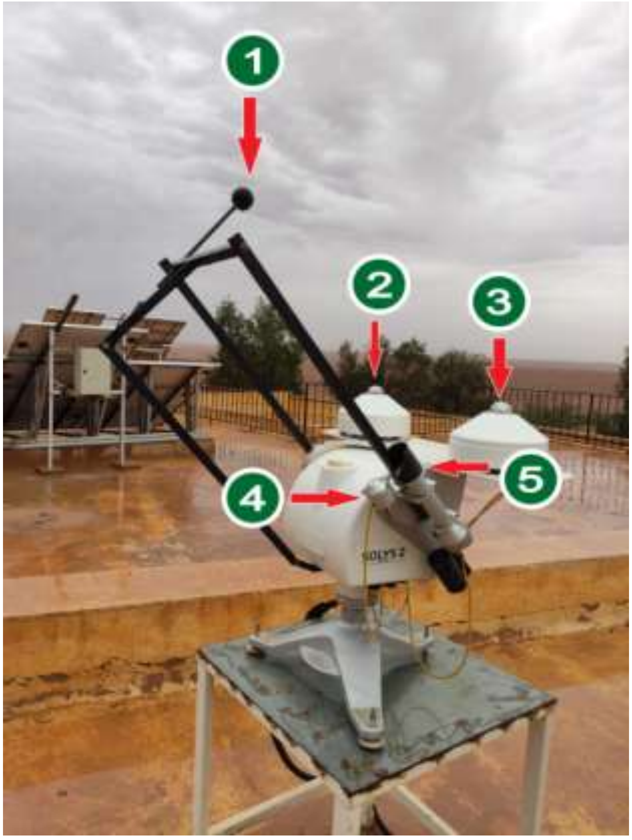

Figure 7 : The RADIOMETRIQUE STATION (Sun-Tracker)

The Sun-Trackuer that follows the different lines and the measures are achieved through the following instruments:

-pyrheliometer (5) measures direct rays' incident from the sun

-pyranometer (2) measures diffuse and reflective rays

-pyranometer (3) measures the Global radiation

- (4) The Sun sensor detects the solar position

1.3 Solar geometry:

1.3.1 Solar declination

The declination angle of the sun is the angle between the equatorial plane and the junction line between the center of the earth and the center of the sun This angle varies between +23.45 on June 21 and - 23.45 on December 21, or the so-called winter solstice, and the angle of deviation is 0 degrees in the autumn and spring equinoxes, and this angle is symbolized by δ .The Fig. 1.9 presents the seasonal variation of the declination angle [7]

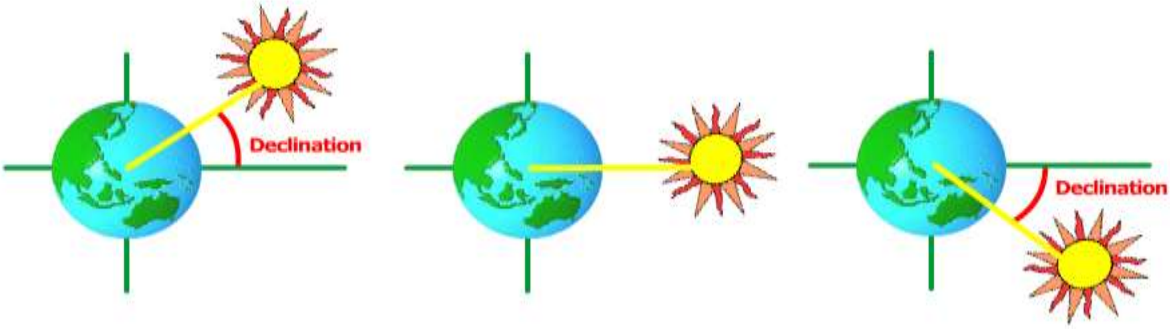

Figure 8 : The seasonal variation of the declination angle

The declination angle can be calculated by the equation:

$$\delta = 23{,}45.\,\mathrm{Sin}\left[\frac{360}{365}(n-81)\right] \qquad \textbf{(1.2)}$$

Where n is the day of the year with Jan 1 as n = 1. The Fig. 1.10 It shows the change in the angle of deviation over the course of the year [8]

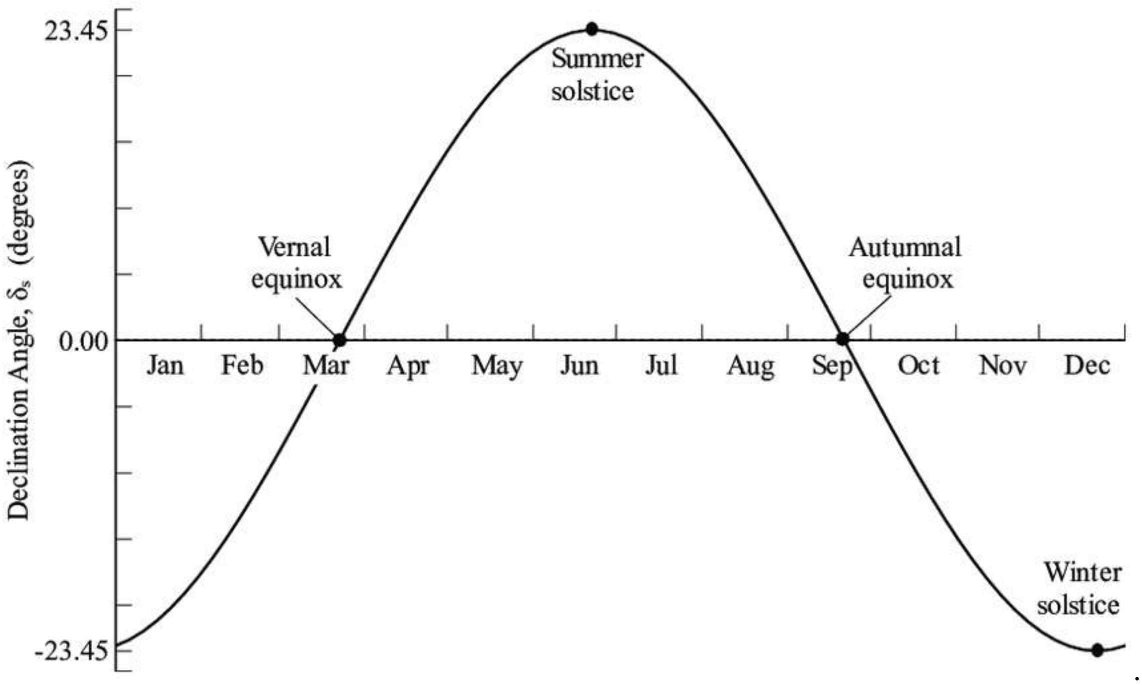

Figure 9 : The declination angle change over the year

One of the most common coordinate systems in use is the Geographic Coordinate System, which uses degrees of latitude and longitude to describe a location on the earth's surface. Lines of latitude run parallel to the equator and divide the earth into 180 equal portions from north to south (or south to north). The reference latitude is the equator and each hemisphere is divided into ninety equal portions, each representing one degree of latitude.

1.3.2 Latitude:

The latitudinal circles are a group of imaginary lines that cut across the globe and are parallel to the line of dispersal, which represents degree (0°), the number of these lines, is 180 lines, 90 of which are in the north, the equator, and the other 90 in the south. These circles are characterized by being irregular in length, the longest is the equator line, and they are smaller towards the north and towards the south until they become two points at the north and south poles separated each other by an equal distance of 1 degree. On the surface of the earth, that degree is equal to 111 km. The following are the main latitude:

- Equator, 0 degrees
- Tropic of Cancer, 23.5 degrees N
- Tropic of Capricorn, 23.5 degrees S
- Arctic Circle, 66.5 degrees N
- Antarctic Circle, 66.5 degrees S
- North Pole, 90 degrees N (infinitely small circle)
- South Pole, 90 degrees S (infinitely small circle)

The latitudes are also divided into 3 thermal regions, each with a specific location, as the warmest zone is the thermo-equatorial zone and lies between the Tropic of Cancer in the north and the Tropic of Capricorn in the south. The coldest region, which is divided between two regions, one between the Arctic Circle and the North Pole, and the other between the Antarctic Circle and the Antarctic, which is very cold.

The temperate zone is divided into two regions, the first being the temperate northern region between the Tropic of Cancer and the Arctic Circle, and the second zone, the southern temperate zone between the Tropic of Capricorn and the Antarctic Circle.

1.3.3. Longitude:

Meridians are the set of imaginary vertical lines that surround the Earth as the distance between them is equal, but not parallel. It consists of 360 lines. The lines begin at the North Pole of the Earth and are limited to the South Pole. The most prominent of these lines is the

Green Line, which divides the meridians into two parts, a group in the east of 180 lines and the other west of the Green Line and amounting to 180 lines and was named by this name as a result of which a corridor in a London suburb called Greenish

Perhaps the most important benefit of longitude is to determine the time and time difference between cities and countries. Cities located on the same line have close timing, so the difference between each longitude and the line that follows it is 4 minutes the following figure1.11 shows latitude and longitude [9].

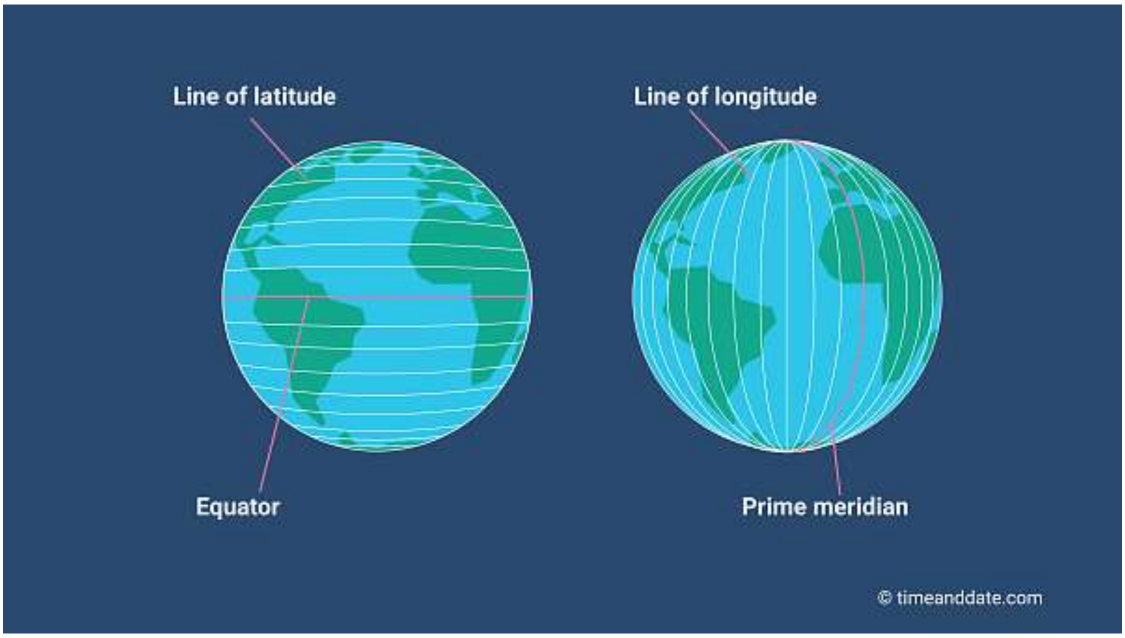

Figure 10 : latitude and longitude

1.3.4 Tilt angle:

Solar panels work best when they face directly into the sun. But that task is complicated by the fact that the sun moves across the sky throughout the day. It also changes angle in the sky as the seasons change. You could have changed the angle once or hands-on with system and make adjustments to optimize output. You can also buy a tracker, which automatically follows the sun’s position in the sky to squeeze the most output from your panels. But trackers are rarely the most cost-effective option. It’s almost always cheaper to buy a few more panels instead of investing in a tracker.

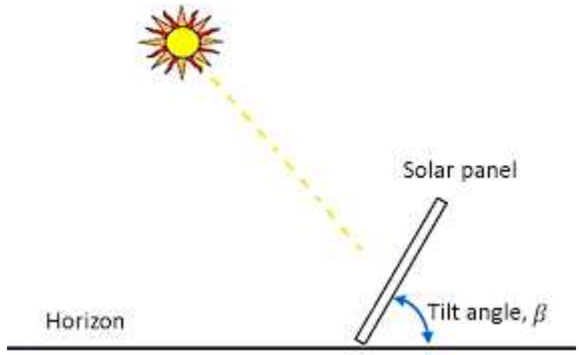

Figure 11 : The Tilt angle

1.3.5 Coordinates of the sun

1.3.5. A. Altitude Angle:

The altitude angle (sometimes referred to as the "solar elevation angle") describes how high the sun appears in the sky. The angle is measured between an imaginary line between the observer and the sun and the horizontal plane the observer is standing on. The altitude angle is negative when the sun drops below the horizon. The following figure 1.12shows this angle [10].

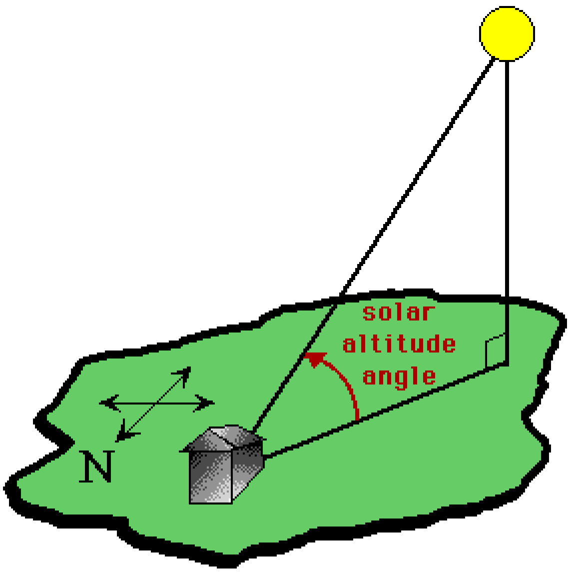

Figure 12 : The Altitude Angle

The altitude angle is calculated as follows:

$$\sin\beta = \cos L \cos\delta \cos H + \sin L \sin\delta \qquad \textbf{(1.3)}$$

1.3.5. B. Zenith:

The zenith angle is the angle between the sun and the vertical. The zenith angle is similar to the altitude angle but it is measured from the vertical rather than from the horizontal, thus making [11].

The zenith angle = 90° - altitude

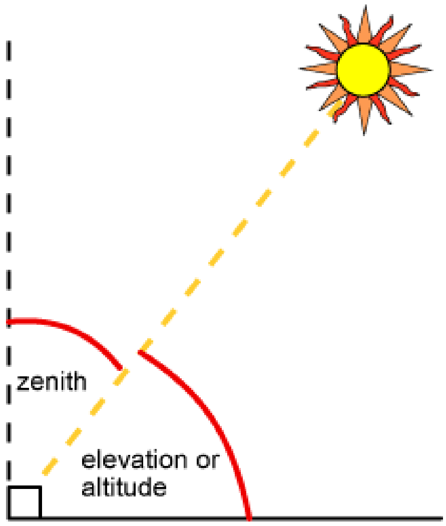

Figure 13 : The zenith angle

1.3.5. C. Azimuth Angle:

The azimuth angle is the compass direction from which the sunlight is coming. At solar noon, the sun is always directly south in the northern hemisphere and directly north in the southern hemisphere. The azimuth angle varies throughout the Day and represented as figure 1.13[12].

The azimuth is calculated from the above parameters

$$\sin\varphi = \frac{\cos\delta \sin H}{\cos\beta} \quad \textbf{(1.4)}$$

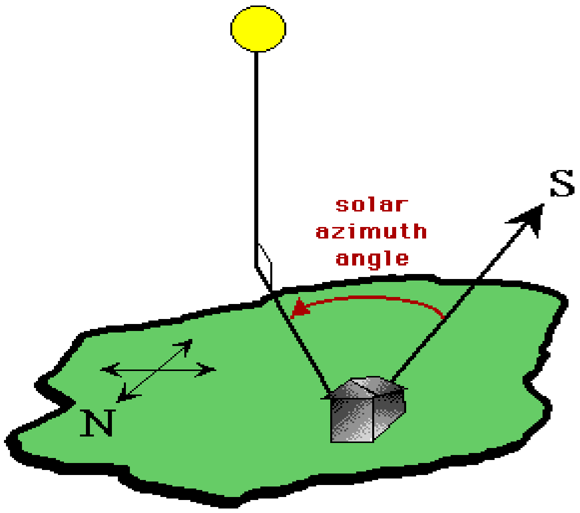

Figure 14 : The azimuth angle

The azimuth angle is measured clockwise from the zero azimuth. For example, if you're in the Northern Hemisphere and the zero azimuth is set to South, the azimuth angle value will be negative before solar noon, and positive after solar noon.

1.3.5. D. Hour angle:

This is the angle formed between the meridian plane passing through the sun and the meridian plane of the place obtained by the angular displacement of the sun author of the polar axis, in its course of East in the West, in relation to the local meridian. The value of the angle is zero at solar noon, negative in the morning, positive in the afternoon and increases by 15 ° per hour (so a 360 ° turn in 24 hours)

$$H = \left(\frac{15°}{\text{hour}}\right) \text{(Hours before noon)} \quad \textbf{(1.5)}$$

We take into account the instantaneous time to have the position of the sun in the sky According to determination the coordinates of the sun we find directly the position of the sun in every moment of the day (Figure 1.14) [13]

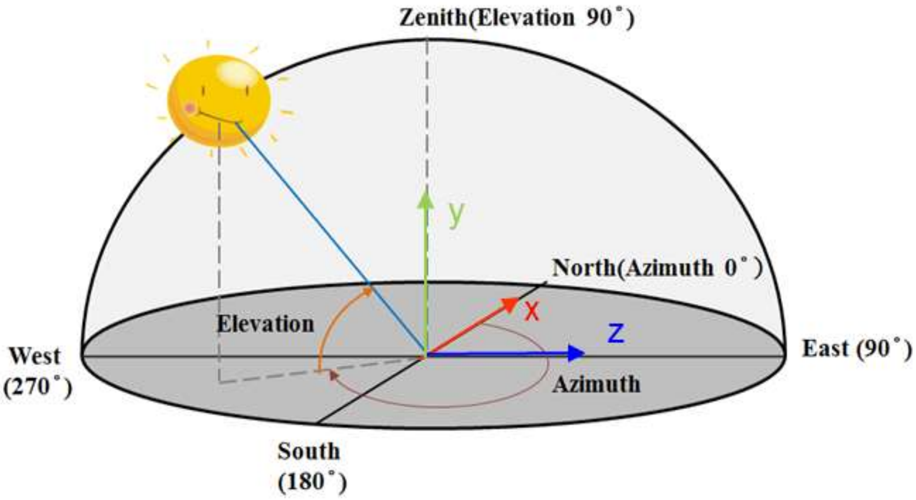

Figure 15 : The position of the sun in the sky.

Example: Where Is the Sun? Find the altitude angle and azimuth angle for the sun at 2:00 P.M. solar time hassi lfhel Latitude: 31.6053, Longitude: 3.67426 on 16 April

Solution:

Hour angle

$$h = \left(\frac{15°}{hour}\right)(2-) = -30°$$

The declination angle

n=107

$$\delta = 23{,}45.\text{Sin}\left[\frac{360}{365}(n-81)\right]$$

$$\delta = -10.14°$$

The altitude angle is:

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

$$\text{Sin}\ \beta = \cos 31.06 \cos -10.14 \cos -30 + \sin 31.06 \sin -10.14$$

$$=0.639441$$

$$\beta = \sin-1\ (0.639441) = 39.7501°$$

The azimuth angle is

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

$\sin \varphi = -0.6401719$

$\varphi = \sin^{-1}(-0.6401719) = -36.9917°$

1.4 Water sources:

Water is the source of life for all living things, and an essential element for its cultivation and use in industrial fields in nature. There are several sources of water, including: sea water, rivers, lakes, dams, fossil water, and the main water sources. The area is of underground origin. They are found in two types of aquifers; Infra-Flux (Phreatic) surface water tables, the captive deep groundwater reservoir in the continental Intercalaire known as Albian

Algeria is rich in the diversity of its water resources, as it is estimated at 23 billion m^3 annually the average precipitation is 400 mm, in addition to a number of dams built by the government Such as the Bani Harun Dam, which has a capacity of 1 billion m^3, and the valleys and lakes, including Wadi Soumam, with a flow rate of 50 m^3 per second. Perhaps the largest reserves of fresh water in the world, 70 % of which are in its deserts, given that the estimates of the level of this basin are 50 000 billion m^3. The following figure1.16 shows water resources and infrastructure, with the groundwater system north of the Sahara highlighted [14].

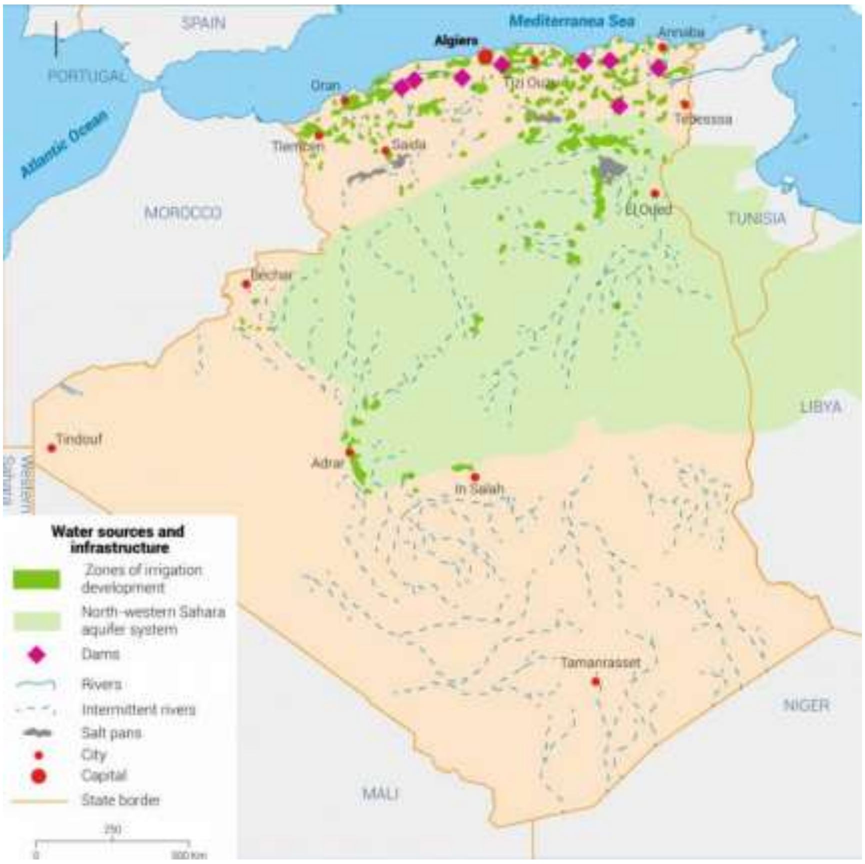

Figure 16 : water resources and infrastructure, with the groundwater system north of the Sahara highlighted

1.4.1Water sources in Ghardaia:

There are two main water tables in the region which are:

The water table exists everywhere in the Algerian Sahara; they are sheltered in the alluvium from the valleys of the wadis of the region. The depth of the water level varies between 10 and 30 m. Supplied in particular by rainwater, irrigation, domestic water, floods, drainage water and groundwater (sources) from aquifers plus deep. These aquifers are captured by hundreds of traditional wells, and mainly intended for to irrigate the palm groves of the valleys. The chemical quality of the water of the M'Zab and Metlili wadi aquifers is good for upstream consumption, bad and unfit for downstream consumption following their contamination by urban water.

1.4.1. A. The Northern Sahara Aquifer System (SASS):

The Northern Sahara Aquifer System (SASS) extends over a vast area whose limits are located in Algeria, Tunisia and Libya. This basin contains a series of aquifers which have been grouped into two reservoirs called: the Continental Intercalaire (CI) and the Complexe Terminal (CT). The SASS domain covers an area of approximately 1,000,000 km², 70% of which is in Algeria, 24% in Libya and 6% in Tunisia and stretches from North to South, from the Atlas Saharan to the outcrops of Tidikelt and the southern edge of Tinhert and West in East from the Guire-Saoura valley to the Hun graben in Libya The Fig. 1.17 presents The Northern Sahara Aquifer System [15]

Figure 17 : The Northern Sahara Aquifer System

1.4.1. B. Le Continental Intercalaire (CI):

The intercontinental is defined as the most extensive aquifer in the basin, which is the extensions also define the boundaries that are set for the SASS domain. Basically, it includes all sandstone, sandstone, and sandy clay formations from the lower Cretaceous. A thick chain of evaporated clay from Cenomanian forms a roof Water from the aquifer.

The Mzab mountain range, oriented roughly between north and south, divides the CI range into two hydrogeological sub-basins: the eastern and western basins. Each of them covers an area of 1,100,000 square kilometers, with an average thickness of 358 meters. The southern portion of the CI Reservoir is largely affected by the north and southwest

1.5.1. C Le Complexe Terminal (CT) :

The plant complex covers an area of 350,000 km^2 and combines several layers of groundwater with different geological formations, all form one hydraulic system. These limits the bumps are: In the north, following the Algerian-Tunisian side.

To the east, along the eastern edge of Dahra and Nafusa, Tunisia.

In the south, on the hills of Tinhart and Tademaite.

To the west, on the Mzab mountain As a TC feeding area.

The tablecloth flows down the center of the sink and breaks free from the edges. She is feeding mainly by the infiltration of exceptional rains in the Moi-Pliocene sands, and thus from frequent runoff along the steep valleys of the Desert Atlas in the north, And from the west is the course of the valleys of the Mzab chebka. [16].

1.5 Conclusion:

In this first part, we defined some solar measurements and important angles to know the position of the sun in the sky by adding an explanation of the types of solar rays and what we need as solar energy In the second part, we got acquainted with the water sources found in Algeria in general and in the Ghardaia region in particular, such as groundwater

Chapter 2:

Photovoltaic conversion

Chapter 2

Photovoltaic conversion

2.1 Introduction:

In this chapter We will discuss semiconductors and their types that are an important component of the photoelectric conversion process We will also mention the history of the discovery of photovoltaic and the first to discover the effect of photovoltaic In addition to the components of photoelectric cells, the principle of their work, and the method of converting the photon into electrical energy that can be used.

The characteristics of these cells such as short-circuit current, peak power, conversion efficiency, etc. We will talk about how to connect these cells with each other to obtain the current and voltage we need In addition to the effect of temperature and intensity of light radiation on cells and their efficiency

And in the end, this chapter we will talk about the types and technologies of photoelectric cells and the fundamental differences between them

2.2 Semi-conducteurs:

Semi-Conductors Solid bodies with electrical conductivity located between the conductivity of the conductive metals and the conductivity of the insulators. Electrical conductivity is a property that varies greatly from one body to another. It is found in a specific solid body depending on its temperature and chemical purity. The electrical conductivity of an object is its ability to induce the flow of electrons.

In general, semiconductors are materials, inorganic or organic, which have the ability to control their conduction based on chemical structure, temperature, illumination and the presence of dopants. The name semiconductor comes from the fact that these materials have an electrical conductivity between that of a metal, such as copper, gold, etc. and an insulator, such as glass. They have an energy gap of less than 4eV (around 1eV). In solid state physics, this energy interval or forbidden band is an energy range between the valence band and the conduction band where electronic states are forbidden. Unlike conductors, electrons in a semiconductor must obtain energy (for example from ionizing radiation) to cross the band gap and reach the conduction band. The properties of semiconductors are determined by the energy difference between the valence and conduction bands.

2.2.1 Types of semiconductors:

2.2.1. A. Intrinsic semiconductor:

Intrinsic semiconductors are made of high purity semiconductor material, and thus are also known as "pure semiconductor". These are basically semiconductors that do not contain doping impurities. At room temperature, internal semiconductors exhibit almost negligible conductivity. As there is no other type of element in its crystal structure. The elements of the fourth group of the periodic table form internal semiconductors. However, silicon and germanium are widely used. This is because in their case only a small energy is required in order to break the covalent bond. Silicon, for example, has 4 electrons in its valence shell. So (4) covalent bonds form between the electrons of the silicon atom. When the crystal temperature increases, the electrons in the covalent bond gain kinetic energy and after breaking the covalent bond they become free. Thus, the free movement of electrons creates a current. The rise in temperature somewhat increases the number of conduction free electrons. [17]. the following figure 2.1 shows the intrinsic semiconductor .[18].

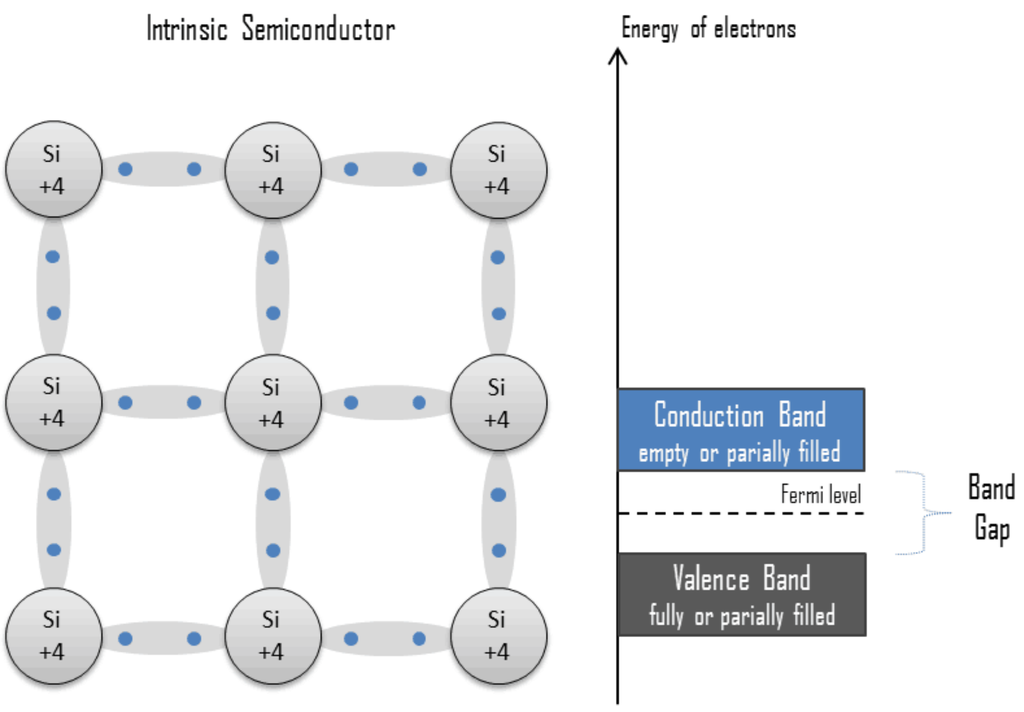

Figure 18 : The intrinsic semiconductor

2.2.1. B. Extrinsic semiconductors:

Extrinsic semiconductors are those that result from the addition of impurities to a pure semiconductor. This is basically called an "impure form of a semiconductor". The process by which a certain amount of impurities is supplied to a pure semiconductor is known as "doping". Therefore, we can say that pure semiconductors are activated to generate external semiconductors. These are very conductive in nature. However, unlike internal semiconductors, external semiconductors are made of two types of p-type and n-type semiconductors. It is worth noting here that the classification of external semiconductors depends on the type of activated element of the pure semiconductor. Also, when the temperature rises, it causes the covalent bond to collapse. Hence generating more free electrons.

P-type: semiconductors are formed by introducing third group elements or trivalent impurities into pure semiconductors. These are also known as acceptor impurity, as trivalent impurity contains (3) electrons only in the valence shell.

N-type: type semiconductors are formed by adding fifth group elements or pentavalent impurities to pure semiconductors. These are called donor impurity, as the pentavalent impurity carries (5) electrons in its valence shell.

2.2.1. C. P-n junction*:*

It consists of two semiconductor parts, the first n-chip has the properties of its electron-rich (negative) structure, and the second chip has the properties of its (positive) holes-rich structure. When the two strips are connected, a (isolation region) is formed between the two parts and we have a diode. The link is important because it is the cornerstone of making diode, solar cells, bipolar relays, photodiodes, etc.

A negative semiconductor has free electrons that can carry the charge and a positive semiconductor has free cavities that can in turn carry the charge as well, and upon contact, both carriers are harnessed to transfer the charge (electricity). The gaps and free electrons are added to the semiconductor through a process called doping.the P-n junction presented by the figure 2.2

Chapter 2 Photovoltaic conversion

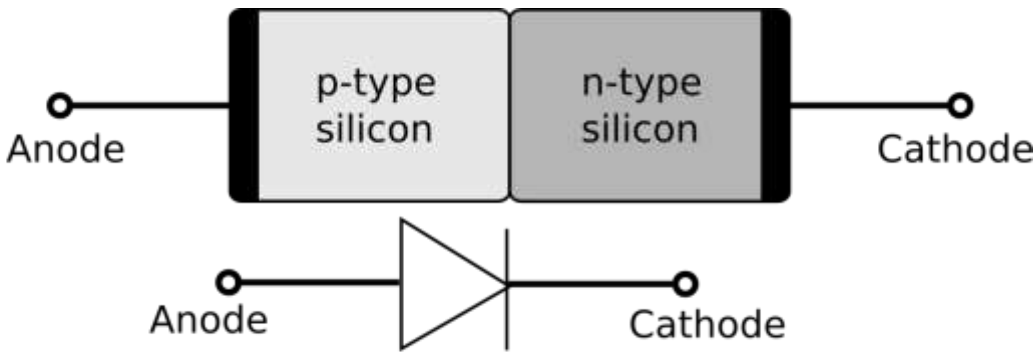

Figure 19 : The P-n junction

2.3 La conversion photovoltaïque:

2.3.1 Solar cell

2.3.1. A. History of photovoltaics:

The development of solar panels is the result of continuous work for several years by different scientists across the world. Thanks to the physicist Alexandre Edmond Becqueret, who noted that some materials can produce energy when exposed to light. With the introduction of the element selenium, in the year 1873 the scientist discovered that the element selenium has the ability to conduct a photoelectric Scientists William Grylls Adams and Richard Evans Day relied on this result to conclude that selenium generates energy when exposed to sunlight in 1876. [19].

Then in 1883 the first selenium wafer photoelectric cell was manufactured by Charles Fritts and in 1954 the first silicon photoelectric cells were made capable of operating an electrical device for a few hours during the day, thanks to Daryl Chapin, Calvin Fuller and Gerald Pearson. The efficiency of these cells was 4%, which equates to less than a quarter of cells today

And photovoltaic panels were used in outer space for the first time in 1985 on the Vanguard 1 Watts satellite, which was carrying a 1-watt photoelectric plate to feed the radio.In 1964, NASA or a fully powered satellite sent a generator from panels and then supplied it with panels with a capacity of 470 watts. In 1973 the University of Delaware or built the first solar-powered house, the armistice between photovoltaic panels and solar thermal energy, and it was called Solar One.

Achievements continued until the University of Southern Wales in 1985 reached 20 % efficient silicon cells until some photovoltaic cells reached laboratory conversion efficiency estimated at 34 % in the third generation of photoelectric cells in some cells such as organic cells and others.

2.3.1. B. Working principle:

A photocell is based on a physical phenomenon called the "photoelectric effect". This is the formation of an electrical pulse when the surface of this cell is exposed to light. The generated voltage can vary between 0.3V and 0.7V depending on the material Use the cell temperature and Cell aging In a PV module, the load is connected between two layers of contact Electric - one behind the panel and the other above. The energy produced by the radiation is separated into a charge and the chain can be used on both poles of cells as a battery. To get better yields, she owns several solar cells. The upper part of the panel is coated with an anti-reflective layer so that the light is received It is not reflected but rather absorbed by the semiconducting layers of the plate. Blueberry Photovoltaic panels include two types of semiconductors, one of which is attached to them Electron positives and negative electron mechanisms. The surface of these panels is polished the photovoltaic cell is designed from two layers of silicon, one of which is doped (doped with Boron) and the other doped N class (doped phosphorous) thus establishing a PN junction with a Potential barrier.

The absorber absorbs photons on a par with a semiconductor It transfers its energy to the atoms of the PN junction so that these electrons accumulate Atoms are released and create electrons (N charge) and holes (P charge). This then creates a potential difference between the two layers. This potential difference is measurable between the positive and negative terminal connections of the cell [20]. The principle of operation of photovoltaic cells presented by the figure 2.3 [21]

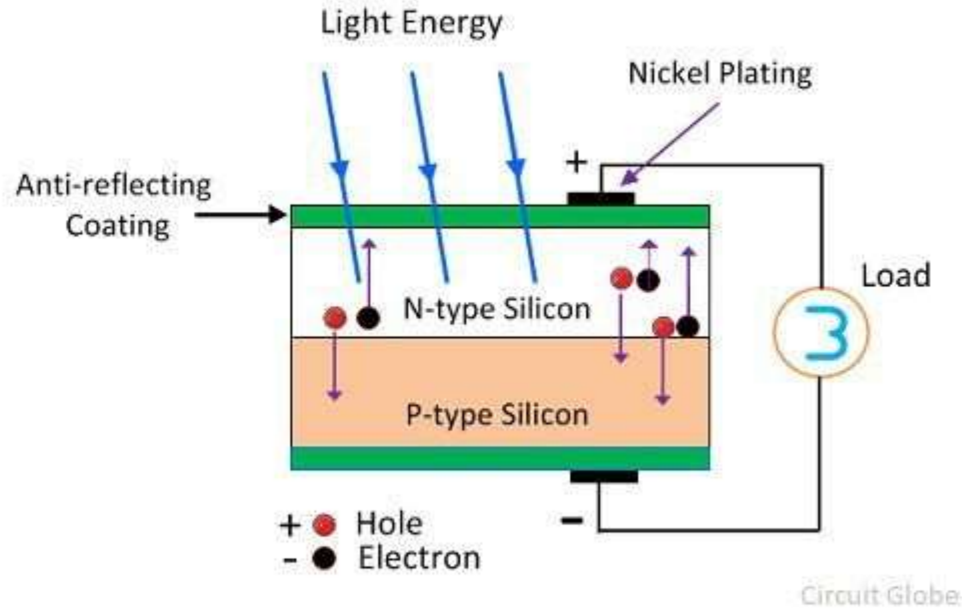

Figure 20 : The principle of operation of photovoltaic cells

❖ Real solar cell

Figure 2.4 shows the equivalent diagram of a real solar cell, where two parasitic resistances are introduced in this diagram, they will influence the characteristic I (V) of the cell. The first is the series resistor Rs, this resistor is linked of the impedance of the electrodes and of the base, it follows that the voltage V at the terminals of the cell is different from the voltage across the junction.

- **Series resistance:** is the internal resistance of the cell; it mainly depends on the resistance of the semiconductor used, the contact resistance of the collector gates and their resistivities;
- **Shunt resistance:** is due to a leakage current at the junction; she depends of the way it was done.

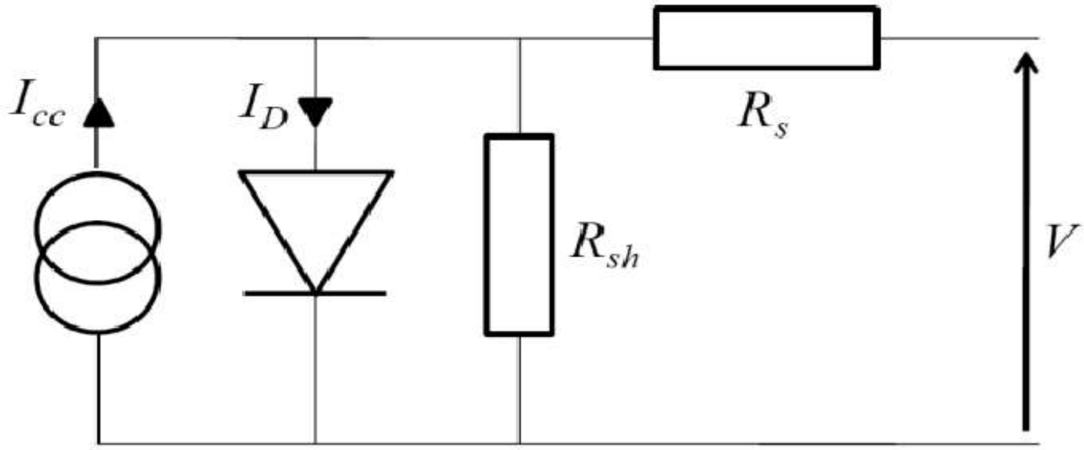

Figure 21 : The Equivalent diagram of a photovoltaic cell

- **Ideal solar cell**

For an ideal cell, the current equation is:

$$\mathrm{Iout} = \mathrm{Iph} - \mathrm{Id} \qquad \textbf{(2.1)}$$

Iout: Current supplied by cell [A];

Id: is the current shunted through the intrinsic diode [A].

Iph: Current produced by the solar cell, this current is proportional to the luminous flux [A].

$$\mathrm{Iph} = \mathrm{Isc} * [\mathrm{Ki}(\mathrm{Tc} - \mathrm{Tref})] * \frac{\mathrm{G}}{\mathrm{Gref}} \qquad \textbf{(2.2)}$$

Where:

Isc is the short-circuit current [A],

Ki is the temperature coefficient of the short-circuit current [%/K],

Tc is the module temperature [K],

G is the irradiation [W/m^2],

Tref = 298 K

Gref = 1000 W/m^2.

If the characteristic of the junction is of the form:

$$\text{Id} = \text{Is}\left(e^{\frac{qv}{kt}} - 1\right) \tag{2.3}$$

We can admit that in the presence of light there is the appearance of a photo-current Additional, **Iph** whose direction is opposite to the direct current. By plugging in a circuit outside on the clear cell, we collect this current. The current under light is worth

$$\text{I} = \text{Iph} - \text{Is}\left(e^{\frac{qv}{kt}} - 1\right) \tag{2.4}$$

And the voltage V is given by:

$$\text{V} = \frac{\text{KT}}{\text{q}}\ln\left(\frac{\text{Iph}+\text{Is}}{\text{Is}} - \text{I}\right) \tag{2.5}$$

q : Charge de l'électron = 1,602. 10^{-19} [Coulomb] ;

K : Constante de Boltzmann = 1,38. 10^{-23} [J/K] ;

T: effective cell temperature [K],

$$\text{I (v)} = \text{Iph} - \text{Id} - \text{Ish} \tag{2.6}$$

$$\text{I(v)} = \text{Iph} - \text{Is}\left(e^{\frac{q(V+RsI)}{KT}} - 1\right) - \text{I}\ \frac{\text{V+Rs}}{\text{Rsh}} \tag{2.7}$$

Rsh: shunt resistance -parallel-[Ω]

Rs: resistance in series [Ω]

2.3.2 The different characteristics of a solar cell

2.3.2. A. Short Circuit Current of Solar Cell:

This is the current obtained by shorting the terminals of the cell. It grows linearly with the intensity of illumination of the cell and depends the illuminated area, the wavelength of the radiation, the mobility of carriers and temperature.

$$\text{Icc (V=0°) =Iph} \tag{2.8}$$

2.3.2. B. Peak power of a PV cell:

The maximum electrical power of a solar panel under these conditions is called peak power (Pmax) and is shown in WP (Watt-peak).The watt-peak idea is used to compare the performance of solar PV installations and to predict how much electricity they can produce under optimal conditions.

To compare the capacity of solar panels, there are constant standard conditions: at irradiation of 1 kW / m2, its spectrum corresponds to the spectrum of sunlight in an air mass of 1.5 (this means that sunlight passing through the atmosphere is equal to one and a half times the average thickness of the atmosphere), and the cell temperature is 25 °C. [22]

2.3.2. C. Open-circuit voltage, Voc:

It is the maximum voltage generated by the cell under certain conditions of light and temperature; it is the voltage when the cell is not connected to any loads, and therefore the current output is zero, and the energy produced at this stage is zero as well.

2.3.2. D. Form factor, FF:

We call form factor FF (fill factor), the ratio between the maximum values of the power that can be extracted (Im, Vm) from the solar cell under standardized measurement conditions, and the product (Icc, Vco):

$$\mathrm{FF} = \frac{\mathrm{Vm.Im}}{\mathrm{Voc.Icc}} \qquad \textbf{(2.10)}$$

2.3.2. E. Conversion efficiency, η:

The efficiency of a photovoltaic cell is given by the ratio between the power output at the point of maximum power and the available light power

$$\eta = \frac{\mathrm{Pm}}{\mathrm{Pi}} \qquad \textbf{(2.11)}$$

Where:

Pi: is the incident power of solar radiation on the ground.

2.3.3 Effects of temperature on a photovoltaic cell:

The work of solar panels requires exposure to sunlight for a long time, and this causes the temperature to rise, and this rise causes a decrease in the value of the energy produced from the panel, and for this reason the thermal coefficient was included with each panel, which is the rate of decrease in the energy produced by the panel when the temperature rises by one degree .Figure 2.5is shown the effect of temperature on the IV characteristics of a solar cell [23]

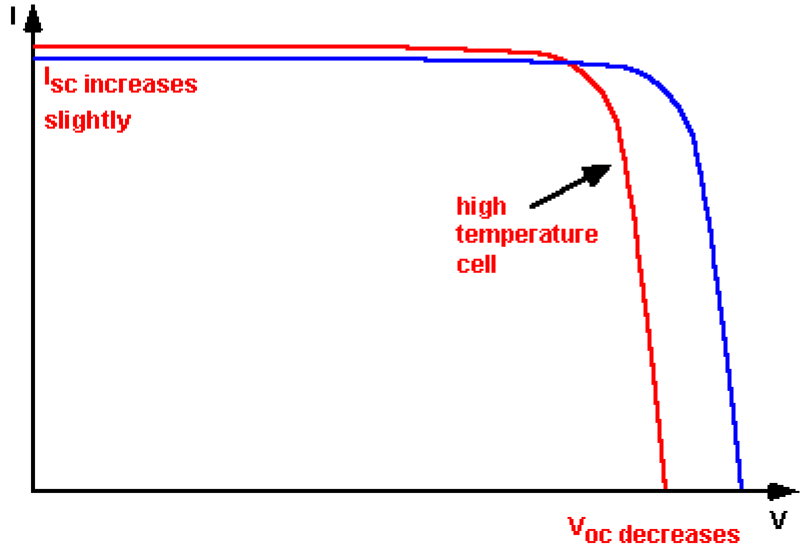

Figure 22 : The effect of temperature on the IV characteristics of a solar cell**.**

The cell temperature can be calculated as follows:

$$Tc = Ta + \left(\frac{NOCT - 20°}{800}\right) G \qquad \textbf{(2.12)}$$

G: Luminous flux [W / m2]

Noct: Nominal operating temperature condition of the cell given by the

Builder [K]

Ta: Ambient temperature [K].

From Equation 2.2 and,2.12 we conclude that the higher the temperature has a negative effect on the operation of the photoelectric cell

2.3.4 The different generations of solar PV cells:

For the production of solar panels, we can distinguish two technologies Major:

- Crystallized solid materials
- Amorphous thin film materials

The first category (crystallized solid materials) represents about 90% of the share of market, amorphous and thin film materials cover 10%, but with a tendency to the rise. There are also emerging technologies like:

- Grätzel photoelectrochemical solar cells
- Concentrated photovoltaic solar cells

These emerging forms of PV cells are not yet ripe for production in mass and installation of large power plants; but their promising properties make them serious candidates for the photovoltaic market in the years to come.

2.3.4. A. Monocrystalline silicon:

Monocrystalline photovoltaics, which are distinguished by their symmetrical appearance, which indicates the purity of the silicon crystals made of them. The efficiency of this type of plate ranges from 15% to 21%, and since the cell consists of a single crystal, it provides the electrons with more space to move for a better flow of electricity, and one of its main disadvantages is that it is expensve Figure2.6 shown the monocrystalline silicon solar cell

Figure 23 : The monocrystalline silicon solar cell

2.3.4. B. Polycrystalline silicon:

The efficiency of a polycrystalline solar panel is lower than that of monocrystalline from 12% to 14%, but it is less expensive than it. The method of making these polycrystalline solar panels melts multiple shards of silicon together to create chips for these panels. This is what gives it its distinctive color, which is multicolored. It gives the electrons in each cell less room to move because there are many crystals in the cell. The Polycrystalline silicon solar cell shown in figure 2.7

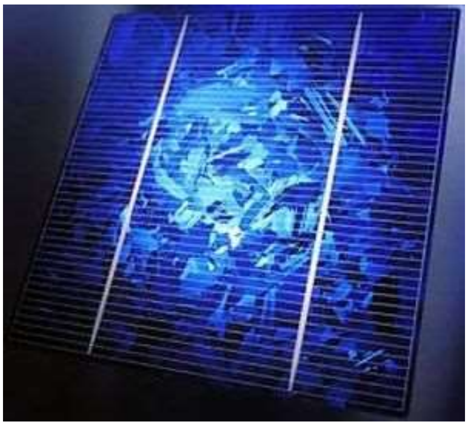

Figure 24 : The Polycrystalline silicon solar cell

2.3.4. C. Amorphous silicon cells:

Amorphous silicon presentd in figure 2.8 (a-Si) is the amorphous form of silicon. It is the most advanced thin film technology on the market for more than 15 years. It is widely used in pocket calculators, but it also powers some homes and private buildings their yield ranges from 6% to 12%. The most important features of these cells are competitive in price, meaning they are less expensive It also has the advantage of being more consistent in large areas in addition to the fact that it can be produced in various shapes: circular, square, hexagonal, or any other shape and this is what helps it in its use in electronic machines such as sensors and wrist watches. Among the main disadvantages of it is that it has low yield, in addition to its short duration of work compared to other types [24]

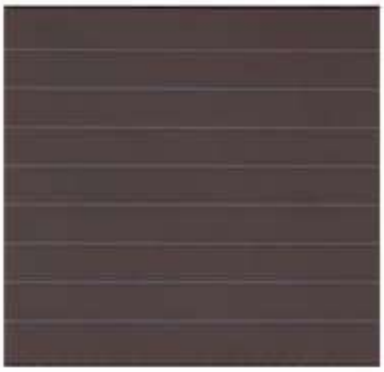

Figure 25 : The amorphous silicon cells

2.3.4. D. Concentrated photovoltaic solar:

Le photovoltaïque «concentré» consiste à capter le rayonnement solaire grâce à un pavage d'optiques (lentilles ou miroirs) à faible coût pour le focaliser sur une surface beaucoup plus petite (1/1000) où il est placé L'empilement de matériaux photovoltaïques tels que le gallium et les arsines forme des cellules performantes de sorte que le spectre du rayonnement solaire converti en énergie électrique est plus complet que dans les cellules photovoltaïques au silicium. Pour le même flux solaire capté, le rendement énergétique atteint aujourd'hui (30% à 40% pour le montage lentille et capteur) est le double de celui des panneaux solaires classiques. [25]

Figure 26 : The concentrated photovoltaic

2.3.4. E. The difference between cell technologies:

Types of Panel	Efficiency	Area per kW	Application	Voltage Rating	Component	Remark
Mono-crystalline silicon cel	15- 18 %	7-9 m²	residential commercial	80%-85% (Higher is better)	Made of silicon wafers cut from one homogenous crystal in which all silicon atoms are arranged in the same direction.	affected by small Shadows, More expensive but Most efficient
Polycrystalline silicon cell	13- 16 %	8-9 m²	residential commercial	80%-85% (Higher is better	Slice cut from a block of silicon, consisting of a large number of crystals	less energy and time needed for production Lower cost, affected by small Shadows
Thin film solar cell: • Copper indium dieseline • Cadmium telluride • Amorphus silicon (a-Si)	6- 12 %	9-11 m²	residential commercial	72%-78%	extremely thin layer of amorphous (non crystalline) silicon onto a wide choice of surfaces	Less expensive, low-cost Large and heavy equipments, less affected by small Shadows

Table 1 : presents Comparison Different Types of PV Modules

2.4 Photovoltaic configuration:

2.4.1 Serial association

By adding identical cells or modules in series, the current of the branch remains the same, but the voltage increases in proportion to the number of cells / modules serial, the Figure 2.7 presents the identical cells in series [26].

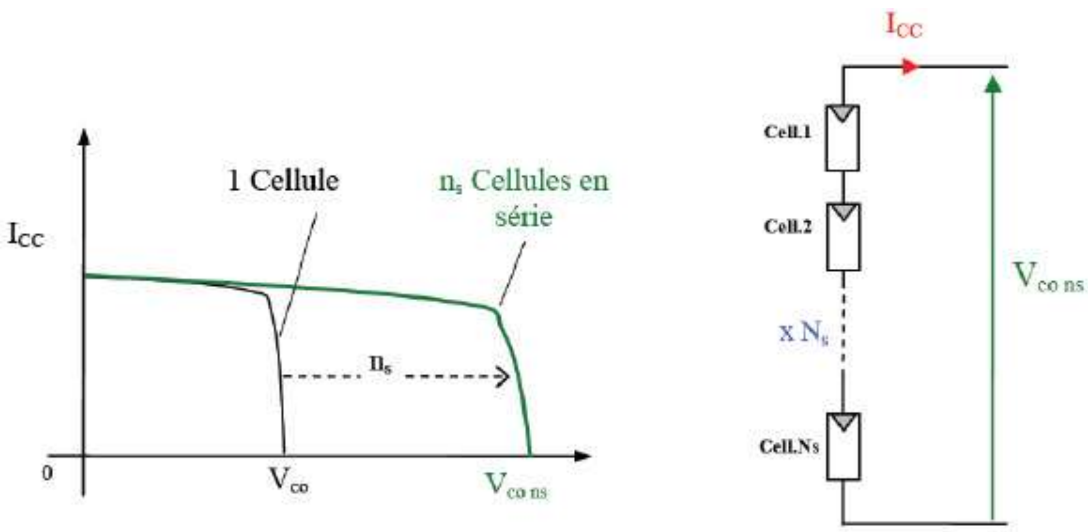

Figure 27 : The identical cells in series

2.4.2 Parallel association

By adding identical modules in parallel, the voltage of the branch is equal to the voltage of each module, but the intensity of the current increases in proportion to the number of modules in parallel in the branch the Figure 2.11 presents the identical cells in parallel [27].

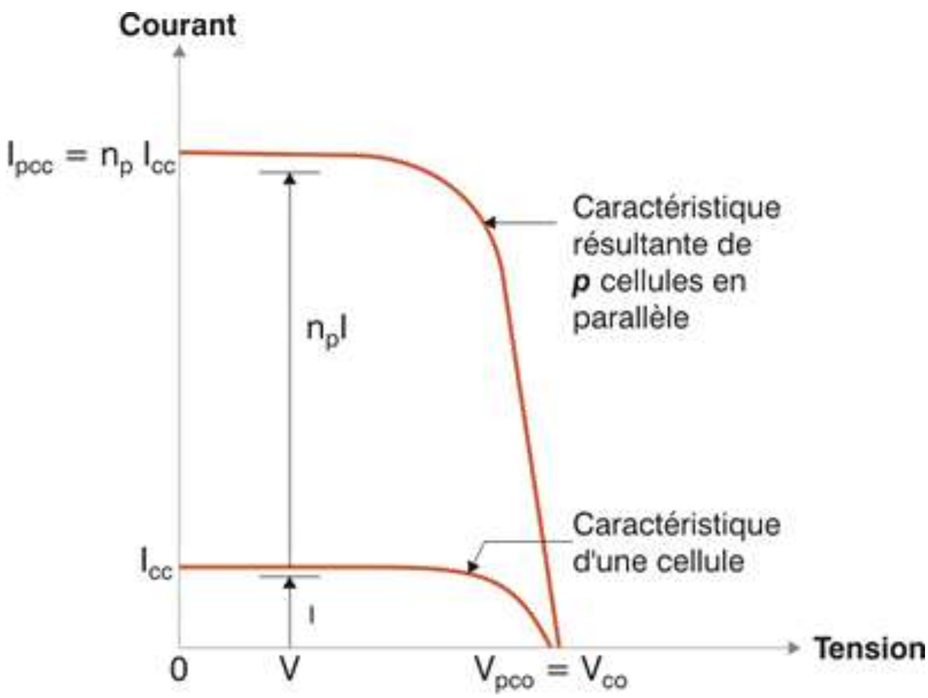

Figure 28 : The identical cells in parallel

2.5 Conclusion:

At the end of this chapter, we learned about semiconductors, their types, and their working principle after that, we touched on the method of converting light energy into electrical energy or the so-called photovoltaic transmission. Then we referred to the photovoltaic cell, its components and how it works, in addition to the method of linking it and the effect of temperature changes on its efficiency, as we also saw some types of solar cell technologies and their most important features in addition to the difference between them

Chapter 3:

Sizing of a solar pumping system

Chapter 3 Sizing of a solar pumping system

Chapter 3

Sizing of a solar pumping system

3.1 INTRODUCTION:

The study of a solar pump system consists of several stages first; we do a study of the well and determine the manometric height Then we calculate the daily consumption or need for water then weeping the energy needed to extract the previous amount of water, and in the last we calculate the organic energy to determine the type and number of solar models and the type of water-pumping motor

In this third part two reviewed various solar pumping systems and components as an electrostatic generator and electric power control units as current converters from direct to alternating

3.2 sizing of a solar pumping system

3.2.1 Definition:

The study of installing a solar pumping system is important to obtain an optimal system and optimal performance; this means maximum production plus cost optimization (optimal price) Before the installation procedure, it is necessary to take into account the study conditions for an effective installation of solar pumps:

- Availability of potential solar energy
- Availability of renewable water resources. We use the groundwater level with an average height of 40 to 60 meters
- No electrical networks at the installation site

3.2.2 Water well data at the site:

Height of elevation or total manometric height in meters is the force which allows the transport of water in the piping and its use at the highest point of installation.

$$\mathrm{HMT} = \mathrm{Hg} + \mathrm{Pch} \qquad \textbf{(3.1)}$$

With:

Pch = the pressure drop caused by the friction of the water against the walls of the pipes. These losses depend on the length and diameter of the pipes, the flow of the pump and the number of devices on the pipe (valves, etc.). Pch is expressed in metres. The diameter of the pipes shall be calculated so that this pressure drop corresponds to a maximum of 10% of the total manométrique height. Pch=0.1*Hg

Hg: geometric height is between the dynamic level and the high level of basin such that:

$$Hg = Hs + Hd + Hb \tag{3.2}$$

Hs: The static level of a well or a borehole is the distance from the ground to the surface of the water before pumping.

Hd: Dynamic height is between the static level and dynamic level of the well

Hb: Basin height is high and ground level

Vb: basin volume

The following figure 3.1shows the water well data [26].

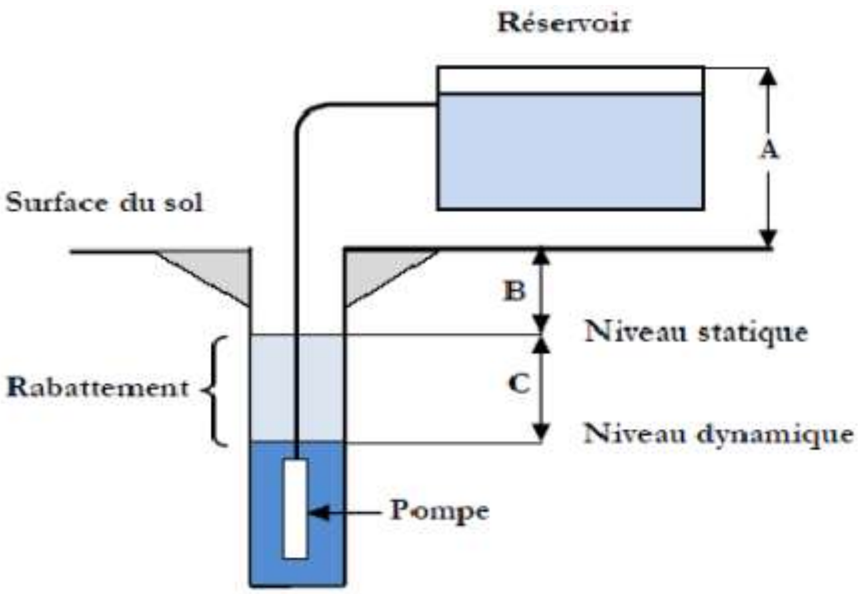

Figure 29 : Water well data

3.3 Methods of photovoltaïques pumping:

We have two types of solar water pumping systems:

3.3.1 Pumping over the sun:

Solar energy is consumed in "real time"; "Pumping over the sun (without battery)". This technique makes it possible to directly use a continuously variable power, that from photovoltaic modules. Pumping rate will therefore change with the intensity of the sun. Indeed in this first technique, it is the water itself which is pumped and stored when there is sufficient sunlight, inatank at a height above the ground. It is then distributed by gravity as needed. Au besoin. The Figure 3.2 represents Pumping over the sun (without battery) [28].

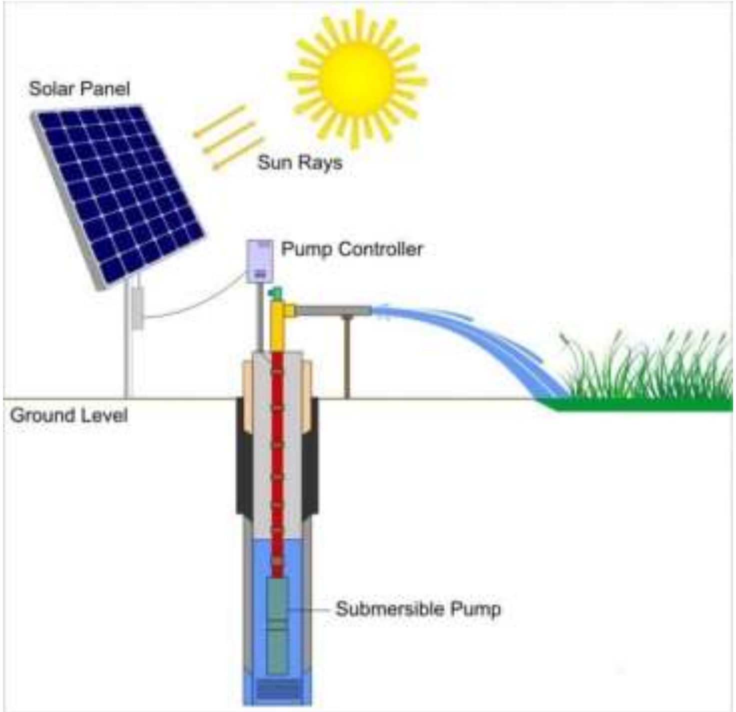

Figure 30 : Pumping over the sun (without battery)

3.3.2 Pumping with energy storage (batteries):

It is the electrical energy which will be stored in the batteries pumping will be possible even in the absence of the sun this system is more expensive [29].

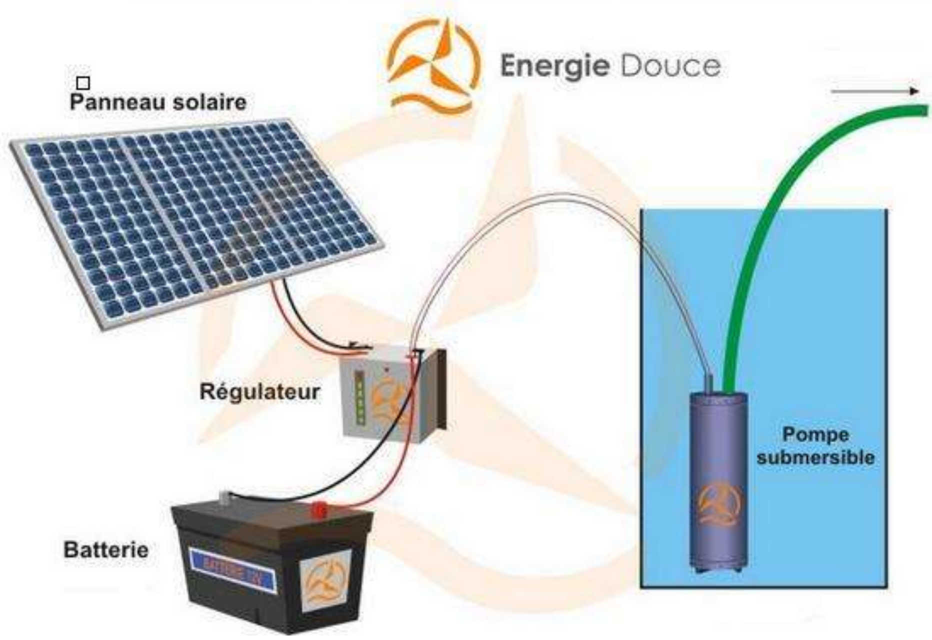

Figure 31 : Pumping with energy storage (batteries)

Systematic pumping over the sun should be preferred, due to the cost of batteries and the poor connection they represent in the PV system due to their limited life. However, it has certain drawbacks that should not be overlooked when choosing. The advantages and disadvantages of the two photovoltaic pumping technologies (2) are summarized in the table 3.1below:

Methods of pumping	advantages	Disadvantages
Pumping over the Sun	• Saving of the cost of batteries and consequently their maintenance • Simpler, more reliable and less expensive photovoltaic system • Better energy efficiency	• Energy loss at the start and end of the day • The pump flow is not constant and the drawdown of the borehole maybe too high during certain periods of the day
Pumping with batteries	• Regular pump flow and at fixed pressure • Possibility of pumping water when the sun is out.	• High cost of upkeep and maintenance batteries • Change of batteries every 5 to 7 years • The batteries introduce a certain degree of yield loss of about 20% to 30% of energy production. • High cost of the photovoltaic system

Table 2 : The advantages and disadvantages of pumps with direct sunlight and with batteries

3.4 Solar pumping system components:

3.4.1 The photovoltaic generator:

The photovoltaic generator can be made up of one or more modules of photovoltaics called photovoltaic field intended to produce electrical energy from solar radiation. Indeed, the photovoltaic field is a series and parallel association of modules photovoltaic according to the power and voltage of use. Its characteristic (I-V) is similar to that of a module and the cells are protected by serial diodes (non-return) and diodes parallel (bypass). It constitutes the surface for collecting solar energy and producing electricity. The ph cells diodes parallèle (by-pass). Il constitue la surface de captage de l’énergie solaire et de production d’électricité.

3.4.2 Command and control electronics:

3.4.2. A. The DC / DC converter:

In order to extract the maximum power available at the terminals of the PV generator and transfer it to the load (pump powered by DC motor), the technique conventionally used is to use an adaptation stage between the PV generator and the charge. This stage plays the role of interface between the two elements by ensuring through an action control commanded by its duty cycle, the transfer of the maximum power supplied by the generator so that it is as close as possible to the maximum power available.

3.4.2. B. The DC / AC converter (inverter):

DC / AC converter ensures optimal power transfer from the solar generator to the electric pump and protects the pump against empty operation when there is no water in the well. The efficiency of the inverter is generally high to make the best use of the energy produced by the generator. It is around 95% at the nominal operating point

3.4.2. C. MPPT regulator (Maximum Power Point Tracking):

MPPT charge regulators, thanks to their more sophisticated microprocessor and charging algorithms, are the most efficient regulators today. This provides up to 30% more efficiency compared to a PWM (especially during cloudy periods). They are equipped with the most advanced charging algorithms and thus allow the best productions to be achieved.

Finally, MPPT regulators accept a higher input voltage (75V, 100V, 150V and up to 250V) compared to PWMs (23V or 55V max) and thus make it possible to limit the loss by Joule effect. They also allow charging a 12V battery park with 24V or more panels.

Figure 32 : MPPT regulator example

3.4.3Engine:

The motor of an electric pump unit converts electrical energy into mechanical energy.It can be direct or alternating current. In case the motor is alternating current, an electronic converter called inverter is needed to convert direct current From the AC photovoltaic generator

3.4.4 Electrical wires:

This is important because it transfers the electrical energy, from the generator to the engine it allows accurate information to be transferred to a surveillance and security system

3.5 The Motor-pumps different types

The electric pump unit consists of an electric motor and a pump.A pump is a device for sucking and delivering a fluid. Water pumps are usually classified according to their principle of operation, either type volumetric or centrifugal. Apart from these two classifications, we also distinguish two other types of pumps depending on the physical location of the pump in relation to the pumped water Figure 33 represents The Pump classification [30].

Chapter 3 Sizing of a solar pumping system

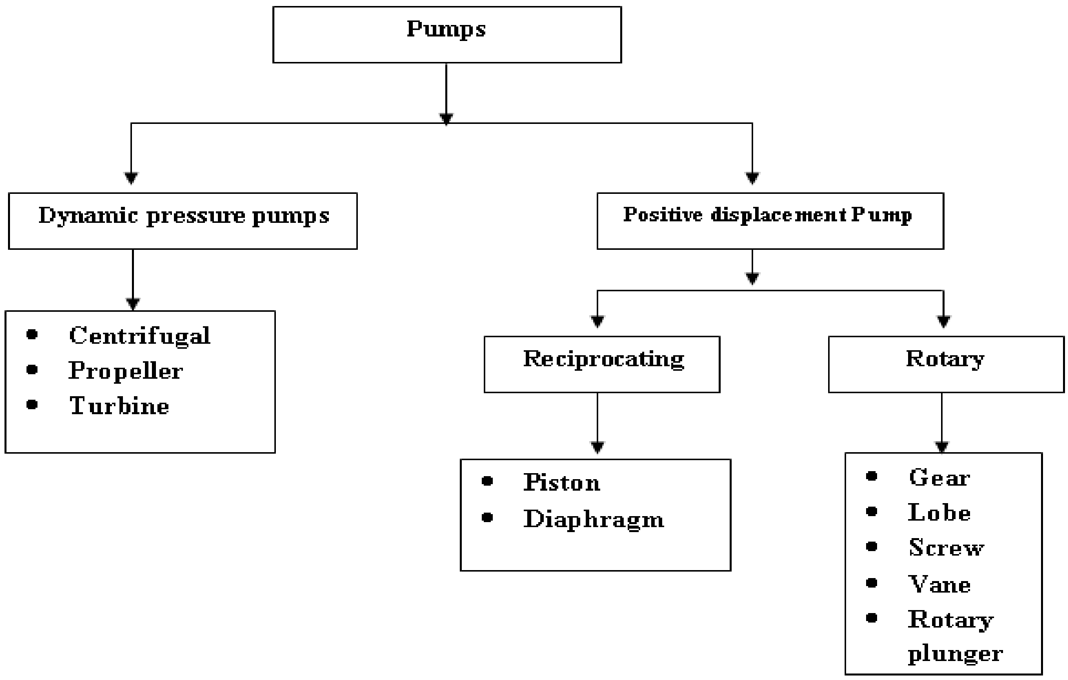

Figure 33 : The Pump classification

3.5.1 The suction pump and the pressure pump:

The suction height of any suction pump is limited to a value theoretical of 9.8 (atmospheric pressure in meters of water) and in practice at 6 to 7 meters. These pumps are therefore always installed at a height lower than this. They must also be primed, i.e. the section upstream of the pump must be filled with water to start the water suction

3.5.2 Delivery pumps:

Are submerged in water and either have their motor submerged with the pump (monobloc pump), or the motor on the surface, in this case the transmission of power is then provided by a long shaft connecting the motor to the pump which generates losses mechanical.

3.5.3 Positive displacement pumps:

Transmit the kinetic energy of the motor to the fluid through a back and forth movement allowing the fluid to overcome gravity by successive variations of a volume connected alternately to the suction port and to the discharge port. These pumps suck the fluid by increasing a volume and then push it back by decreasing the same volume

3.5.4 Centrifugal pumps:

Transmit the kinetic energy of the motor to the fluid through a rotational movement of paddle wheels or vanes. The water enters the center of the pump and is thrust outwards and upwards thanks to the centrifugal force of the blades. They use the variations in the speed of the pumped fluid combined with the effect of centrifugal force to obtain an increase in pressure. The Figure 3.6 represents Centrifugal pumps.

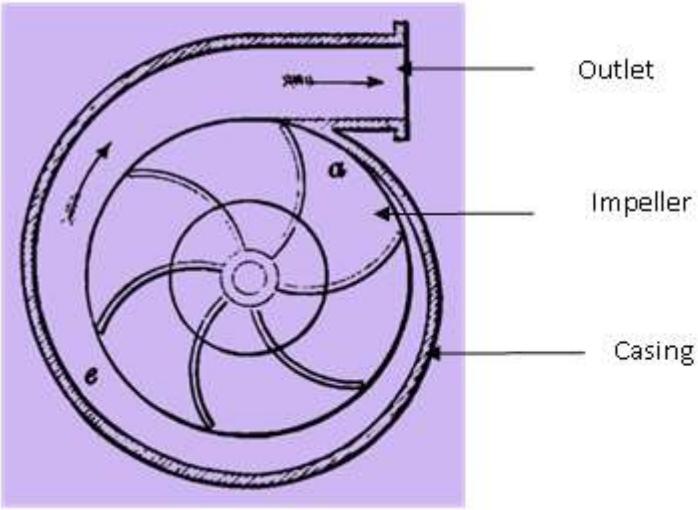

Figure 34 : Centrifugal pumps

The Table 3.2 represents Comparison of Positive displacement pumps and Centrifugal pumps

Positive displacement pumps	Centrifugal pumps
▪ Low flow and high total manometric head ▪ The flow and powerabsorbed are proportional to speed ▪ The torque is a function of the HMT ▪ The starting torque is 3 to 5 times the nominal torque	▪ High flow ▪ The flow rate is proportional to the speed when it reaches some value ▪ The power absorbed is proportional to the cube of the speed ▪ The Torque is a function of the square of the speed ▪ The pressure is proportional to the speed

Table 3 : Comparison of Positive displacement pumps and Centrifugal pumps

3.6 Steps for sizing the solar pumping system

3.6.1 Daily hydraulic energy:

Potential energy required lifting a volume V (m^3) of water / day

$$Eh = Ch \times Vd\ max \times HMT \qquad \textbf{(3.3)}$$

With:

Vd max: the maximum volume of water requested by user such As:

$$Vd\ max \leq Vb \qquad \textbf{(3.4)}$$

Ch: represents the hydraulic constant

$$Ch = g \times \rho = \frac{9.81 \times 1000}{3600} = 2.725 \qquad \textbf{(3.5)}$$

g: is the constant of gravity

ρ: is the density of water

3.6.2 Daily electrical energy:

Electric energy to transfer at a certain height of elevation (in m) a certain quantity of water Vd in (m3 / day) with an electric efficiency pump η_p

$$Ee = \frac{Eh}{\eta p} \qquad \textbf{(3.6)}$$

With:

$\boldsymbol{\eta_p}$: the efficiency of the electric pump generally varies between 45% and 55%

3.6.3 Peak power:

$$Pc = \frac{Ee}{Dh(1-losses\%)} \qquad \textbf{(3.7)}$$

With:

Dh: the number of hours of sunshine in the most unfavorable month

Losses%: losses of energy produced due to temperature and dust are estimated from 10% up to 15%

3.6.4 Configuration of a solar pumping system:

The choice of material:

- **the Pump:**

$$Pp \leq 30\% \, Pc$$

$$Pp \leq 0.3 \, Pc$$

Pp: pump power

- **photovoltaic module:**

$$Nt = \frac{Pc}{Pm} \quad \textbf{(3.8)}$$

Nt: module number

Pc: Peak power

Pm: Peak power of the module

3.7 configuration of the PV Generator:

- NS: Number of the PV module in series

$$Ns = \frac{Nt}{Vpvg} \quad \textbf{(3.9)}$$

Nt: total number of the PV module

Vpvg: Nominal voltage of each PV module

- NP: Number of the PV module in parallel

$$Np = \frac{Nt}{Ipvg} \quad \textbf{(3.10)}$$

Nt: total number of the PV module

Ipvg: Nominal current of each PV module

3.8 Practical experiences:

We have carried out some practical operations of the dimensional study process at the URAER Institute of Renewable Energy, located in Ghardaia

3.8.1 URAER: (Unit Research Applied in Renewable Energies)

Create in November 2002; the URAER attached to the development center of renewable energies (CDER) is located 1 km from Ghardaia airport and 600 km from Algiers. Its main mission is applied scientific research in energies renewable URAER aims to develop, disseminate and promote new avenues of research applied in order to provide a place of consultation and coordination for the activities of research related to renewable energies. [31].

URAER provides services, in particular the study and implementation of solar systems:

- Study and realization of photovoltaic systems: photovoltaic lighting, pumping solar…
- Solar energy supply for autonomous houses: electricity, hot water sanitary, air conditioning ...
- Smart agricultural greenhouses and Energy audits
- Metrological data: solar illumination, temperature, humidity, speed and wind direction…

3.8.2 Test Bench installed at the URAER:

The test bench installed at the URAER makes it possible to test and characterize different PV pumping systems. It allows simulating pumping heights under real operating conditions. The measuring intervals can reach 1kW of power, 120m of pumping height and 10 m^3/ h of water flow. Pumping systems can be powered either from the PV generator or from a programmable DC power supply. We have three measurement procedures different: measurements without control, I-V curve measurements at height constant, height-flow curve measurements at constant voltage the complete characterization of a pump in the test bench allows to obtain the parameters of the mathematical models for the simulation and optimization The system under test can be powered by using the GPV or by using the DC power supply.

Photovoltaic generator it consists of 25 ISOFOTON 110 modules, a total power of 2,750 kWp plus

DC power source The EA-PS 6065-10 power supply, model AP10090A of 650W of power with a range of voltage 0-65V and current 0-10A. It contains two parts:

3.8.2. A. The inner part:

- The experimental well, which contains a basin, a pump, and a tube system, allows us to measure the flowing water and a change in manimetric height using pressure.

Figure 35 : The experimental well

- A control panel that allows us to monitor the change of data during the experiment such as a change in radiation, current, temperature, etc

Figure 36 : The control panel

- A computer and an input panel are here to scan and input accurate information from the well BenchLink Data Logger software for configuration and analysis of Data.

Figure 37 : computer and an input panel

3.8.2. B. The out part:

Abroad, a set of ISOFOTON (110/24) solar panels with monocrystalline cells made in Spain

Figure 38 : The solar panels

3.9. Conclusion:

In this part, we got acquainted with the well data, such as the manometric height, which determines the distance between the surface of the water and the place of exit of the water. We also learned about the stages of the study of dimensions and the most important components of the solar pumping system for engines and their types and the advantages of each type and the difference between them

Chapter4:

Techno-economic study

Chapter 4 Techno-economic study

Chapter 4

Techno-economic study

4.1 Introduction

Algeria has enormous potential for wheat production, as the annual production in 2020 was estimated at 3.9 million tons [33] and Algeria seeks to achieve self-sufficiency in this material and reduce the import bill Algeria is distinguished by its large areas suitable for cultivation, especially in the desert. However, the biggest problem facing farmers in these areas is the high cost of production as being away from the electricity main grid, whereas the diesel generators are the frequently used, which constitutes a burden on the investors. In this study, we will present a technical and economic attempt to reduce the cost of water extraction in the goal to reduce the overall cost production, over, a medium-term investment, by exploiting the solar potential in pumping and supplying water

4.2 Water demands:

In this part, we will estimate the water needs is estimated for watering durum wheat throughout the wheat life cycle, taking into account the different seasons and the specificity of each region in terms of soil quality and local climate. The winter wheat season in Algerian southern part extends from October-November to the harvest in May. The plant cycle of wheat is represented by the sequence of several stages of development and growth, which allow the plant to multiply in the right environment. This cycle includes two important periods, namely:

The vegetative period: the sowing and germination phase and the tillering phase

Productive period: related to the elongation stages and the grain formation stage

The following table 4.1 shows the water needs at each stage of wheat ripening [34]

Initial irrigation from 7 days to 10 days before sowing	sowing	germination	tillering	grain formation	Harvesting starts 10 to 15 days after the irrigation stops
6 mm/day	every day 6 mm	8 mm/day	10 mm/day	12 mm/day	

Table 4 : The water needs

4.3 Sample dimensioning: Case Study Ghardaia region

The southern part of Algeria is one of the highest sunny areas in the world. The estimated daily energy received is 2632 kwh/m^2. The average duration of radiation in the south is 3,500 hours per year .[35]

The province of Guardaia, similar to the other southern regions, keeps specific climate proof agricultural. The area suitable for cultivation in the province is 69.350 hectares [36], while the region is seeking to achieve self-sufficiency from its agricultural needs .Wheat occupies an important care of the cultivated area, where it was estimated that the mass planted with wheat was estimated at 10.360 hectares, with an estimated production of 0.5million quintals in the year 2020. [37]

Experimental area

- Location: Hassi Fahl - Ghardaia
- Coordinates: 31°36′19″N 3°40′27″E
- Elevation 375 metres
- Area: 1000 m2
- Head of pumping: 20 m
- Cultivation type: durum wheat
- Watering method: center pivot irrigation.

4.3.1 Estimation of water demands:

The highest crop of dry soils and hard climate is the most water demanded since there is stress in rainwater in southern Algeria (Sahara). In arid and semi-arid areas the average gross amount of water required by durum wheat is about 500-600 mm per hectare, which corresponds to 5000-6000 Liters per hectare (5 -6 m3/ha). Ploughing and Sowing are usually in autumn and grows over the in vernal seasons to be harvested in the early hot season of arid zones or early summer in semi-arid areas. Its maturity takes an average of between six and seven months in humid and semi-arid areas to be harvested in early summer and between five to six months in arid soils. Durum wheat grown in different climatic zones will have different Gross depths (water needs). The lowest values can be obtained in cold and humid zones. The gross depth (annual required water volume per hectare) through the different regions of Algeria is presented in table 5:

Areas	Sub-humid (Costal area)	Sem-arid area (High plateaus)	Arid area (North Sahara)	Hyper-arid (South Sahara)
Length of maturity	7 month &1/2	7 month	6 months	5 months
Length of full irrigation/day	160 days	180 days	150 days	120 days
Gross depth (mm/ha)	445 mm	530 mm	590 mm	667 mm
Water volume (m^3/ha/day)	4.45 m^3	5.30 m^3	5.90 m^3	6.67 m^3
Gross Depth ($m^3.ha^{-1}$/Y)	712	954	885	800

Table 5 : annual required water volume per hectare through the different regions of Algeria

4. 3.2Electricity Consumption Estimation

Sufficient energy must be available to operate our pumping system, and we must determine the type of pump, the pumping height, and the volume of pumped water, surface groundwater can be available at a depth of 15 to 60 meters

After conducting a dimensional study with the following data: Vd =5m^3.HMT=20m

- Calculation of daily hydraulic power

$$Eh=Ch\times Vd\ max\times HMT$$

$$Eh=2.725\times 5\times 20$$

$$Eh= 272.5\ wh$$

- Daily electrical energy

$$Ee = \frac{Eh}{\eta p}$$

$$Ee = \frac{272.5}{0.55}$$

$$Ee=495.45 \text{ wh}$$

- Peak power

$$Pc = \frac{Ee}{Dh(1 - losses\%)}$$

$$Pc = \frac{495.45}{4.5(1 - 0.15)}$$

$$Pc \approx 140w$$

We find that the energy required to provide this amount of water is Pc= 140w

4.3.3Economic Study

In the economic study, we will compare in terms of cost between the solar pumping system and the traditional pumping system in which we use electric power generators, including the diesel pumps.

4.3.3. A.Using a solar pumping system

In this part, we are designing a solar system to pump the required quantity for watering wheat about 5 m3. We will need a pump with a depth of 20 meters with a flow rate of 5000 liters per day, from which we will choose a Lorentz pump with characteristics of 300 watts and two solar models (150 watts) to meet the electrical needs of the pump.

The invoice for the above-mentioned solar pumping system, in addition to all accessories and installation, is estimated by a specialized company twinpower at 280000 DA [39]

4.3.3. B.Using electrical networks

The determination of the global cost of irrigation is very complex due to the multiple objectives. Adding to the price of water which depends on the application (kind of crop), installation, pumping, storage and distribution must be included. The rates of water price fixed by SEAAL (National Society of Water and Sanitation) in Algerian Dinars per cubic meter (DA/m3) for the drinking water, industrial or agricultural bill are subject to specific tariffs for each territorial (zone tariff), majored with a saving fee of amount 4% for north and 2% for the south, as presented in table 6:

Territorial tariff zone	**Base tariff in DA/m^3**	**Gross tariff in DA/ m^3**
Northern region (humid and sub-humid)	6.30	6.552
High plateaus (semi-arid region)	6.10	6.344
Southern part (arid and hyper-arid region)	5.80	5.916

Table 6 : Distribution of the zone water consumption tariffslgeria territory

Average of annual irrigation cost per hectare of durum wheat

Areas	Sub-humid (Costal area)	Sem-arid area (High plateaus)	Arid area (North Sahara)	Hyper-arid (South Sahara)
Water volume (m^3/ha/day)	4.45 m^3	5.30 m^3	**5.90 m^3**	6.67 m^3
Gross Depth (m^3.ha^{-1}/Y)	712	954	**885**	800
Cost of irrigation (DA.ha^{-1}/Y)	4665.024	6052.176	**5235.66**	4732.8

Table 7 : Annual irrigation cost of durum wheat through Algeria territory

4.3.3. C. Comparison

In this comparison, we compare the cost in both systems over the course of 10 years

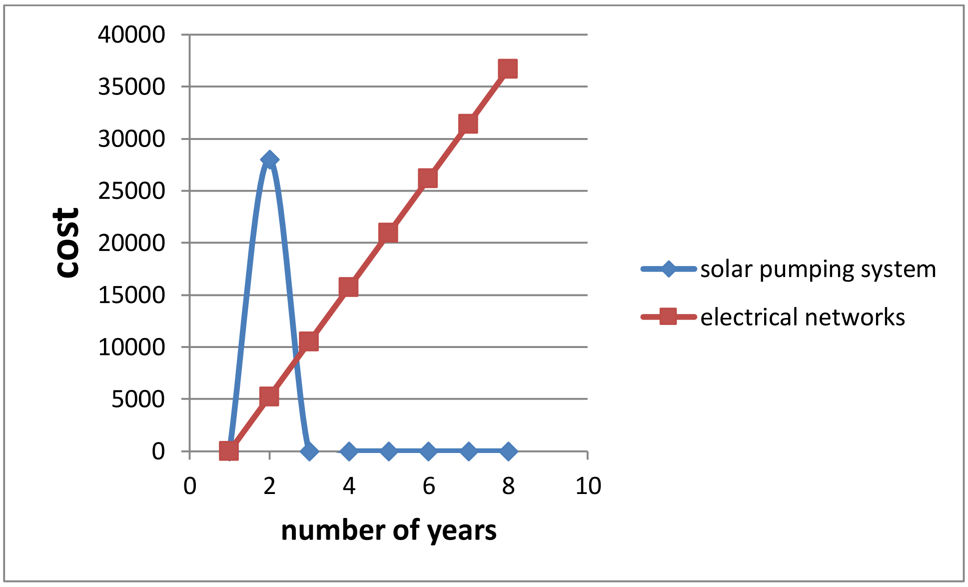

Figure 39 : Comparison between solar and conventional pumping system

We conclude from this comparison that the solar pumping system is a successful investment at the average level, as we note that we can pay the dues for the installation of the system after nearly 3 years since the installation of the Photovoltaic water pumping system , as it can be observed in the curve, where the intersection of the two graph costs are due within three (03) years . Contrary to the traditional system, which obliges us to spend money for the duration of cultivation or investment

4.4 Conclusion:

in this chapter we made a technical and economic study for an area of 1 hectare of durum wheat in the province Ghardaia, where we determined the needs of water and electric energy needed to cover it, and at the end we made an economic comparison between two pumping systems, one solar and the other traditional to find out the extent of the real investment and we will conclude that the solar pumping system is a medium-term investment, as shown in this attempt, through a duration of 3 years.

Conclusion

General

Conclusion general

In this work, a general overview on PV water pumping system option has been treated in enhancing the irrigation in agriculture sector. We must take advantage of the solar energy that Algeria has, as it receives 265 terawatts annually and can become the first global supplier of solar electricity and has an average of 3,000 hours annually as an alternative energy. Algeria has the highest rate of solar radiation in the Middle East, where we can use the vast areas of the desert to set up solar energy generation systems, as the desert is characterized by a high rate of sky purity and a low pollution rate, which allows direct access to solar radiation and a better yield. Algeria also has great water resources and resources in the north. It has many dams of water bodies, in addition to high rainfall amounts of up to 1000 mm in some areas, and in its desert is the largest reserve of fresh water in the world. It contains more than 50 000 billion m^3 of water, the so-called alpine aquifer

Techno-economic study of PV water pumping system has been adopted an irrigated area of Durum Wheat, located in Hassi Lefhal, province of Ghardaia with in an area of 1000 m^2 Where we studied the dimensioning, we first determined the manometric data and the metric height, then determined the daily water demand, and we also calculated daily hydraulic power and daily electrical energy. And we estimate the electrical energy needed to pump the required amount of water. Then we estimated the price of electricity consumption for an area of one hectare for watering durum wheat throughout the season. Then we assumed a solar pumping system capable of irrigating the same area and able to meet the water demand of wheat. Finally, we compared the two economic systems over a certain period of time, and in the latter we concluded that PV water pumping system is a medium-term investment.

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