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# Theme

# Study and Design of Solar Tracker

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بِسْمِ ٱللَّهِ ٱلرَّحْمَٰنِ ٱلرَّحِيمِ

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With sincere appreciation,

[TOUMI Djamel , SABOUR Mustapha]

# إهداء

إلى من قال : "لا يكتمل ايمان المرء حتى أكون أحب إليه من نفسه وماله وولده"محمد صلى الله عليه وسلم .

إلى من قال فيهما الله تعالى:" وَاخْفِضْ لَهُمَا جَنَاحَ الذُّلِّ مِنَ الرَّحْمَةِ وَقُل رَّبِّ ارْحَمْهُمَا كَمَا رَبَّيَانِي صَغِيرًا " والديّ العزيزين.

إلى جدي وجدتي (من ناحية الأب) رمز الحنان والدفء، شكراً على دعمكما المستمر وتضحياتكما العظيمة.

إلى جدي وجدتي (من ناحية الأم) مصدر الحكمة والتوجيه، شكراً لكل لحظة عطاء وحب.

إلى أخوالي وخالاتي، أنتم القلب النابض بالعطف والمودة، وجودكم في حياتي جعلني أشعر بدفء العائلة الكبيرة، ودعمكم كان له الأثر البالغ في نفسي.

إلى العم ، شكراً لك على كل كلمة تشجيع وكل لحظة مشاركة، كنت دائماً داعما لي بشكل لا يقدر بثمن، ووجودك أثرى حياتي بالحب والقوة.

إلى أخي وأختي، الركيزتين الأساسيتين في حياتي. شكراً لكل موقف دعم، أقدر محبتكما ومساندتكما الدائمة بكل امتنان .

تومي جمال

# إهداء

قال تعالى: (قل اعملوا فسيرى الله عملكم ورسوله والمؤمنون )

الهي لا يطيب الليل إلا بشكرك .....ولا يطيب النهار إلا بطاعتك ...

ولا تطيب اللحظات إلا بذكرك .. ولا تطيب الآخرة إلا بعفوك ... ولا تطيب الجنة إلا برؤيتك « الله جل جلاله »

إلى من بلغ الرسالة وأدى الأمانة ... ونصح الأمة ... إلى نبي الرحمة ونور العالمين سيدنا محمد صلى الله عليه وسلم

إلى من كلله الله بالهيبة والوقار .. إلى من علمني العطاء بدون انتظار .. إلى من أحمل أسمه بكل افتخار ... أرجو من الله يرحمك ويتقبلك من الشهداء وستبقى كلماتك نجوم أهتدي بها اليوم وفي الغد وإلى الأبد والدي العزيز - رحمه الله

إلى ملاكي في الحياة .. إلى معنى الحب وإلى معنى الحنان والتفاني .. إلى بسمة الحياة وسر الوجود إلى من كان دعائها سر نجاحي وحنانها بلسم جراحي إلى أغلى الحبايب أمي الحبيبة

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وفي الاخير نسأل الله ان يحفظهم و يبارك لنا في عملنا هذا طالبين منه عزوجل ان يجعلنا منفعة للناس بهذا العمل.

صابور مصطفى

## خلاصة

تعد الطاقة الشمسية موردًا وفيراً يمكن استغلاله بفعالية من خلال استخدام الخلايا الشمسية الكهروضوئية والتأثير الكهروضوئي لتحويل ضوء الشمس إلى كهرباء. ومع ذلك، فإن كفاءة الخلية الكهروضوئية القياسية منخفضة نسبيا بسبب اعتمادها على شدة الضوء، مما يؤدي إلى انخفاض كفاءة الامتصاص في أوقات معينة من اليوم والسنة عندما يتغير موضع الشمس. تكون الخلايا الشمسية الكهروضوئية أكثر إنتاجية عندما يتم وضعها بشكل عمودي على أشعة الشمس. لتعزيز توليد الطاقة وكفاءتها، يتم استخدام أجهزة تتبع الطاقة الشمسية.

تقدم هذه الدراسة نظام تتبع شمسي ثنائي المحور فعال من حيث التكلفة مصمم لتتبع حركات الشمس من أجل زيادة إنتاج الطاقة من الألواح الشمسية أثناء متابعتها للشمس. يتم استخدام المقاومات المعتمدة على الضوء للكشف عن موقع الشمس، والتي يتم نقلها بعد ذلك إلى متحكم Arduino Uno. يأمر هذا المتحكم الدقيق زوجًا من خطوة ب خطوة لضبط اتجاه اللوحة الشمسية لتظل عموديًا على أشعة الشمس.



**الكلمات المفتاحية :** الألواح الشمسية، المتتبع الشمسي، لوح اردوينو، المقاومات الضوئية، محركات الخطوة بخطوة.



## Abstract

Solar energy is a plentiful resource that can be effectively utilized through the use of solar photovoltaic cells and the photovoltaic effect to convert sunlight into electricity. However, the efficiency of a standard PV cell is relatively low due to its dependency on light intensity, resulting in decreased absorption efficiency at certain times of the day and year when the sun's position changes. Solar photovoltaic cells are most productive when positioned perpendicularly to the sun's rays. To enhance energy generation and efficiency, solar trackers are employed.

This study introduces a cost-effective dual-axis solar tracking system designed to track the sun's movements in order to maximize power output from solar panels as they follow the sun. Light Dependent Resistors are utilized to detect the sun's position, which is then transmitted to an Arduino Uno microcontroller. This microcontroller commands a pair of stepper motors to adjust the orientation of the solar panel to remain perpendicular to the sun's rays.



**key words :** Solar Panels(PV), Solar Tracker, Arduino Board, Light Dependent Resistor (LDR) Sensor, Stepper Motors.



## Résumé

L'énergie solaire est une ressource abondante qui peut être utilisée efficacement grâce à l'utilisation de cellules photovoltaïques et de l'effet photovoltaïque pour convertir la lumière du soleil en électricité. Cependant, l'efficacité d'une cellule PV standard est relativement faible en raison de sa dépendance à l'intensité lumineuse, ce qui entraîne une diminution de l'efficacité d'absorption à certains moments de la journée et de l'année lorsque la position du soleil change. Les cellules photovoltaïques sont les plus productives lorsqu'elles sont positionnées perpendiculairement aux rayons du soleil. Pour améliorer la génération et l'efficacité de l'énergie, des suiveurs solaires sont employés.

Cette étude introduit un système de suivi solaire à double axe rentable, conçu pour suivre les mouvements du soleil afin de maximiser la production d'énergie des panneaux solaires qui

suivent le soleil. Des résistances dépendantes de la lumière sont utilisées pour détecter la position du soleil, qui est ensuite transmise à un microcontrôleur Arduino Uno. Ce microcontrôleur commande une paire de moteurs pas à pas pour ajuster l'orientation du panneau solaire afin de rester perpendiculaire aux rayons du soleil.

**Mots clés** : Panneaux Solaires, Tracker Solaire, Carte Arduino, Capteur de résistance dépendant de la lumière (LDR), Moteurs pas à pas.

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# 1 General Introduction

## OVERVIEW

Solar energy and solar cells started from the creation of God Almighty for the sun because it is the first source for generating thermal energy and then it became generating electrical energy, so the man used to benefit from the energy of solar radiation in drying crops, agriculture and other things. Thermal transfer occurs when solar or light radiation is converted into electrical energy by solar cells through the techniques of photoelectric conversion and thermal conversion of solar energy. Einstein was the first scientist to identify this event, and he was awarded the Nobel Prize in 1921 for his explanation of this cosmic occurrence.

Sun cells are unique in that they produce electricity by directly converting solar energy into electricity without harming the environment.

Due to the rising demand for electricity, renewable resources are currently one of the main issues, although conventional energy sources' quality and availability are insufficient. Any nation in the world can only develop if it has access to energy. Fossil fuels are primarily used in the generation of energy. Energy from renewable resources like solar, geothermal, and tidal wave energy is becoming more and more necessary; because the supply of fossil fuels is finite. The photovoltaic "PV" system has the greatest potential among all renewable energy sources to displace current energy sources. The only way to improve a solar panel's performance is to intensify the light that hits it. The best technology is solar tracking by maintaining the solar panel aligned with the position of the sun, to maximize solar panel efficiency.

A system that tracks the sun as it moves across the sky is called a solar tracker.

Together with solar panels, the latter may follow the path of the sun and produce more renewable energy for your needs.

## EXISTING PROBLEMS

Algeria's energy sector remains heavily dependent on non-renewable energy sources such as crude oil and natural gas to meet its energy needs. Despite this dependence, the country has great potential in solar energy. According to the International Energy Agency, Algeria has vast land and abundant sunlight and can generate up to 162 terawatt hours (TWh) of electricity. This highlights Algeria's untapped potential to diversify its energy mix and harness renewable energy [1] , thereby reducing its dependence on fossil fuels and reducing its environmental impact.

## PROJECT OBJECTIVE

Solar energy is a widespread and promising renewable energy source that can theoretically meet global energy needs and address global energy challenges. Capturing even just 1% of solar energy could meet global energy needs [1] . The climate conditions in Algeria, especially in the Sahara region, are extremely conducive to the development of solar energy, with abundant sunshine throughout the year. The World Energy Council (WEC) reiterated this potential, noting the region's ideal production conditions: plenty of sunshine, low humidity,

minimal rainfall and vast flat lands close to infrastructure networks. About 10% of the Algerian Sahara Desert can meet the EU'S energy needs [1]. Our paramount objective revolves around optimizing solar energy utilization through state-of-the-art dual-axis solar tracking technology, with a view towards positioning Algeria as a preeminent global player in the solar energy domain while progressively reducing reliance on non-renewable resources."

# 2 Chapter 1: "Optimizing Solar Energy: Angles and Geographic Factors"

## 2.1 Introduction

Solar energy has earned its rightful place among other sources of energy in the present time, with substantial budgets being allocated in most countries to exploit this energy source.

Each point on the Earth's surface receives solar radiation from sunrise to sunset at angles determined by various solar angles resulting from the movement of the sun and the Earth. Additionally, the intensity of direct solar radiation varies depending on the location on the Earth's surface and over time throughout the day (from sunrise to sunset) and throughout the year.

To estimate the intensity of solar radiation reaching the Earth's surface, it is necessary to understand the different solar angles and expressions for estimating solar radiation for photovoltaic conversion. This is what we will address in this chapter of our research.

## 2.2 The movement of revolution and the seasons

The Earth's rotation around the Sun describes a slightly flattened ellipse with a period of 365.25 days. During this annual journey around the Sun, the Earth completes one full rotation on its axis in 24 hours around the poles. This north-south axis makes an angle of $\delta = 23°45'$ with the direction perpendicular to the plane of the Earth's orbit around the Sun.

This inclination remains constant throughout the orbit around the Sun and is responsible for the seasonal variations. Thus, during our winter months in the northern hemisphere, the duration of sunlight is relatively short and the Sun does not rise very high in the sky, while summer prevails in the southern hemisphere. During our summer months, the situation is reversed, with the northern hemisphere facing the Sun. Days are then longer than nights in the northern hemisphere, and the incident radiation approaches the vertical. [2]

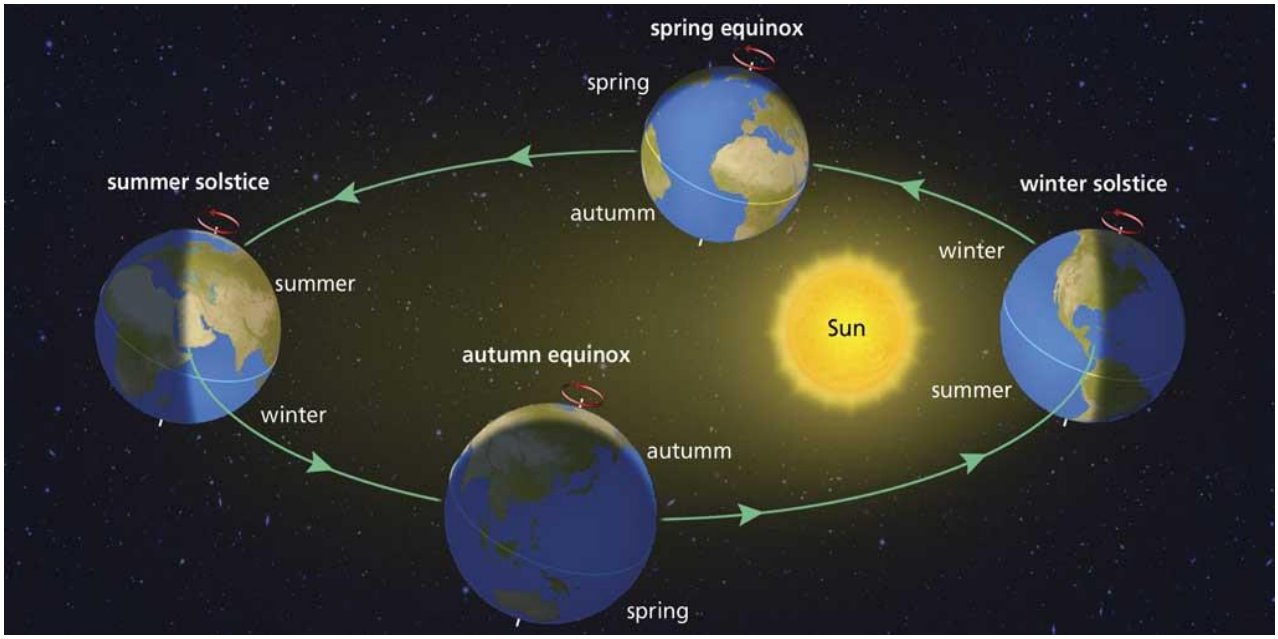



Figure 1:Seasonal variation in solar radiation. [2]

## 2.3 Solar Angles

The concept of solar tracking relies on determining the local position of the sun relative to the Earth at any time during the day. This includes the rotation of the Earth on its axis, resulting in the sequence of day and night, in addition to its orbit around the sun causing variations in daylight length. Solar timing depends on the apparent angle of the sun in the sky.

To understand the impact of the sun and utilize it in site selection and treatment, one must, of course, know the position of the sun in the sky at all times. [3]

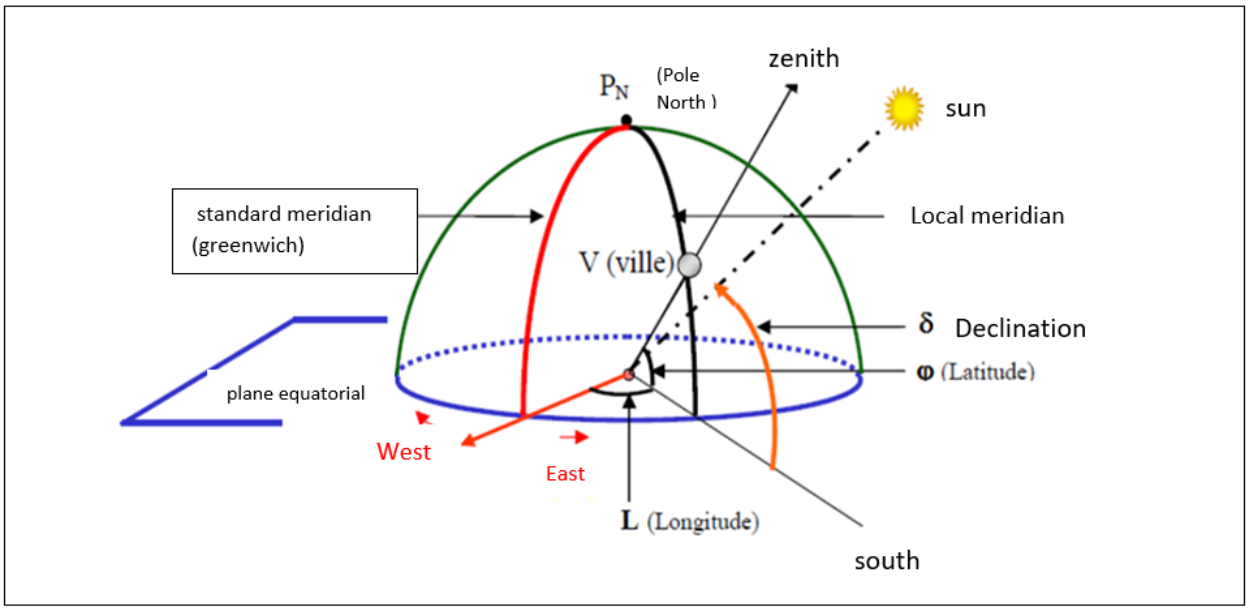



Figure 2: Coordinates of a Point on Earth. [3]

## 2.4 Geographic Angles

### 2.4.1 Latitude Angles (ϕ)

The latitude angle is the angle formed by the plane of the equator with the direction connecting the center of the Earth to the point under consideration. The Earth's equator is characterized by a latitude of 0°, the North Pole by a latitude of +90°, and the South Pole by a latitude of -90°, where 90°≥ φ ≥ -90°. [3]

### 2.4.2 Longitude Angles (L)

The longitude angle is the angle formed by the local meridian passing through the point under consideration with the prime meridian passing through the city of Greenwich. The meridian passing through the Greenwich Observatory has been chosen as the prime meridian (0°). By convention, meridians east of this meridian are assigned a positive sign (+), and those west of it are assigned a negative sign (-), where 180°≥ L ≥ -180°. [3]

### 2.4.3 Time Angles

#### *2.4.3.1 Solar Declination Angle (δ):*

The declination angle (δ) is the angle formed by the axis of the solar center when the sun is on the local longitude line with the equatorial plane (positive north). It is given by the equation: [3]

$$\delta = 23{,}45° \; sin\,[0.986(n + 284)] \qquad (1.1)$$

"$\delta$ :Declination of the Sun"

"$n$ : number of days"

#### *2.4.3.2 Solar Hour Angle (ω):*

The solar hour angle (ω) is the angle formed between the center of the sun and the Earth's longitude line, or it is the displacement of the sun eastward or westward from the local longitude line due to the Earth's rotation around its axis at 15° per hour. With solar noon considered the reference point (where w=0) , the solar hour angle is given by the equation: [3]

$$\omega = 15(\mathrm{TSV} - 12) \qquad (1.2)$$

"$\omega$ : Hour angle (absolute value) from 0° to 180°"

"TSV represents true solar time, or in French, Temps Solaire Vrai"

In the afternoon, w>0, while in the morning, W<0. [3]

## 2.5 Solar radiation

### 2.5.1 Definition:

Solar radiation is the energy emitted by the Sun, which is sent in all directions through space as electromagnetic waves. Emitted by the surface of the Sun, this energy influences atmospheric and climatological processes. The Sun emits energy in the form of short-wave radiation, which is weakened in the atmosphere by the presence of clouds and absorbed by gas molecules or suspended particles. After passing through the atmosphere, solar radiation reaches the oceanic and continental land surface and is reflected or absorbed. Finally, the surface returns it to outer space in the form of long-wave radiation.[4]

### 2.5.2 The different types of solar radiation

#### *2.5.2.1 Direct Solar Radiation:*

This Solar radiation penetrates the atmosphere and reaches the surface without dispersing all the way. [5]

#### *2.5.2.2 Diffuse Solar Radiation:*

Diffuse solar radiation, also known as diffuse sky radiation, is the radiation that reaches the Earth's surface after being scattered in the atmosphere. [5]

#### *2.5.2.3 Global radiation:*

is the sum of two types of radiation: direct and diffuse . [5]

## 2.6 Photovoltaic Energy

This is energy transformed directly into electricity from sunlight by photovoltaic panels. It results from the direct conversion in a semiconductor (such as silicon, cadmium telluride, gallium arsenide, copper indium selenide, etc.) of a photon into an electron, through the photovoltaic effect. The word "photovoltaic" comes from the Greek "photos" meaning light, and "volta" from the name of the Italian physicist who discovered the electric battery in 1800. [6]

The photovoltaic effect was discovered in 1839 by Alexandre Edmond Becquerel, who wondered why certain materials produced sparks when exposed to light. He was able to demonstrate that it involved the direct conversion of light into electrical energy.

The photovoltaic effect relies mainly on three key principles, whose combined action results in the conversion of solar energy into electrical energy:

* Absorption of photons

* Conversion of the absorbed energy into free electric charges

* Collection of these particles in an external electrical circuit. [6]

## 2.7 solar cells

### 2.7.1 Definition

A solar cell (also known as a photovoltaic cell or PV cell) is defined as an electrical device that converts light energy into electrical energy through the photovoltaic effect. A solar cell is basically a p-n junction diode. Solar cells are a form of photoelectric cell, defined as a device whose electrical characteristics – such as current, voltage, or resistance – vary when exposed to light.

Individual solar cells can be combined to form modules commonly known as solar panels. The common single junction silicon solar cell can produce a maximum open-circuit voltage of approximately 0.5 to 0.6 volts. By itself this isn’t much – but remember these solar cells are tiny. When combined into a large solar panel, considerable amounts of renewable energy can be generated. [7]

### 2.7.2 Working Principle of Solar Cell

The interaction of light photons with a p-n junction is the fundamental mechanism of a solar cell. Light photons transport energy to the semiconductor material and create electron-hole pairs when they reach the thin p-type layer of the solar cell. The junction's thermal balance is upset by this process.

This energy releases electrons, which travel to the n-type side of the junction and the resultant holes to the p-type side. These freshly formed electrons, however, are unable to freely cross over to the p-type side of the junction because of the barrier potential of the junction, just as the holes are unable to freely go back to the n-type side. Similar to a battery cell, this separation results in a voltage differential known as the photovoltaic.

A little amount of current flows through the solar cell when an external load is connected across it; this current is driven by the established voltage. The conversion of light energy into electrical energy, which enables the solar cell to function, is represented by this current flow. [7]

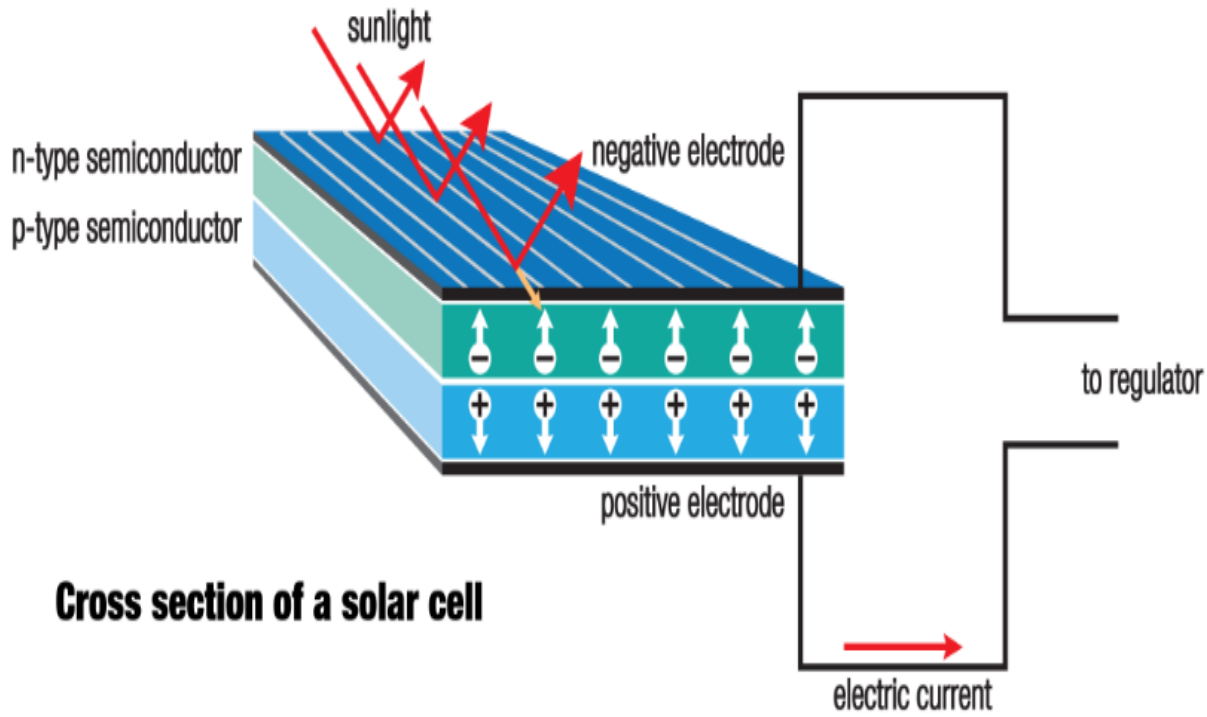



Figure 3: Working of Solar Cells . [8]

### 2.7.3 Types of photovoltaic cells

Photovoltaic cells or PV cells can be manufactured in many different ways and from a variety of different materials. Despite this difference, they all perform the same task of harvesting solar energy and converting it to useful electricity. The most common material for solar panel construction is silicon which has semiconducting properties. Several of these solar cells are required to construct a solar panel and many panels make up a photovoltaic array.

There are currently three main types of photovoltaic panels which are differentiated by the type of cells that compose them. [9 ]

#### *2.7.3.1 Monocrystalline Silicon Cell*

Monocrystalline silicon solar cells represent a pinnacle of efficiency in harnessing solar energy. Their production involves a meticulous process: a seed crystal is carefully drawn from molten silicon, yielding a singular, flawless cylindrical ingot with a continuous crystal lattice. These ingots are then precisely sliced into thin wafers, undergo meticulous polishing, and are doped to form the crucial p-n junction. Subsequent steps include the application of an anti-reflective coating and the attachment of front and rear metal contacts. Finally, the cells are meticulously wired and assembled into solar panels alongside numerous counterparts.

While monocrystalline silicon cells boast remarkable efficiency, their manufacturing is characterized by its deliberate pace and labor-intensive nature. [9]

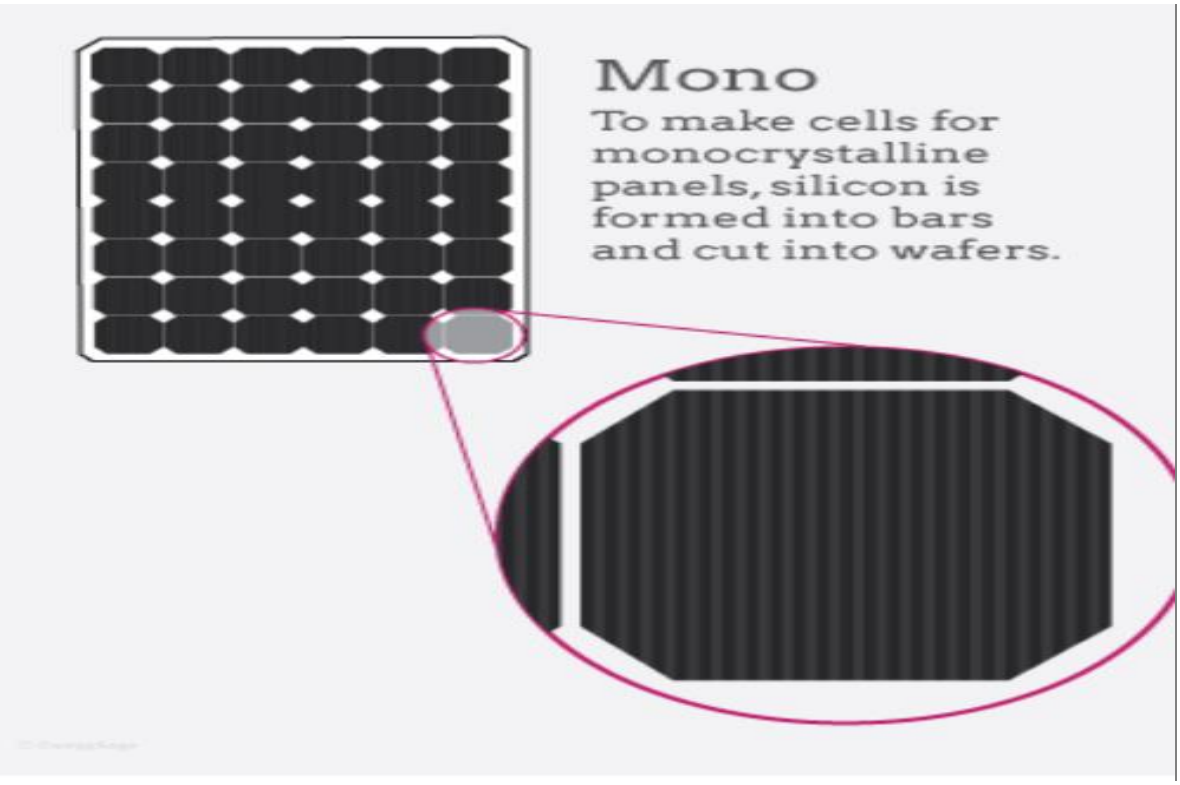



Figure 4: Monocrystalline silicon cell and photovoltaic module. [10]

#### *2.7.3.2 Polycrystalline Silicon Cell*

Polycrystalline silicon cells exhibit a distinct structure comprising numerous small crystal grains, in contrast to the uniform crystal lattice of monocrystalline cells. The production process for polycrystalline cells offers a degree of simplicity: a cube-shaped ingot is cast from molten silicon, then meticulously sliced and packaged akin to their monocrystalline counterparts. Alternatively, the edge-defined film-fed growth (EFG) method involves drawing a thin ribbon of polycrystalline silicon from a molten silicon mass.

While polycrystalline silicon PV cells present a cost-effective option, they sacrifice some efficiency compared to their monocrystalline counterparts. Despite this trade-off, they have emerged as a dominant force in the global PV market, constituting approximately 70% of worldwide PV production. [9]

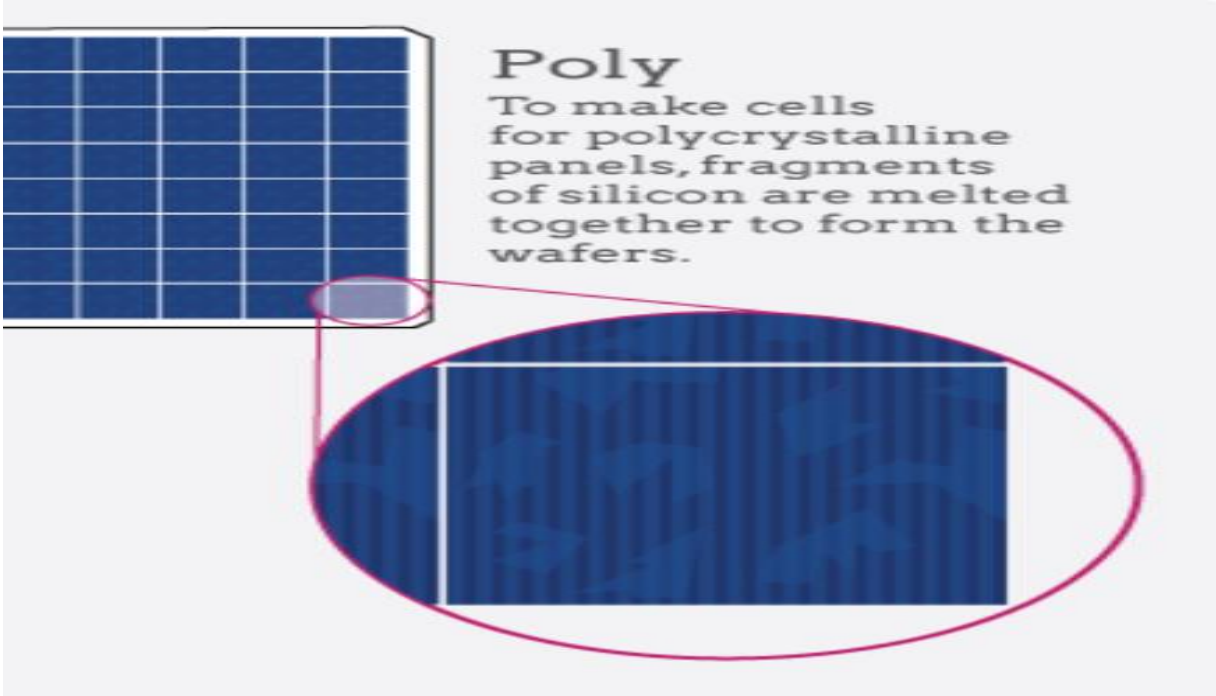



Figure 5: Polycrystalline Silicon Cell and photovoltaic module. [10]

#### *2.7.3.3 Thin Film Cells*

Although crystalline PV cells dominate the market, cells can also be made from thin films—making them much more flexible and durable. One type of thin film PV cell is amorphous silicon (a-Si) which is produced by depositing thin layers of silicon on to a glass substrate. The result is a very thin and flexible cell which uses less than 1% of the silicon needed for a crystalline cell. Due to this reduction in raw material and a less energy intensive manufacturing process, amorphous silicon cells are much cheaper to produce. Their efficiency, however, is greatly reduced because the silicon atoms are much less ordered than in their crystalline forms leaving 'dangling bonds' that combine with other elements making them electrically inactive. These cells also suffer from a 20% drop in efficiency within the first few months of operation before stabilizing, and are therefore sold with power ratings based on their degraded output. [9]

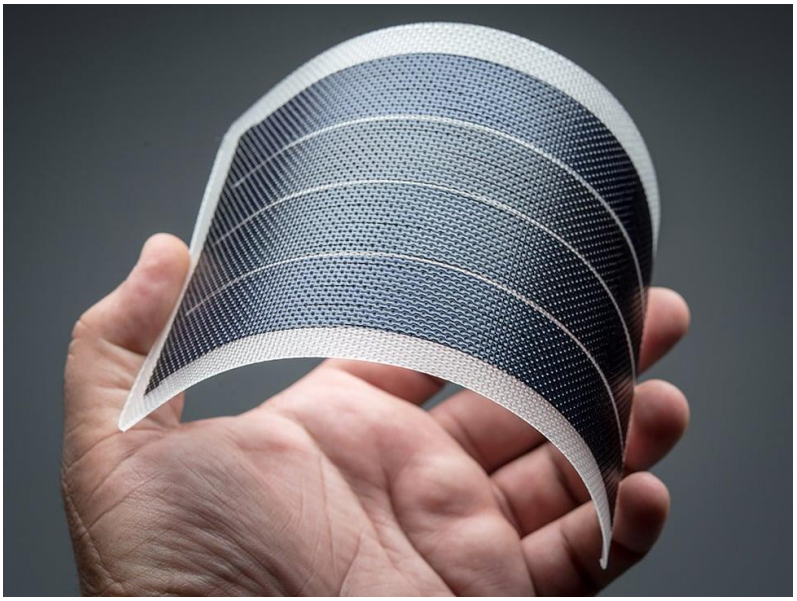


Figure 6: Thin Film Solar Cells [11]

## 2.8 Advantages and Disadvantages of Solar Cell

### 2.8.1 Advantages of Solar Cell

- ✓ No pollution associated with it.
- ✓ It must last for a long time.
- ✓ No maintenance cost. [7]

### 2.8.2 Disadvantages of Solar Cell

- ✓ It has high cost of installation.
- ✓ During cloudy day, the energy cannot be produced and also at night we will not get. [7]

## 2.9 Conclusion

In this chapter, we have presented the phenomenon of converting solar energy into electrical energy using photovoltaic (PV) technology. the study of solar radiation is necessary for selection the best site for installing a solar capture system. the radiation received by a PV module also depends on the level of sunshine at the considered site and its orientation relative to the sun. For the solar radiation to be perpendicular to the PV solar panel, and to optimize the entire system, it is necessary to use the solar tracking technique known as a "solar tracker".

# 3 Chapter 2: solar tracking techniques .

## 3.1 Introduction

Photovoltaic (PV) module efficiency is closely related to how well they line with incident sun energy. Throughout the day, accurate modification of orientation settings is essential to guarantee consistent and optimal energy output. Solar tracking systems become essential as a result. With the help of these complex processes, which dynamically track the path of the sun, PV modules are constantly positioned to maximise their exposure to sunlight. Solar trackers are essentially the pinnacle of engineering perfection since they allow PV installations to maximise their efficiency and output by seamlessly adapting to the movement of the sun.

## 3.2 TYPES OF SOLAR PANEL BASES &THE DIFFERENCE

### 3.2.1 Fixed Solar Panel Bases

Static solar panel foundations hold firmly in place and provide a stable platform, but cannot dynamically adjust to solar radiation throughout the day. Installation typically requires screws or welding. Although cost-effective compared to their mobile counterparts, they cannot dynamically adjust orientation And the tilt remains static. [12]



Figure 7: Fixed solar cells . [13]

### 3.2.2 Moving solar panel bases

To meet the dynamic demands of solar power, the mobile solar panel base offers adjustable angles to optimize productivity. These bases are equipped with "tracker" motors that rotate on two axes, effectively following the sun's path from east to west throughout the day. This ensures that the solar cells remain oriented perpendicular to the sunlight, maximizing efficiency. [12]



Figure 8: Moved solar cells . [14]

The moving bases follow the sun in one axis and in two axes.

## 3.3 solar trackers

### 3.3.1 Definition

Manufacturers are constantly making incremental improvements to their solar panels to create a higher energy yield per unit than previous and competing models. Another proven way to increase system output is by using solar trackers, which, unlike fixed-tilt ground-mount systems, make solar panels follow the sun's path throughout the day.

Solar trackers are sophisticated mechanical devices created to maximize solar radiation collection efficiency.

Thanks to their design, they can adjust their axis and accurately orient the photovoltaic panels to point towards the optimal position of the sun, which allows solar energy to be collected exceptionally. [15]

### 3.3.2 TYPES OF TRACKERS:

#### *3.3.2.1 Solar trackers with a single axis*

The single axis solar panel, in Fig. 1(b), will possess the capacity to track the sun as the sun careens from east to west throughout the day. It should be noted that single axis refers to the changes in the position of the tracker to be following the sun's one dimensional movement. The sun's changing position with respect to seasons, will not be taken into account by the single axis tracker. A single axis tracker able to generate considerably more energy than what a fixed axis does. Generally, single axis ST easily increase their energy produced up to 20% when compared to fixed flat PV systems. [15]

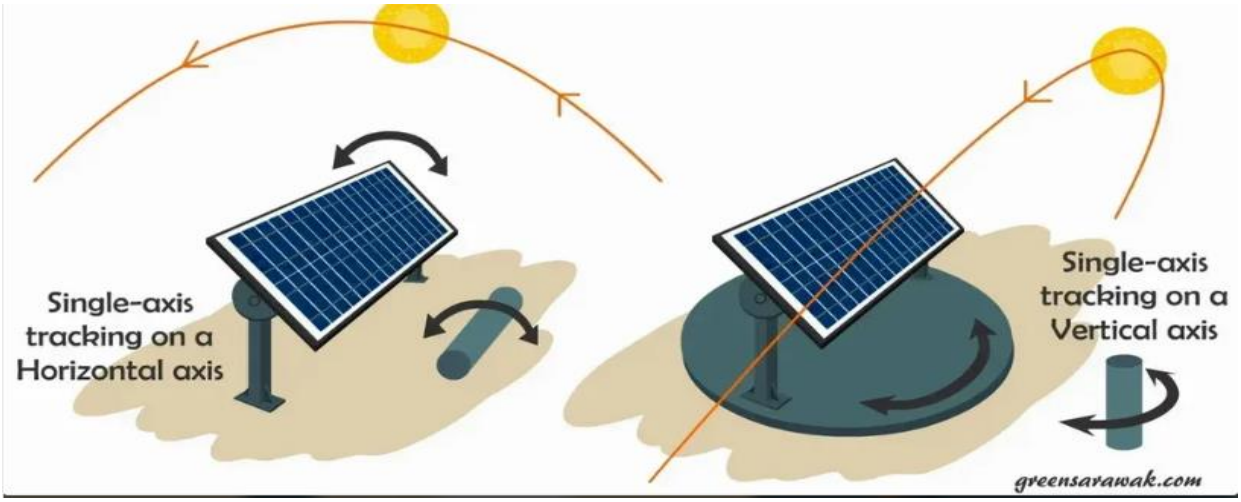



Figure 9: Single-axis tracker[16]

#### *3.3.2.2 Dual-axis solar trackers:*

The dual axis tracker is essentially able to follow the sun as it changes its positioning throughout a day as well as a year. Figure 1(c) shows a dual axis solar tracker. The sun doesn't only shift from east to west on a daily basis, as seasons change, the sun's position also varies moving from north to south. The dual axis tracker essentially follows the sun's two dimensional movement to ensure the angle of incidence between the sun ray and the panel is always kept minimum. This way the system is able to absorb maximum sunlight and therefore should be capable of producing more energy than single and fixed axis trackers. Dual axis trackers achieve good performances with greater efficiencies between 20% and 50% energy gains when compared to fixed flat PV panels [15].

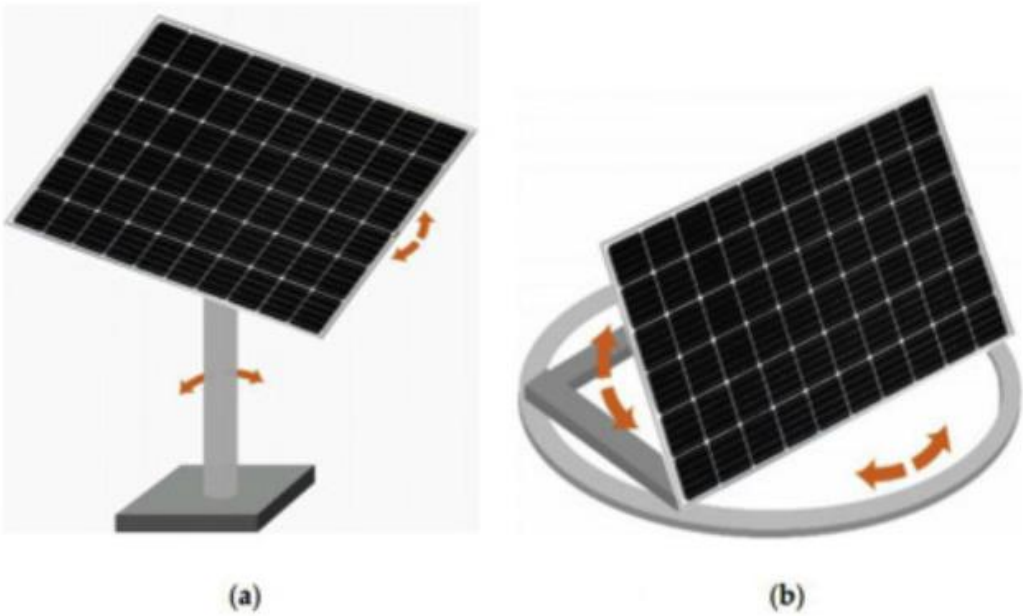



Figure 10: dual-axis trackers. [17]

Solar trackers are increasingly popular for maximizing the productivity of photovoltaic panels by dynamically adjusting their orientation to the sun's position. Unlike stationary mounts,

which have fixed positions, trackers follow the sun's path across the sky, optimizing energy output. While beneficial, it's essential to weigh potential drawbacks and considerations before implementing them on a specific jobsite.

### 3.3.3 The Function of the Rotational Axis in Solar Tracking Devices

Enhancing the effectiveness of solar panels hinges significantly on the deployment of solar tracker systems, whose functionality is intricately linked to their rotational axis. Within this realm, three distinct categories emerge as particularly notable:

#### *3.3.3.1 Horizontal Axis*

The horizontal axis tracker rotates along the North-South axis and is distinguished by its single degree of freedom. Large-scale commercial projects frequently use this arrangement, which is especially well-suited for areas with low to medium latitudes. [18]

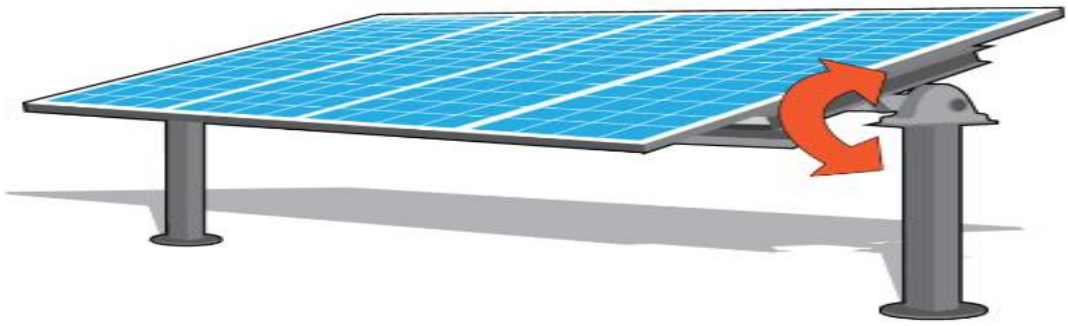


Figure 11: Horizontal Single Axis Solar Tracking System. [19]

#### *3.3.3.2 Vertical Axis*

The vertical axis tracker revolves around the East-West axis while having one degree of freedom. It finds its place in high latitude regions, where it provides a customised solution to maximise solar capture, despite being less prevalent in large commercial installations. [18]

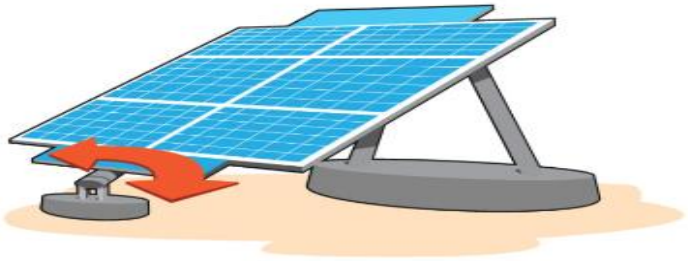


Figure 12: Vertical Single Axis Solar Tracking System . [19]

#### *3.3.3.3 Dual Axis*

This tracker rotates along both the East-West and North-South axes, providing two degrees of freedom and improved manoeuvrability. Because of its adaptability, it may be used effectively in a range of latitudes. [18]

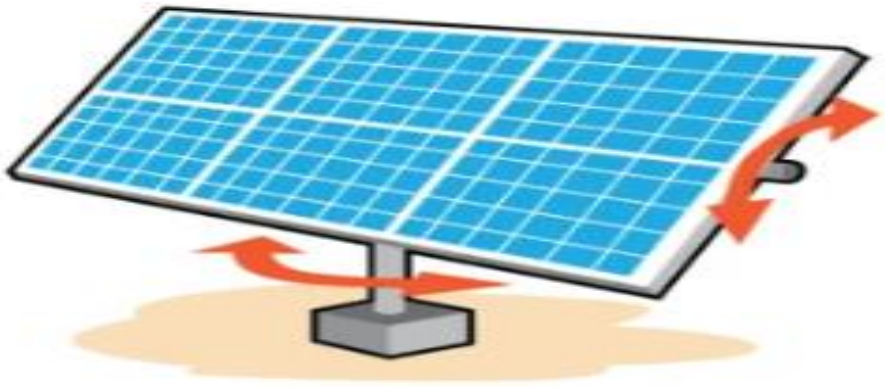


Figure 13: Dual Axis Solar Tracker . [19]

## 3.4 working principle of the project

We will explain the working principle of the project that talks about dual axis tracker.

### 3.4.1 Understanding the Mechanism of Dual Axis Solar Trackers

The dual-axis solar tracker, essential for maximizing solar energy absorption, works with a variety of custom mechanisms to optimize its positioning throughout the day. Here's a detailed explanation of how these trackers work:

#### *3.4.1.1 Manual adjustment*

In some cases, especially in developing countries where labor costs are relatively low, manual adjustment is still a viable method. Professionals regularly change the direction of the sun tracker to ensure optimal solar radiation. [20]

#### *3.4.1.2 Passive Tracking*

Some solar trackers utilize innovative technologies and utilize passive tracking mechanisms. These trackers have a fluid-filled bulb that heats up when exposed to sunlight. As the liquid inside the bulb evaporates, its volume expands, exerting pressure that tilts the solar tracker and adjusts it to the position of the sun. [20]

#### *3.4.1.3 Active Tracking*

Dual axis solar trackers frequently use hydraulic cylinders or electric motors for accurate and effective tracking. These parts react to the movement of the sun throughout the day by dynamically changing the tracker's orientation in real-time. While hydraulic systems deliver strong force for smooth tracking even in challenging circumstances, electric motors enable quick changes. [20]

"Active tracking, with a specific focus on electric motors, is considered a fundamental pillar in my research during the design and implementation phases."

## 3.5 Advantages and Disadvantages of dual axis trackers

Solar trackers are increasingly popular for maximizing the productivity of photovoltaic panels by dynamically adjusting their orientation to the sun's position. Unlike stationary mounts, which have fixed positions, trackers follow the sun's path across the sky, optimizing energy output. While beneficial, it's essential to weigh potential drawbacks and considerations before implementing them on a specific jobsite.

### 3.5.1 Advantages of dual axis trackers

- Profitable:



The installation of a solar tracker is a safe and profitable investment. These systems can pay off in a period of between 5 and 10 years, so, for the next 20 years or more, it can bring significant profits.

- Efficiency:



These trackers generate 45-50% higher power output per year, as compared to a static station of the same installed capacity.

- Location:



Solar trackers are perfect for locations with high latitude, where the sun's position varies a lot during the year. Thanks to their mobility, they adapt very well to the different seasons, maximizing solar energy.

- Make most of sunlight:



The high capacity of solar tracking allows devices to make the most of the additional hours of sunlight, which increases energy production in the mornings and evenings, optimizing the performance even

- Duration:



With appropriate maintenance, solar trackers can prolong the useful life of solar panels, as mechanical stress and thermal stress are reduced. [20]

### 3.5.2 Disadvantages of dual axis trackers

- Dual-axis trackers have higher technical complexity, which makes it potentially vulnerable to glitches.
- Low performance in cloudy or overcast weather. [20]

## 3.6 Conclusion

In this chapter, we reviewed solar panel mounts, focusing on fixed and tracking systems. We highlighted dual-axis tracking systems for their superior ability to maximize energy collection by precisely following the sun.
Despite their higher cost and complexity, dual-axis systems offer enhanced performance and efficiency, making them a worth while investment.
Our project aims to design an efficient dual-axis tracking system to boost solar energy output. In the next chapter, we will cover the design and maintenance of this system, including engineering standards, materials, and maintenance protocols for long-term efficiency and sustainability.

# 4 Chapter 3:Design and Creation of our Sun Tracking System.

## 4.1 Introduction

In the preceding chapter, we extensively examined the importance of monitoring solar energy systems and emphasized the significant advantages associated with this advanced technology. In this concluding and third chapter, we shift from theoretical investigation to practical implementation, with a focus on the design of a comprehensive solar tracking system. We will begin by clarifying the engineering and technical principles that are crucial for system design, addressing fundamental elements such as motors, sensors, and the necessary software for achieving precise tracking.

Following that, we will proceed to the assembly stage, elucidating the practical procedures for integrating various components. This process will commence with the preparation of the required infrastructure and culminate in the connection of electrical and electronic elements.

Lastly, we will present the installation and final testing phase of the system, accompanied by guidance and recommendations on system maintenance to uphold optimal performance in the long run.

## 4.2 Methodology

The primary component utilized in this study is the Arduino Uno, a single-board microcontroller renowned for its open-source physical computing platform and development environment for software writing. The Arduino Uno is also cost-effective, making it an ideal choice for this project. Other essential components include Light Dependent Resistors (LDRs), servo motors, and a solar panel. Diagram 1 illustrates the methodology adopted.

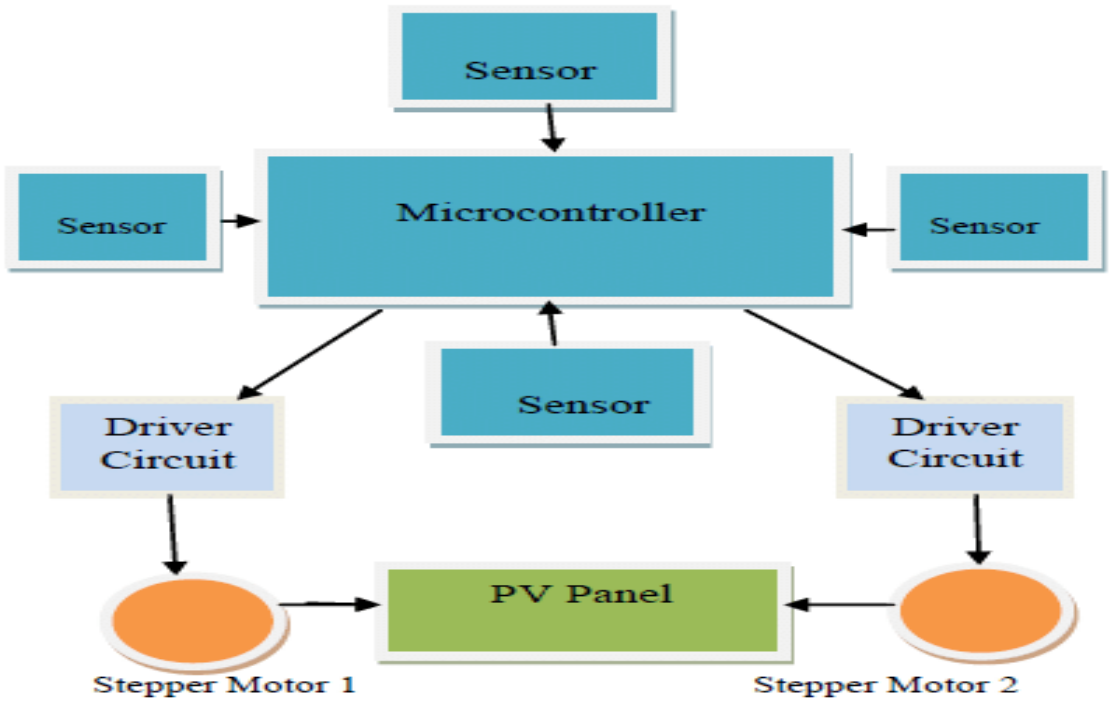



Diagram 1: Block Diagram [21]

The Dual-Axis Solar Tracking (DAST) system consists of the following phases:

- Electronics and control part.
- Mechanical part.
- System Control Programming.

## 4.3 Electronics and control part

This section primarily consists of a set of advanced electrical components and circuits. Its role is to precisely control the various maneuvers and movements executed by the system during the dual-axis solar tracking process, ensuring optimal orientation of the solar panel to maximize solar energy utilization efficiency.

### 4.3.1 Arduino:




Figure 14:Arduino LOGO.

Arduino, a renowned open-source electronics platform, is widely recognized for its user-friendly hardware and software. Its versatility allows users to effortlessly connect with various inputs, such as sensors or user commands, and translate them into desired outputs, such as activating motors or illuminating LEDs. This seamless functionality is made possible through the use of a programming language specifically designed for Arduino boards, based on Wiring, and the Arduino Software (IDE), which is built upon Processing.

From its humble beginnings as a tool for rapid prototyping at the Ivrea Interaction Design Institute, Arduino has grown into a globally embraced platform utilized in a wide range of projects. These projects span from everyday gadgets to sophisticated scientific instruments, showcasing the platform's adaptability. Arduino's inclusive ethos has fostered a vibrant community of makers, including students, hobbyists, artists, programmers, and professionals. This collaborative community has created a wealth of accessible knowledge, catering to both beginners and experts.

Furthermore, Arduino has continuously evolved to meet emerging needs and challenges. Originally developed as a solution for individuals without prior experience in electronics and programming, Arduino has expanded its offerings to encompass a diverse range of applications. These applications include Internet of Things (IoT), wearable technology, 3D

printing, and embedded systems. This adaptability has solidified Arduino's position as a versatile platform that can meet the demands of various industries and projects. [22]

#### *4.3.1.1 The different ranges of Arduino cards*

Arduino boards are extensively utilized in various applications, with each board catering to specific needs. The differentiation among Arduino boards lies in the number of analog/digital or analog input output pins they possess.

Currently, there are more than 20 versions of Arduino board, we will cite the most used in the field of electronics in order to see their evaluation: [23]

| **Card type** | **The figures** | **The description** |
|---|---|---|
| **UNO** |  | This card serves as an ideal gateway to the ARDUINO platform, equipping novices with all the necessary tools to embark on their first projects. |
| **Leonardo** |  | The card designed to replace the Arduino UNO aims to offer similar features with improved ergonomics and enhanced stability. However, due to its limited availability, users may find less support online compared to the Arduino UNO. |
| **Mega** |  | The Arduino Mega card is the most widely used card after the Arduino UNO card. It offers a number<br><br>much larger I/O (54 versus 14), a more powerful processor with a larger memory which allows more complex algorithms to be used. |
| **Due** |  | The Arduino Due card is an evolution of the Arduino Mega card which offers performance reputed to be 3 times higher. It allows you to quickly manipulate heavy algorithms that are particularly useful in the world of robotics, for example. |
| **Nano** |  | The Arduino nano board is a compact version of the Arduino UNO board. Its diminished dimensions and lighter weight render it appropriate for utilization in confined areas, such as textiles, as well as in the realms of robotics and model-making, where weight and size play pivotal roles in determining the feasibility of applications, such as helicopters and drones. |

| | | |
|---|---|---|
| **Yun** |  | The Arduino Yun board, recently offered by Arduino, is designed to counter the advantages of the Rasberry board. It is a derivative of the Leonardo board and aims to combine the power of Linux with the ease of use of an Arduino board. It is also the first Arduino board to be natively equipped with integrated wifi |

**Table ( I ) :** The different ranges of Arduino cards.

In our project, we are using an Arduino UNO board., which sets itself apart from other models due to its distinct atmega processor.

#### *4.3.1.2 Arduino UNO Board*

##### 4.3.1.2.1 Arduino - Hardware Design

It's a PCB-mounted microcontroller that you can program and use for simple daily tasks, mathematical computations, and prototyping and testing. An **Arduino development board** consists of the core microcontroller with its supplementary components and the necessary circuitry to communicate with the PC which we will be using for both communications as well as programming the microcontroller. For communication or programming purposes, we will be using a **USB to TTL converter**, which will be embedded within the Arduino board. So, if we look into an Arduino board at a block level it will look like this. [22]

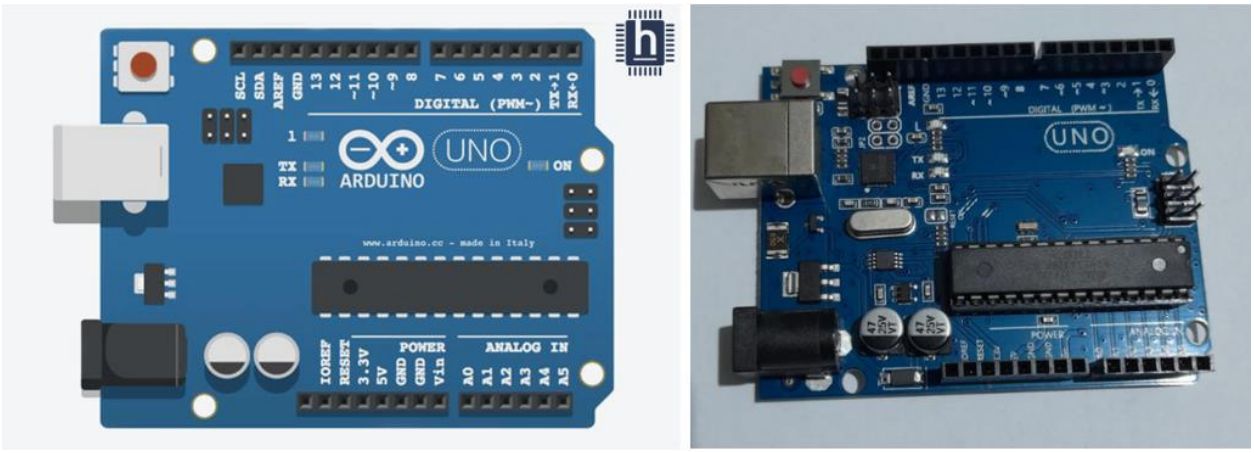



Figure 15: Product Image: Arduino UNO Board[22]

##### 4.3.1.2.2 Choosing Arduino Uno

There are multiple reasons why Arduino Uno was selected for our experiment:

- User-Friendliness: Arduino Uno is known for its user-friendly interface, making it a suitable option for beginners and educational purposes.
- Affordability: Arduino Uno is cost-effective in comparison to other electronic boards, making it a budget-friendly choice for a wide range of projects.
- Satisfactory Performance: The tasks performed in our experiment do not demand high-speed processors or advanced boards. Therefore, the capabilities of Arduino Uno are more than satisfactory for our requirements. [22]

#### 4.3.1.2.3 Components of the the Uno card:

an ATMega 328P processor

14 digital inputs/outputs of which 6 can be used as PWM

6 analog inputs/outputs which can also be used as digital inputs/outputs

a 16 MHz ceramic resonator

a female USB B connection

a 3.5/2.1 mm jack for power

a reset button

an ICSP connector

We will see in detail the different specifications of the card: [22]

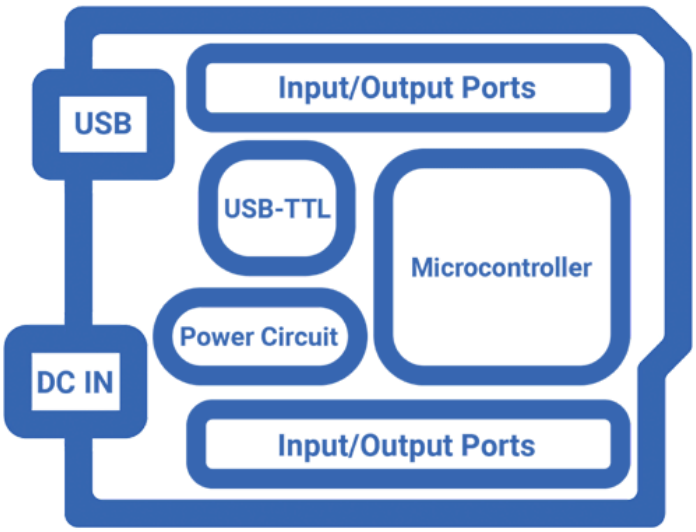



Figure 16: Card specifications. [22]

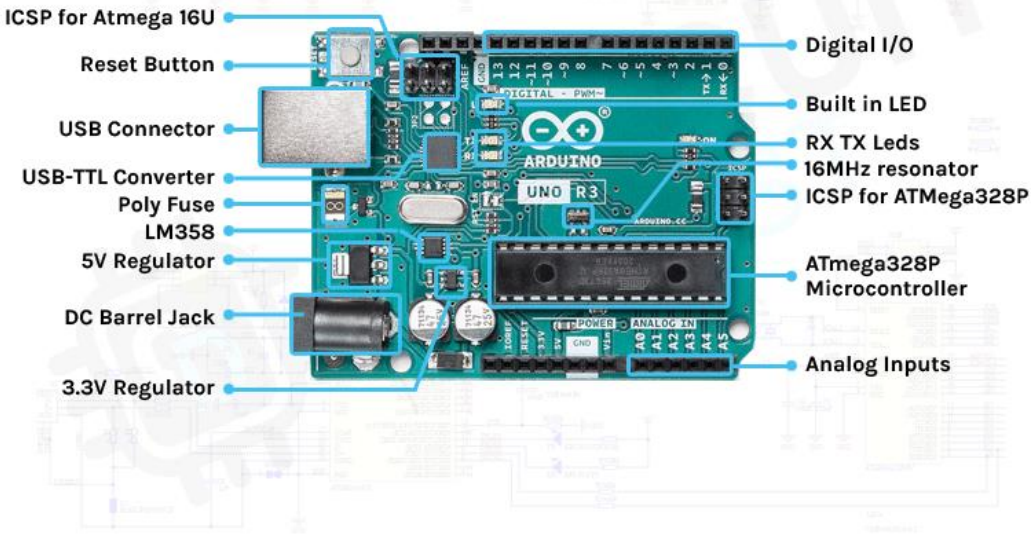



Figure 17: Constructing the Arduino UNO board [22]

#### 4.3.1.2.4 WORKING PRINCIPLE

The functioning of the Arduino microcontroller involves establishing proper connections and ensuring the correct input ports and power supply are connected. The output pins can then be connected to external devices based on their specific applications. The Arduino software is used to write and edit the program required for these applications. This software supports programming languages such as C and C++, making it a high-level language.

By utilizing the working conditions, a program can be created to carry out the desired tasks. Once the program is ready, it can be uploaded to the Arduino microcontroller using a power jack cable. The microcontroller, specifically the ATMEGA-328, acts as a processor and stores the program, allowing it to execute the tasks without any errors. By providing analog or digital inputs to the system, the process can be controlled according to the specific applications.

The program can be modified in the Arduino software to adjust the application's process, and then re-uploaded to the microcontroller via the power jack cable. Additionally, there is a reset button available to erase the previous program and prepare the Arduino for other application purposes.

The Arduino ATMEGA-328 microcontrollers can be utilized for numerous applications, making them widely used in automation industries to control processes and operate systems in an automated manner.

The Arduino Integrated Development Environment (IDE) is a software tool designed for writing and uploading code to Arduino-compatible microcontroller boards. This application offers a user-friendly platform for coding, compiling, and uploading programs to Arduino boards. Built on the foundation of the Processing programming language and Wiring libraries, the IDE provides a seamless experience for developers. [22]

#### *4.3.1.3 Arduino IDE*

Within the Arduino IDE, there is a text editor that allows users to input their code, complete with features like syntax highlighting, auto-indentation, and code completion to enhance the coding process. Furthermore, the IDE includes a compiler that converts the written code into machine-readable instructions for the microcontroller on the Arduino board.

A notable aspect of the Arduino IDE is its user-friendly nature and accessibility, which makes it particularly suitable for beginners looking to delve into microcontroller programming. Moreover, the IDE supports a wide array of Arduino-compatible boards, making it a versatile tool for a variety of projects and applications. [22]

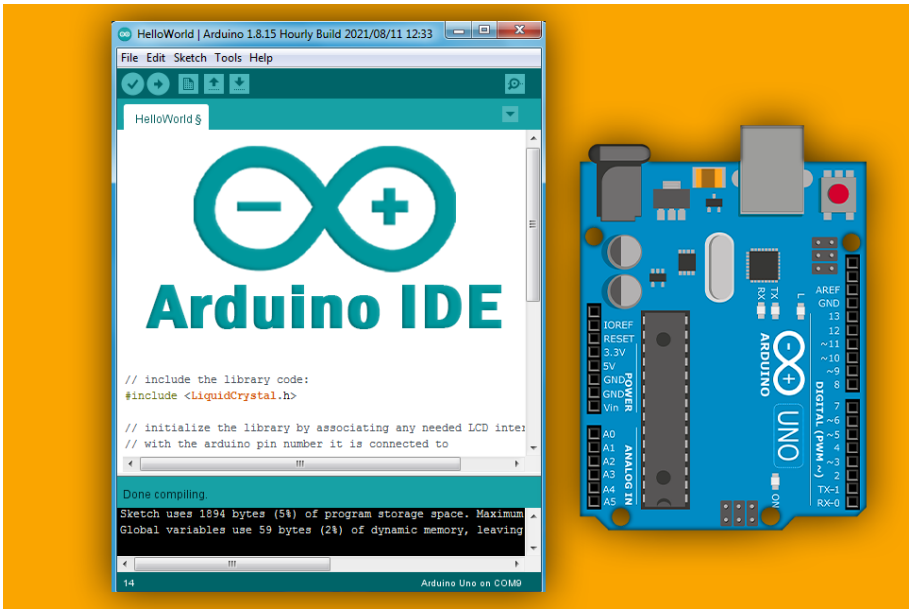



Figure 18: The main interface of the Arduino editor. [22]

#### *4.3.1.4 The L293D shield*

##### 4.3.1.4.1 Overview of the L293D Shield

The L293D shield is an electronic module that simplifies the control of direct current (DC) motors in various projects such as robotics, automation, and control systems. It is commonly used in conjunction with microcontrollers like Arduino due to its user-friendly nature and compatibility. [24]

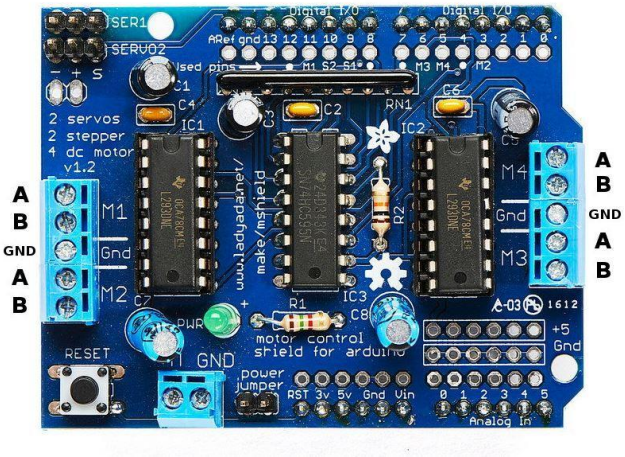



Figure 19: L293D Shield Board. [24]

#### 4.3.1.4.2 Key Features

Driver Circuit:

The L293D integrated circuit (IC) serves as the central component of the shield. It functions as a quad H-bridge driver, allowing voltage to be applied to a DC motor in either direction, enabling both forward and backward rotation. The L293D can control up to four DC motors simultaneously. [25]

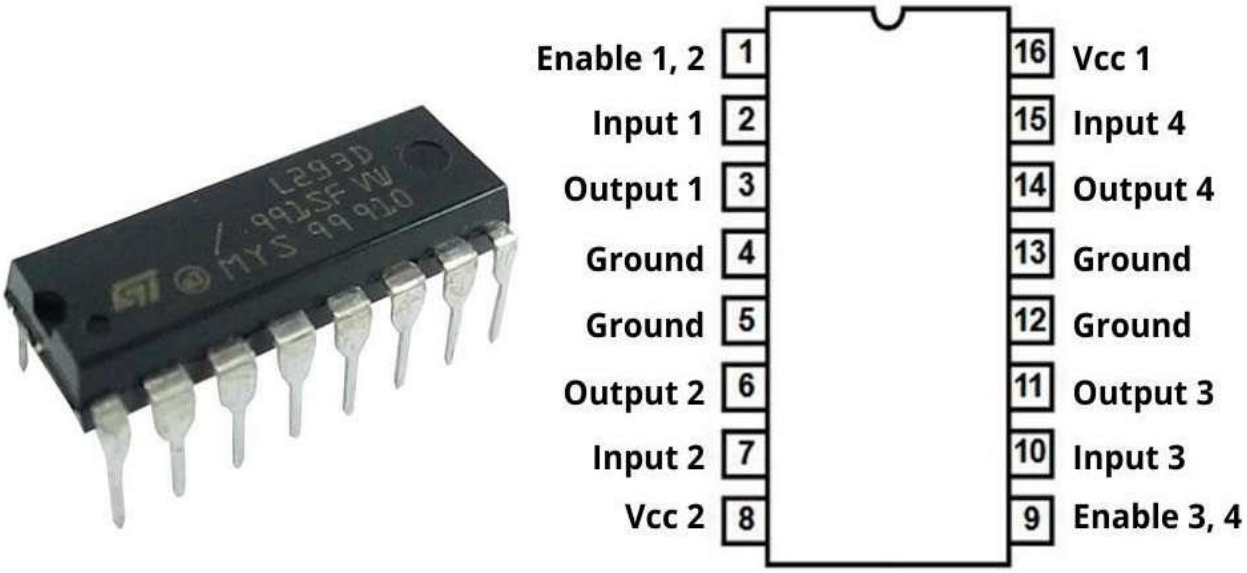



Figure 20: The L293D integrated circuit (IC). [25]

Motor Control:

By sending control signals, typically in the form of pulse width modulation (PWM), from your microcontroller to the L293D shield, you can control the speed and direction of the motors. PWM adjusts the duty cycle of the supplied voltage to regulate the motor's speed effectively. [25]

Current Capacity:

The L293D shield can typically handle a maximum current of 600mA per motor channel. However, it is essential to consider the specific design of the shield and the current requirements of your motors to ensure safe operation. Some shields may incorporate additional circuitry to provide higher current capabilities. [25]

Voltage Range:

The L293D shield typically operates within a motor supply voltage range of 4.5V to 12V. The logic supply voltage, which powers the microcontroller on the shield, is usually set at 5V. [25]

#### 4.3.1.4.3 Applications

Robotics:

The L293D shield plays a crucial role in controlling the movement of robots, enabling tasks such as steering, navigation, and manipulation. [25]

Line-Following Robots:

These robots utilize sensors to detect lines on a surface and utilize the L293D shield to control their motors, allowing them to follow the lines accurately. [25]

Remote-Controlled Vehicles:

L293D shields are well-suited for controlling the motors of remote-controlled cars, robots, or other similar devices. [25]

Automation Projects:

The shield can be utilized to automate tasks involving DC motors. [25]

### *4.3.1.5 Arduino accessories*

Throughout this study, we utilized key Arduino accessories such as a USB cable and Arduino jumper wires to enhance smooth connectivity and component incorporation.

#### 4.3.1.5.1 USB cable

USB cables enable the powering of Arduino projects and the programming of the card through the (Arduino IDE).

They facilitate high-speed data transmission with error-free and high-performance capabilities.

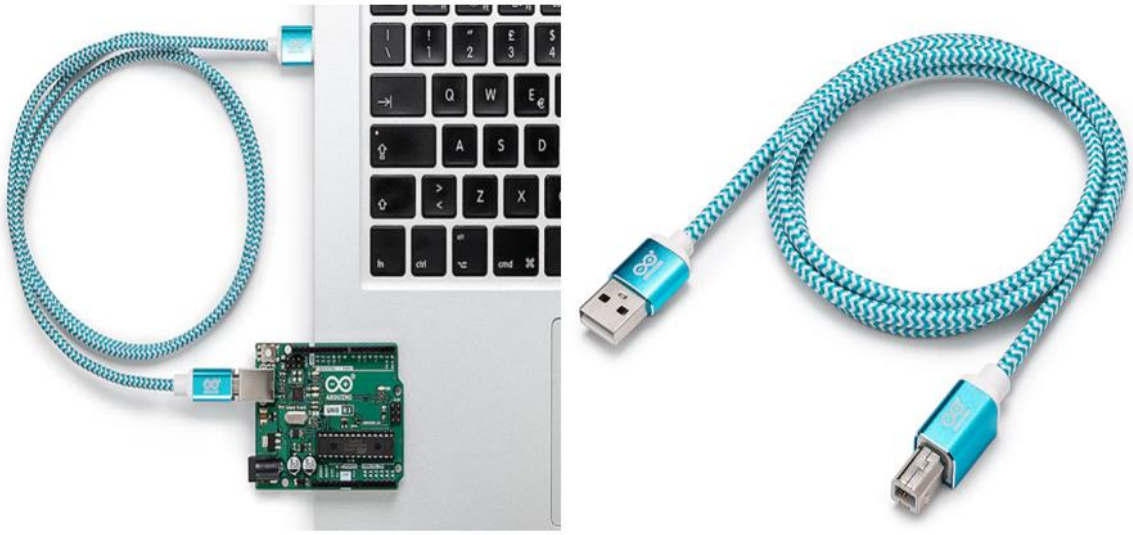


Figure 21: micro usb cable. [26]

#### 4.3.1.5.2 prototyping threads

## Prototyping Threads

The purpose of these cables and wires is to facilitate the prototyping process by establishing connections between the Arduino board and various components. This range of wires encompasses three distinct types: {(male/male), (male/female), and (female/female).



Figure 22: arduino pin wires of different types .

#### 4.3.1.5.3 the test plate

A breadboard, commonly known as a protoboard, plays a crucial role in the initial stages of electronic prototyping activities. Featuring interconnected holes, it allows for easy placement of electronic parts and connections, facilitating quick testing of circuit layouts before moving on to large-scale manufacturing. This adaptable tool helps to expedite the design process, giving engineers the flexibility to refine and improve their designs efficiently. Widely utilized in Arduino projects, its usefulness spans a wide range of electronic applications.

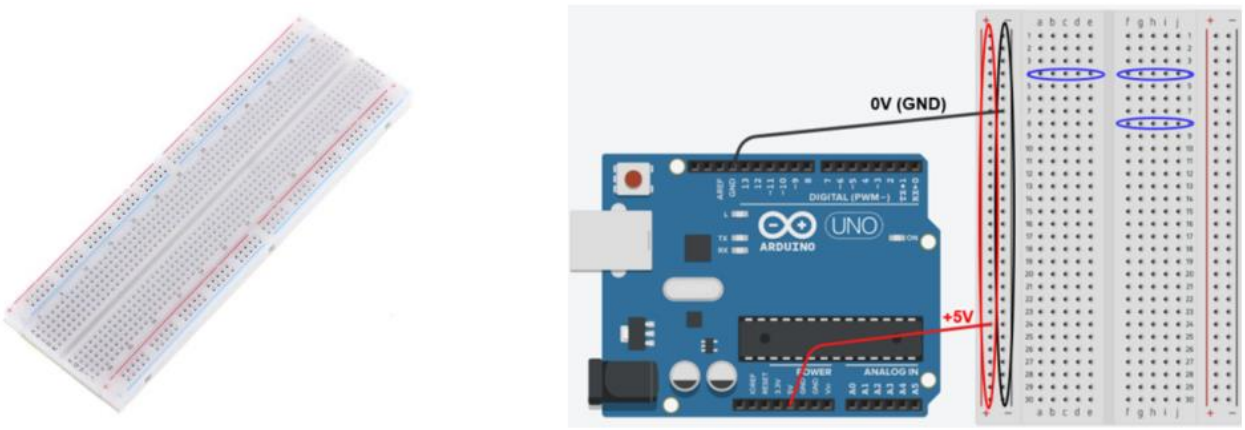



Figure 23: test plate . [27]

### 4.3.2 Light Dependent Resistor (LDR) Sensor

#### *4.3.2.1 Definition*

The LDR Sensor, a marvel in the field of optoelectronics, is a sensor used for detecting light in the environment. It operates by sensing changes in illumination and converting these changes into electrical signals. This feature makes the LDR an indispensable tool in automation systems, allowing for the detection of objects without physical contact. LDRs have low power requirements, making them perfect for energy-saving applications such as solar cells. Their high sensitivity enables precise control of illumination, even under strict conditions.

Furthermore, their compact size offers versatility across various projects, fitting even in tight spaces. An LDR sensor can automatically turn off electrical equipment based on daylight intensity, enhancing safety and energy efficiency. [28]

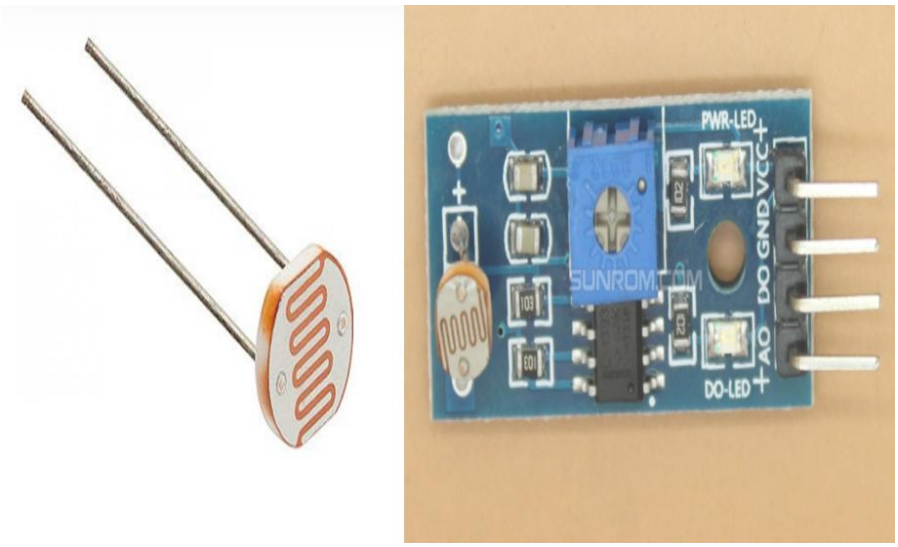



Figure 24: LDR Photoresistor [29]

#### 4.3.2.2 *Working Principle of LDR*

The operational principle of the LDR Sensor, also known as the Light Dependent Resistor, is based on the concept of photoconductivity. When the LDR sensor is in darkness, it demonstrates a high resistance, typically in the megaohm range. However, when exposed to light, the electrons within the sensor's material become energized and move from the valence band to the conduction band. As a result, the resistance of the LDR sensor decreases significantly, often reaching a few hundred ohms in bright light.

The remarkable feature of the LDR sensor is its ability to swiftly alter its resistance in response to changes in light intensity. This characteristic makes the LDR sensor highly reliable and valuable in a wide range of applications. The effectiveness of the LDR sensor lies not only in the change in resistance but also in the speed at which this change occurs, enabling the module to promptly respond to variations in light levels. [28]

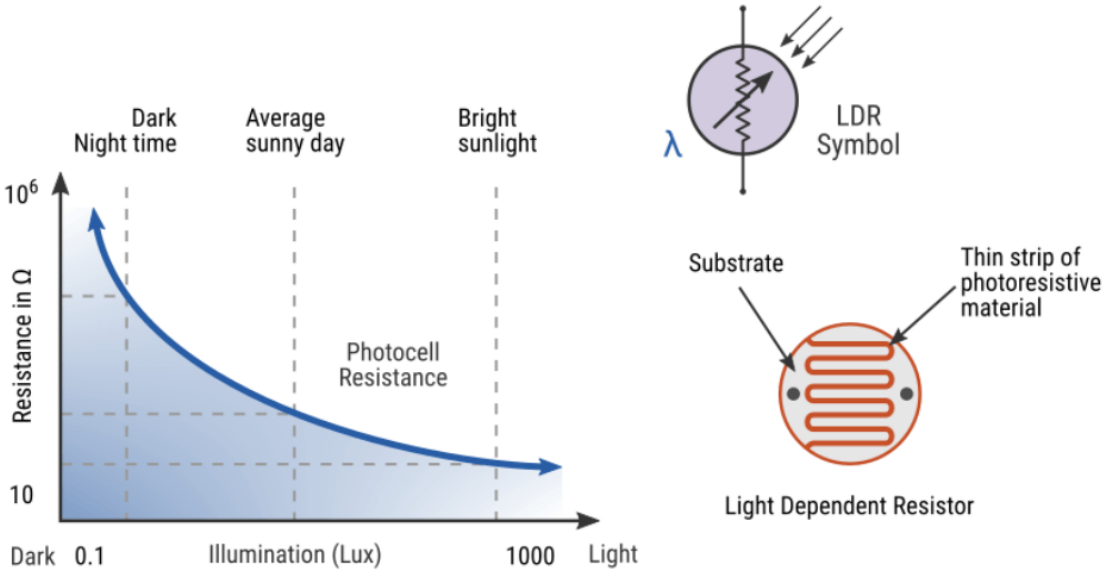



Figure 25: Operational Principle of a Light Dependent Resistor (LDR). [30]

### 4.3.3 Motors Used

#### 4.3.3.1 *Definition*

For our project, we have opted for " step-by-step" motors in order to attain accurate system orientation in all four directions, in accordance with the control unit's commands. This decision was based on the motors' accessibility and seamless integration with the design of our solar tracking device, providing convenient installation and customization to meet our specific requirements.

#### 4.3.3.2 *Stepper Motor*

A stepper motor is an electric motor whose main feature is that its shaft rotates by performing steps, that is, by moving by a fixed amount of degrees. This feature is obtained thanks to the internal structure of the motor, and allows to know the exact angular position of the shaft by simply counting how may steps have been performed, with no need for a sensor. This feature also makes it fit for a wide range of applications. [31]

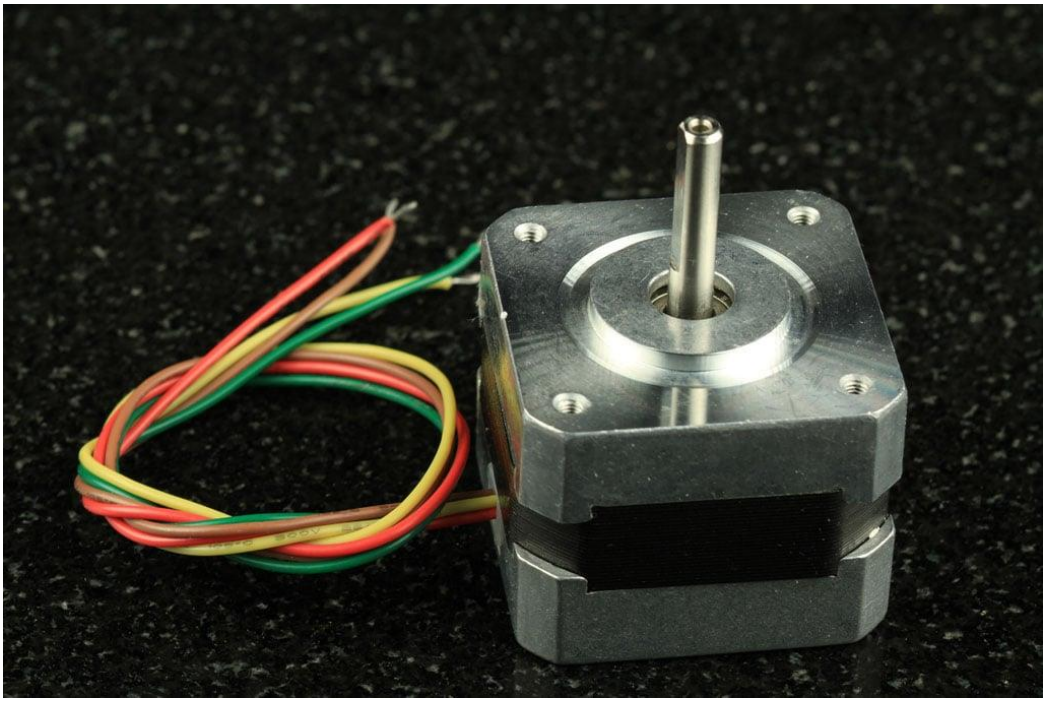


Figure 26: The stepper motor employed. [32]

#### *4.3.3.3 Stepper Motor Working Principles*

As all with electric motors, stepper motors have a stationary part (the stator) and a moving part (the rotor). On the stator, there are teeth on which coils are wired, while the rotor is either a permanent magnet or a variable reluctance iron core. Figure 1 shows a drawing representing the section of the motor is shown, where the rotor is a variable-reluctance iron core. [31]

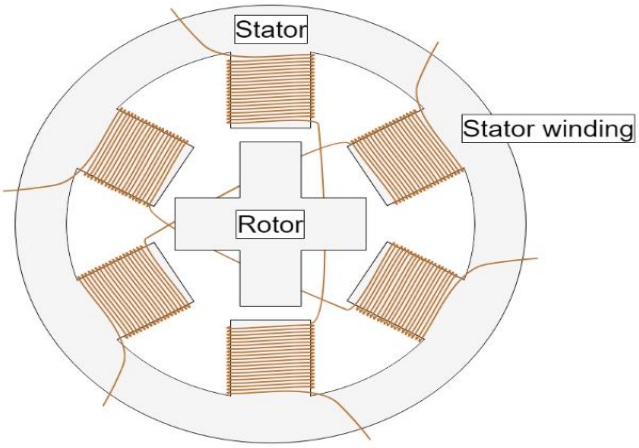



Figure 27: Cross-Section of a Stepper Motor. [31]

## 4.4 Mechanical part

In the preceding section, we acquainted ourselves with the units responsible for issuing commands and receiving data, deemed the most advanced aspect of the solar tracker's implementation. Nonetheless, the mechanical component also bears notable significance in materializing the solar tracker. It shoulders the responsibility of carrying the solar panels and maneuvering them in all four directions (north, south, east, and west).

### 4.4.1 Mechanical movement

The mechanical energy is typically generated through the conversion of electrical energy. In a solar tracking system, mechanical motion is achieved by employing motors that operate on direct current (DC), facilitating their direct operation through the photovoltaic energy generated by solar panels.

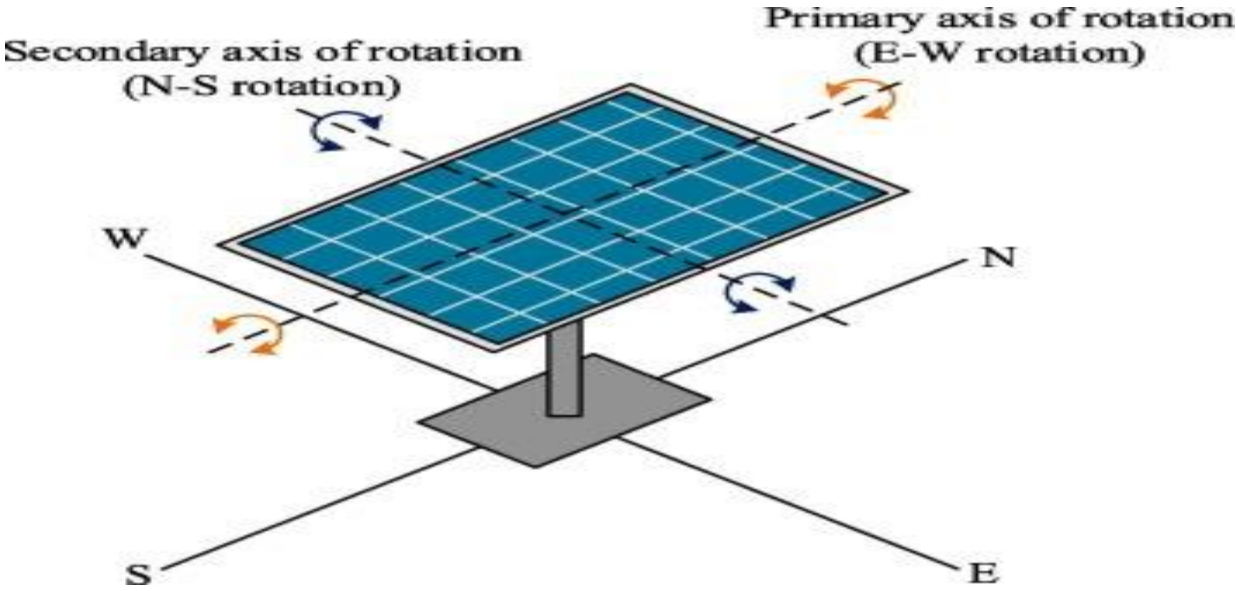



Figure 28: Mechanical movement of the solar panel [33]

### 4.4.2 Structure design

We used the program SOLIDWORKS in the base design

#### *4.4.2.1 SOLIDWORKS*

is a powerful 3D CAD design software used for product engineering and design. It allows you to create detailed 3D models, perform simulations, and manage product data. Whether you're designing mechanical parts, assemblies, or complex structures, SOLIDWORKS provides a comprehensive suite of tools to streamline your design process.If you're interested in downloading SOLIDWORKS, you can find the latest versions and add-ins on their official website.

In this section, we will discuss designing the frame that will hold the project components. The frame needs to be robust enough to support the added weight, and we will highlight the motion axes and the motors responsible for them.

Where the design process will go through two stages:

#### *4.4.2.2 Step 1: Parts Design*

During the preliminary stage of the mechanical design process, our foremost objective is to precisely conceive and fabricate the fundamental elements of the system. Throughout this phase, we shall devise the principal components of the system, with particular emphasis on the foundation that will uphold the entire structure, in addition to the other constituent parts. The measurements of the remaining parts will be detailed in Appendix A

a. **Frame:** Since we are working on a small-scale project, we have chosen to use wood for the frame due to its strength and lightweight properties. (Appendix A)

b. **Solar Panel :** The solar panel used is specially designed for electronic and robotic devices . (Appendix A)

c. **Stepper Motor** : The dimensions of the engine are further elaborated in a systematic manner within (Appendix A).

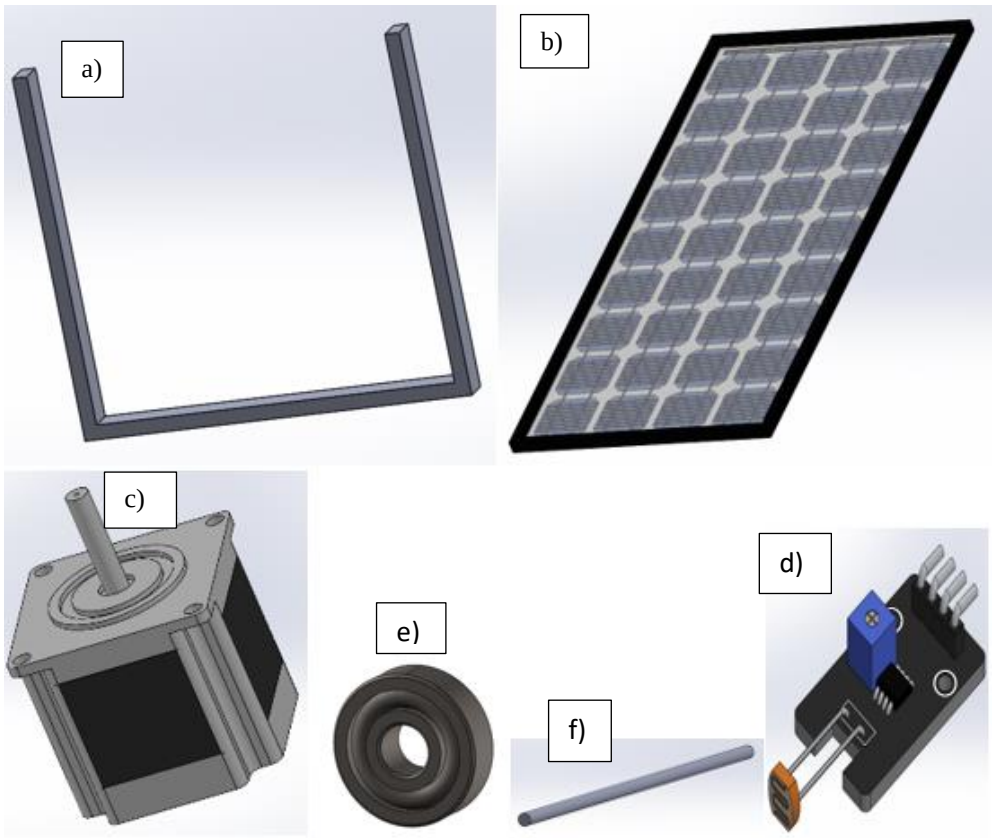



Figure 29: Designed Solar Tracker Components in SolidWorks

#### 4.4.2.3 *Step 2: Mechanical Integration*

In the second phase, we painstakingly combined the mechanical elements of the setup to establish the ultimate configuration, specifically crafted to smoothly accommodate and track the movements of the sun.

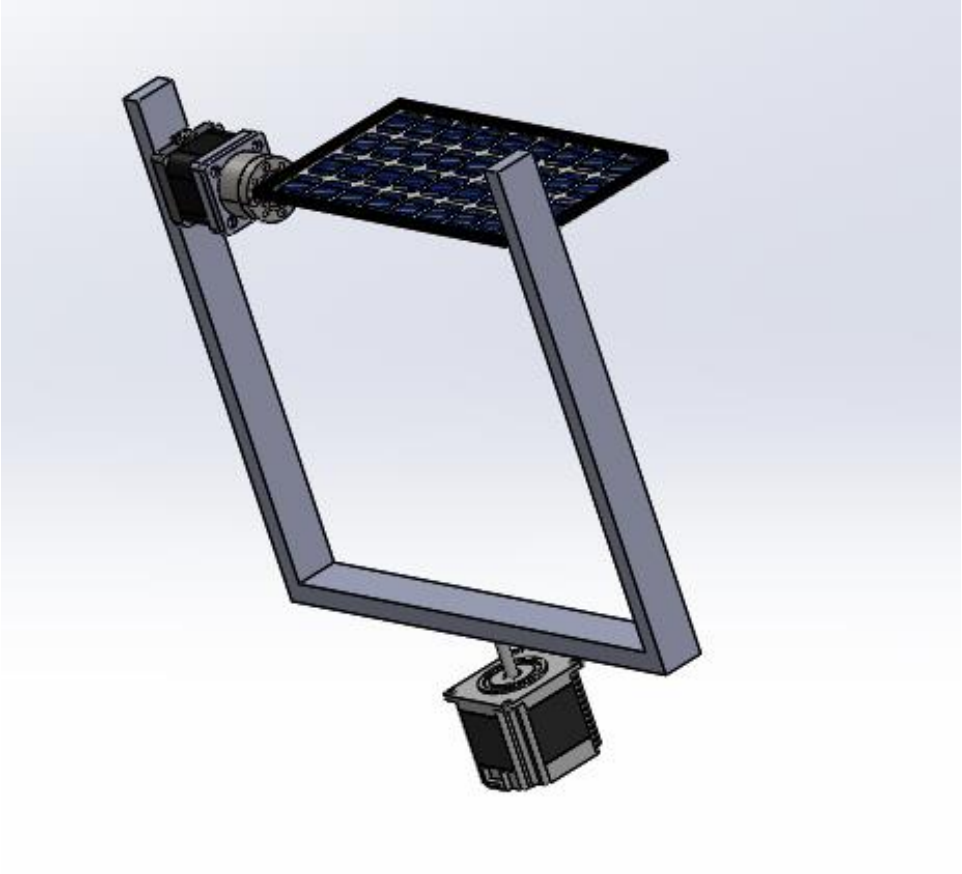


Figure 30: La structure mécanique totale du Tracker solaire in SolidWorks.

## 4.5 System Control Programming

Here's a professional and clear explanation of the provided code:

### 4.5.1 Overview

This Arduino sketch is designed to control a solar panel's orientation using stepper motors, based on the input from four Light Dependent Resistors (LDRs). The goal is to optimize the solar panel's position to receive maximum sunlight by adjusting its angle based on light intensity measurements.

**Libraries and Definitions**

```cpp
#include <AFMotor.h>
```

// Define LDR pin connections

#define LDR_TopLeft A0

#define LDR_TopRight A1

#define LDR_BottomLeft A2

#define LDR_BottomRight A3

```

**- AFMotor.h:** This library is included to control the Adafruit Motor Shield, which is used to drive the stepper motors.

**- LDR pin definitions:** The four LDRs are connected to analog pins A0 through A3.

**Stepper Motor Instances**

```cpp

// Create instances for the stepper motors

AF_Stepper stepperX(200, 1); // 200 steps per revolution for motor on port 1

AF_Stepper stepperY(200, 2); // 200 steps per revolution for motor on port 2

```

- Two stepper motor instances are created: `stepperX` for the X-axis (horizontal movement) and `stepperY` for the Y-axis (vertical movement). Each motor has 200 steps per revolution and is connected to ports 1 and 2 on the motor shield, respectively.

**Threshold Definition**

```cpp

// Define the threshold value for light difference

int threshold = 50;

```

**- threshold:** This variable sets the minimum difference in light intensity required to trigger motor movement, to avoid unnecessary adjustments.

**Setup Function**

```cpp

void setup() {

```
  Serial.begin(9600);
  // Set the speed of the motors (RPM)
  stepperX.setSpeed(10);
  stepperY.setSpeed(10);
}
```

**- Serial.begin(9600):** Initializes serial communication for debugging purposes.

**- stepperX.setSpeed(10) and stepperY.setSpeed(10):** Set the speed of both stepper motors to 10 RPM.

**Loop Function**

```cpp
void loop() {
  // Read the LDR values
  int topLeft = analogRead(LDR_TopLeft);
  int topRight = analogRead(LDR_TopRight);
  int bottomLeft = analogRead(LDR_BottomLeft);
  int bottomRight = analogRead(LDR_BottomRight);

  // Calculate the average light intensity on each axis
  int avgTop = (topLeft + topRight) / 2;
  int avgBottom = (bottomLeft + bottomRight) / 2;
  int avgLeft = (topLeft + bottomLeft) / 2;
  int avgRight = (topRight + bottomRight) / 2;

  // Calculate the difference in light intensity
  int diffVertical = avgTop - avgBottom;
  int diffHorizontal = avgLeft - avgRight;

  // Adjust the position of the solar panel based on the light difference
  if (abs(diffVertical) > threshold) {
```

```
  if (diffVertical > 0) {
    stepperY.step(1, FORWARD, SINGLE);  // Move motor Y forward
  } else {
    stepperY.step(1, BACKWARD, SINGLE); // Move motor Y backward
  }
 }

 if (abs(diffHorizontal) > threshold) {
  if (diffHorizontal > 0) {
    stepperX.step(1, FORWARD, SINGLE);  // Move motor X forward
  } else {
    stepperX.step(1, BACKWARD, SINGLE); // Move motor X backward
  }
 }

 // Delay to allow the motors to move
 delay(10);
}
```

**Reading LDR values:** The light intensity values are read from the four LDRs.

**Calculating average light intensity:** Averages are calculated for the top, bottom, left, and right LDR pairs to determine the general light intensity in each direction.

**Calculating light intensity differences:** The differences in average light intensity between the top and bottom, and left and right pairs are computed.

**Adjusting motor positions:**

- If the vertical light difference exceeds the threshold, the Y-axis motor adjusts the panel position. Positive differences move the motor forward, and negative differences move it backward.

- Similarly, if the horizontal light difference exceeds the threshold, the X-axis motor adjusts the panel position.

**Delay:** A short delay (10 ms) allows the motors to complete their movements before the next loop iteration.

This code continuously adjusts the solar panel to the optimal position for maximum sunlight exposure by comparing the light intensity from different directions and making necessary adjustments with the stepper motors.

## 4.6 Assembly of Solar Tracker Components

### 4.6.1 Electrical Assembly

#### *4.6.1.1 Step 1: Circuit Design and Assembly*

First, we will design and assemble the essential circuits for our project, which include:

- The control circuit.
- The power circuit.

Once these circuits are designed and built, we will interconnect them, as depicted in Figure 31.

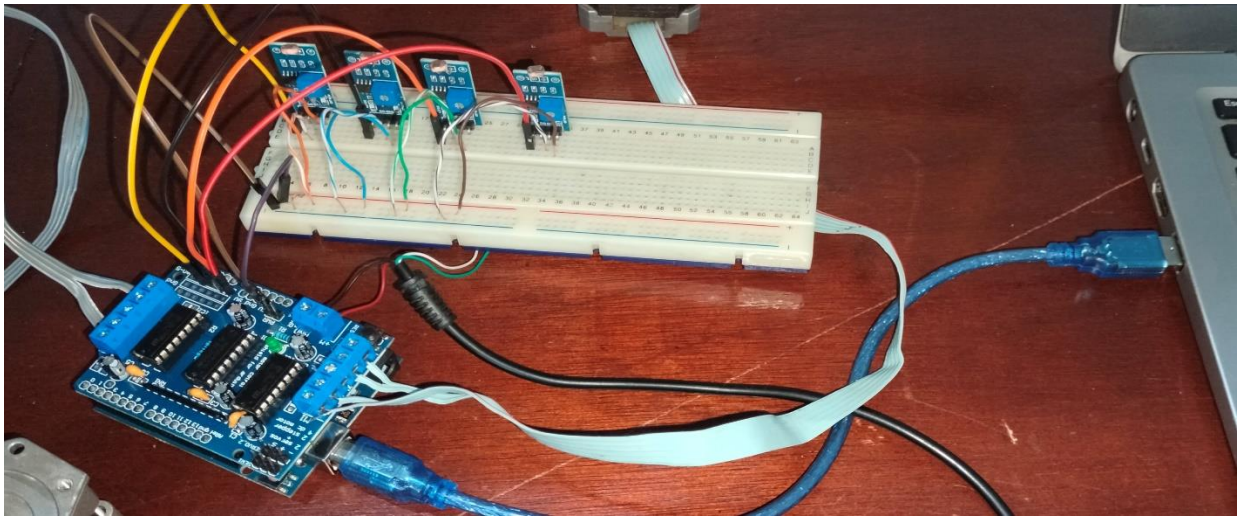


Figure 31: the connection of the different components

#### *4.6.1.2 Step 2: Integration and Testing of Motors and Sensors*

In the second step, we will integrate the two stepper motors. We will test their rotation directions based on signals sent from the Arduino board. Additionally, we will place the sensors in their designated positions, as illustrated in Figure 32.

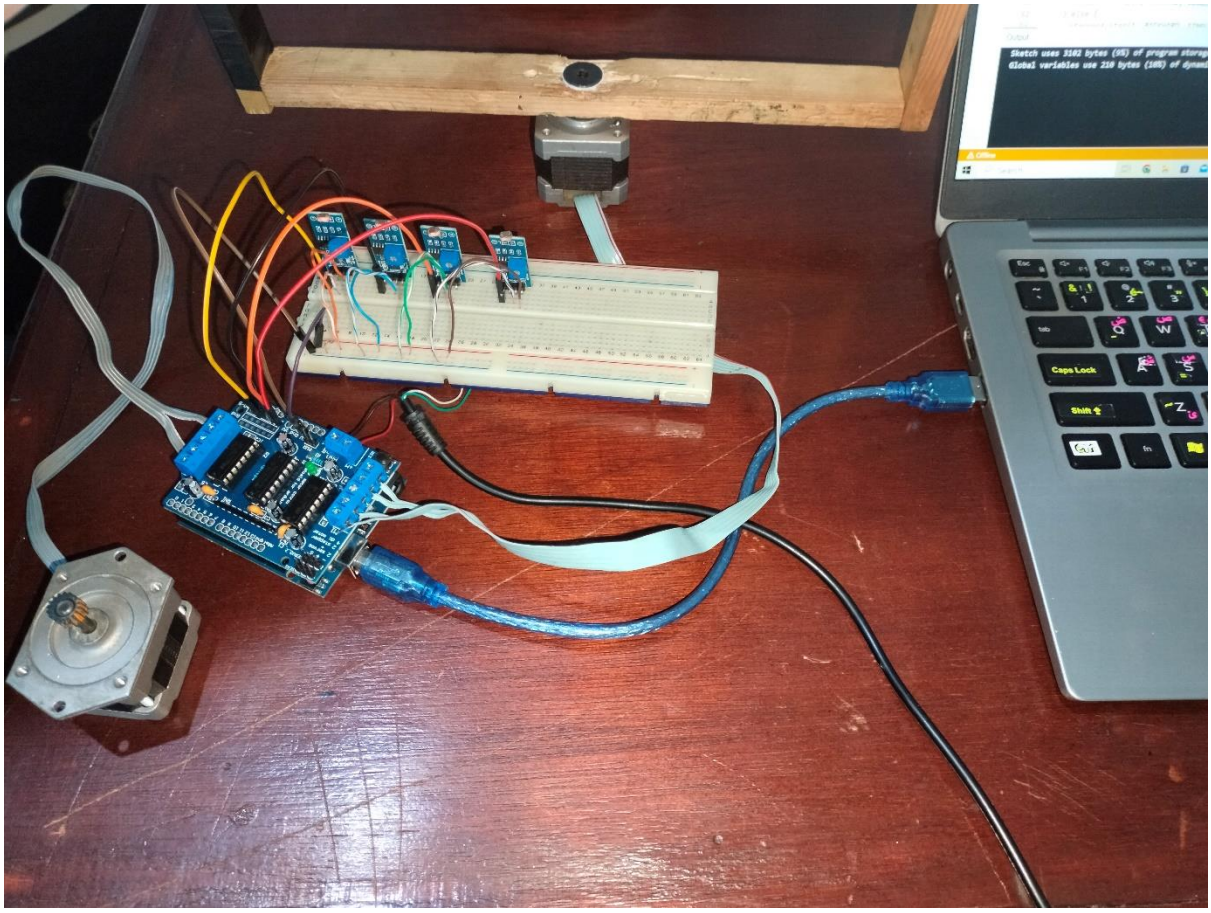


Figure 32: Overview of assembly with stepper motors and LDR sensors

Following these steps ensures that we verify the overall functionality of the system before moving on to more advanced testing and deployment.

### 4.6.2 Mechanical Assembly

The Solar Tracker's mechanical assembly is the culmination of our design process, meticulously carried out based on our SolidWorks simulations. The final configuration is displayed in Figure 1, showcasing its meticulous alignment to seamlessly track the sun's movement. Every component has been seamlessly integrated into the structure, utilizing resilient wooden plates for both durability and structural integrity. Critical elements, such as the LDR sensor for luminosity detection, precision stepper motor for accurate orientation adjustments, and compact photovoltaic solar panel for efficient energy harvesting, have been thoughtfully chosen and incorporated. This careful assembly not only ensures durability but also guarantees precise functionality in capturing solar energy, reflecting our unwavering commitment to excellence in design and engineering.



Figure 33:Photo of Realization of the Mechanical Structure of Solar Tracker.

### 4.6.3 Assembly of Solar Tracker Components final

The assembly of the solar tracker is a crucial phase that integrates electrical and mechanical realization into a highly efficient and precise sun-tracking mechanism. This advanced fusion of cutting-edge technology and exceptional engineering design ensures optimal solar energy utilization, significantly enhancing the system's performance and sustainability. Refer to Figure 1 for a detailed illustration.

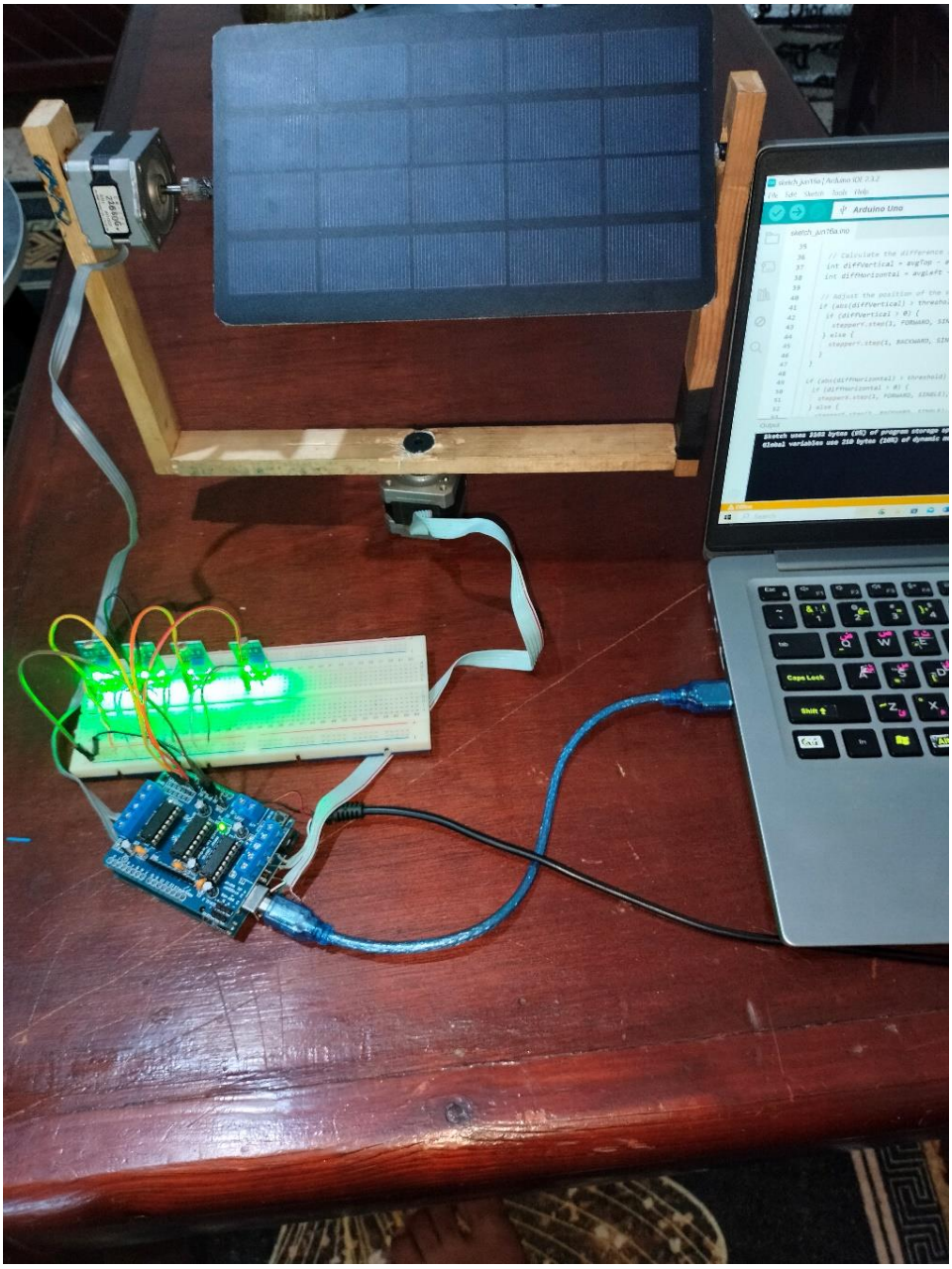


Figure 34: overview of the solar tracker produced .

## 4.7 Factors That Can Affect Solar Power And Their Remedies

There are several factors that can affect the production of solar power. According to type some of them can increase solar output efficiency and some can reduce it. The factor can be many out of which some major factors are cloudy day, sun intensity, time of year (season), relative humidity, high wind speed, and snow and dust accumulation. Some of these factors are controllable and some are not. Factor like sun intensity, season, rain, clouds are not controllable and also we cannot compensate for it.

### 4.7.1 Dust Accumulation

Controlling factors such as dust accumulation on solar panels is possible through the use of automatic solar cleaners. These devices either operate independently or can be manually cleaned using water, as depicted in Figure 35. [34]



Figure 35: Automatic solar cleaner. [34]

### 4.7.2 SNOW

Similarly, snow can also reduce the generation of solar power drastically because when snow falls it completely covers the solar panel. To solve this problem our model has a snow mode. When we activate snow mode then the controller send signal to the motor to tilt the solar panel . By this it protects the panel from further accumulating the snow on the panel, shown in figure below. [34]



Figure 36: Removing the snow from panel by tilting. [34]

### 4.7.3 Wind

The presence of strong winds can have detrimental effects on solar power systems, particularly on the setup and positioning of solar panels. In order to mitigate this issue, our system incorporates a stow mode feature. This functionality is triggered when wind speeds surpass a predetermined threshold, as specified in the control system of the panels. Upon activation, the stow mode repositions the panels horizontally, effectively safeguarding them against any potential harm caused by the wind. This mechanism is further elucidated in Figure 37. [34]

Integrating a stow mode to protect solar panels from high winds involves a combination of sensors and control mechanisms. Here are some detailed comments on how this option can work:

1. Wind Velocity and Direction Sensors:

- **Integration of Sensors**: Install anemometers and wind vanes to measure wind speed and direction. These sensors should be strategically placed to ensure accurate readings.

- **Real-time Data Collection**: The sensors continuously monitor wind conditions and send data to the solar panel control system.

2. Control System Response:

- **Signal Processing**: The control system processes the wind data and determines if the conditions require stow mode activation.

- **Automated Actuation**: Upon activation, the control system sends commands to the actuators of the solar panels to reposition them.

- **Horizontal Repositioning**: The panels are tilted to a horizontal position to reduce their exposure to wind forces. This minimizes the risk of damage from high winds.

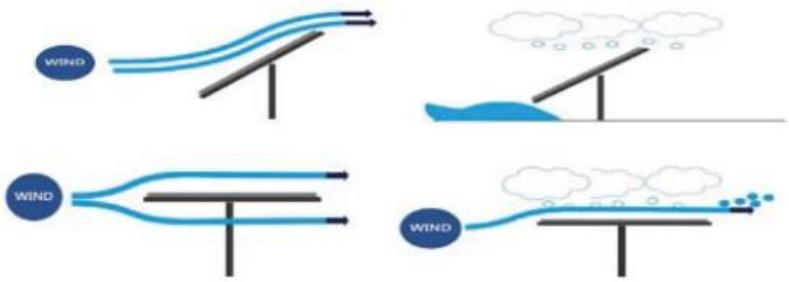



Figure 37: Stow mode of Solar panel. [34]

## 4.8 Conclusion

In this chapter, we have moved from theoretical analysis to practical implementation, with a specific focus on creating a complete solar tracking system. We have provided a detailed explanation of the engineering principles and components that are crucial for this system, such as the Arduino Uno microcontroller, LDR sensors, and stepper motors. Our discussion has also covered the electronic and mechanical assemblies, emphasizing the integration process and the testing phases that guarantee precise solar tracking. Furthermore, we have addressed various factors that can impact solar power efficiency and have suggested solutions, such as automatic cleaning and protective modes for different weather conditions. By adopting this comprehensive approach, we ensure that the system performs optimally and remains sustainable in the long run.

# 5 General Conclusion

In this study, we have effectively progressed from theoretical frameworks to the practical application of a dual-axis solar tracking system. The project involved a detailed analysis of key components, such as the Arduino Uno microcontroller, Light Dependent Resistors (LDRs), and stepper motors, and their integration into a coherent system aimed at maximizing solar energy capture. The implementation phase included meticulous procedures for assembling both electronic and mechanical parts, ensuring accurate solar tracking through precise calibration and testing processes.

Our implementation outcomes illustrate that dual-axis solar trackers significantly boost the efficiency of solar panels by maintaining optimal orientation in relation to the sun's position. This heightened efficiency leads to increased energy output. The engineering principles utilized, particularly the real-time adjustment capabilities facilitated by active tracking mechanisms, have proven to be successful in maximizing solar energy absorption and enhancing overall system performance.

One notable challenge encountered during this project was the scarcity of used engines in the market. This issue complicated the acquisition of essential components, leading to delays .

Future research in this field can explore various avenues to advance the current understanding:

- Component Optimization: Investigating the use of advanced sensors and microcontrollers can significantly improve the precision and responsiveness of the tracking system, thereby enhancing its overall performance.

- Weather Adaptation: Further development in this area can concentrate on improving the system's performance under different weather conditions. By integrating robust protective measures against adverse weather, the tracking system can maintain its efficiency and reliability.

- Energy Storage Integration: Combining the tracking system with advanced energy storage solutions can greatly enhance the utility and efficiency of solar energy systems. This integration would ensure a consistent energy supply, even during non-peak sunlight hours, thereby maximizing the system's overall effectiveness.

Ultimately, through the examination and resolution of these specific aspects, subsequent scholars will be able to expand upon the groundwork established by this endeavor, thereby enhancing the wider acceptance and efficacy of solar tracking technologies.

## Bibliography

[1] A. B. Stambouli, Z. Khiat, S. Flazi, and Y. Kitamura, "A review on the renewable energy development in Algeria: Current perspective, energy scenario and sustainability issues," Renewable and Sustainable Energy Reviews, vol. 16, no. 7, pp. 4445–4460, Sep. 2012, doi: https://doi.org/10.1016/j.rser.2012.04.031.

[2] "The Earth's movements," Blinklearning. https://www.blinklearning.com/coursePlayer/clases2.php?idclase=40033109&idcurso=734099

[3] K. Abderrahim, "Etude et Réalisation d'un Tracker solaire autopiloté Commande via une carte Arduino ‹Mémoire master academique," 2018.

[4] "Solar radiation: what is its impact on the planet and on humans?," Iberdrola. https://www.iberdrola.com/social-commitment/solar-radiation

[5] "Solar Radiation | Measurement, Types, Impact, Importance, & Drawbacks," www.carboncollective.co. https://www.carboncollective.co/sustainable-investing/solar-radiation

[6] M. Bechou, "Réalisation d'un tracker solaire commandé par une carte ARDUINO," di.univ-blida.dz, 2017, Accessed: Jun. 07, 2024. [Online]. Available: https://di.univ-blida.dz/xmlui/handle/123456789/7461

[7]"Solar Cell: Working Principle & Construction (Diagrams Included) | Electrical4U," https://www.electrical4u.com/, Apr. 18, 2024. https://www-electrical4u-com.translate.goog/solar-cell/?_x_tr_sl=ar&_x_tr_tl=en&_x_tr_hl=fr&_x_tr_pto=wapp#google_vign

[8] Solarsquare.in, 2024. https://www.solarsquare.in/blog/wp-content/uploads/2022/06/Blog-images-inside-1000800px-4-1000x730.jpg

[9] "Types of photovoltaic cells - Energy Education," energyeducation.ca. https://energyeducation.ca/encyclopedia/Types_of_photovoltaic_cells#:~:text=There%20are%20three%20types%20of In-text citation (accessed May 24, 2024).

[10] Ases.org, 2024. https://ases.org/wp-content/uploads/2021/02/Mono-Si.png (accessed May 24, 2024).

[11] "j jiang Small Flexible Thin Film Solar Panel Power Cells 0.75w/4.5v/190ma (Black) : Buy Online at Best Price in KSA - Souq is now Amazon.sa: Industrial & Scientific," www.amazon.sa.https://www.amazon.sa/-/en/jiang-Small-Flexible-Solar-Panel/dp/B07RBSL4JS (accessed May 24, 2024).

[12]E. Ali, B. Eng, S. Lana, Eng, A. Malak, and J. Raed, "DUAL AXIS SOLAR TRACKER," 2022. Available: https://repository.najah.edu/server/api/core/bitstreams/b7c7b768-fa2f-4719-b4e7-695e3c65831f/content

[13] D. Biermeier, "How To Install Solar Panels," Forbes Home, Nov. 15, 2022. https://www.forbes.com/home-improvement/solar/how-to-install-solar-panels/

[14]Imimg.com,2024. https://5.imimg.com/data5/SELLER/Default/2021/1/PH/MO/KI/11413170/solarpanels-opt-1--500x500.jpg

[15] "Solar trackers: What they are, types, and advantages," REPSOL. https://www.repsol.com/en/energy-and-the-future/future-of-the-world/solar-trackers/index.cshtml

[16]"Single Axis Solar Tracker," indiamart.com. https://www.indiamart.com/proddetail/single-axis-solar-tracker-22460624333.html (accessed Jun. 08, 2024).

[17]"Dual-Axis Tracking - an overview | ScienceDirect Topics," www.sciencedirect.com. https://www.sciencedirect.com/topics/engineering/dual-axis-tracking.

[18]"Dual Axis Solar Panel Explained - saVRee," savree.com. https://savree.com/en/encyclopedia/dual-axis-solar-panel.

[19]"Single Axis Trackers," sinovoltaics.com. https://sinovoltaics.com/learning-center/csp/single-axis-trackers/.

[20] "Dual Axis Trackers," sinovoltaics.com. https://sinovoltaics.com/learning-center/csp/dual-axis-trackers/.

[21]A. Surti, H. Mansoori, S. Salunke, and S. Jain, "Dual Axis Solar Tracker." Accessed: Jun. 08, 2024. [Online]. Available: https://www.ijert.org/research/dual-axis-solar-tracker-IJERTCONV5IS01088.pdf.

[22] E. Technology, "Download arduino IDE versi terbaru full Open Source | Hai Inovator,IDE itu merupakan kependekan dari Integrated Developtment Enviroenment, atau secara bahasa mudahnya merupakan lingkungan terintegrasi yan," *www.elmechtechnology.com*. https://www.elmechtechnology.com/blog/download-arduino-versi-terbaru-full (accessed May 16, 2024).

[23]N. Abbas, "Conception et réalisation d'un suiveur solaire à base d'une carte Arduino nano," dspace.ummto.dz, Sep. 26, 2018. https://dspace.ummto.dz/items/78d3c84c-3c4e-44b6-9eb3-d0ad0f334988 (accessed Jun. 08, 2024).

[24]"Using L293D Motor Driver Shield without any library," *Arduino Forum*, Dec. 04, 2020. https://forum.arduino.cc/t/using-l293d-motor-driver-shield-without-any-library/685601.

[25]M. Lab, "Arduino L293D Motor Driver Shield Control DC, Servo, and Stepper Motors," *Microcontrollers Lab*, Jan. 15, 2022. https://microcontrollerslab.com/arduino-l293d-motor-driver-shield-tutorial/.

[26]Arduino.cc, 2024. https://store.arduino.cc/cdn/shop/products/TPX00132_00.default_863x647.jpg?v=1684913106 (accessed May 27, 2024).

[27]"Plaque d'essai 830 points Maroc | Breadboard 830 | meilleur prix," ARDUINO MAROC. https://marocproduits.com/produit/plaque-dessai-830points-maroc/ (accessed Jun. 02, 2024).

[28] “What is LDR Sensor,” www.linkedin.com. https://www.linkedin.com/pulse/what-ldr-sensor-vayuyaan-knwbf#:~:text=The%20LDR%20sensor%20full%20form

[29] Techdelivers.com, 2024. https://techdelivers.com/image/cache/catalog/Sensor%20Modules/Optical/ldr-light-dependent-resistor-550x550w.jpg (accessed May 18, 2024).

[30] Circuitgeeks.com, 2024. https://www.circuitgeeks.com/wp-content/uploads/2022/01/LDR-Resistance-vs-Illumination.png (accessed May 18, 2024).

[31] C. Fiore, “Stepper Motors: Types, Uses and Working Principle | Article | MPS,” www.monolithicpower.com. https://www.monolithicpower.com/stepper-motors-basics-types-uses

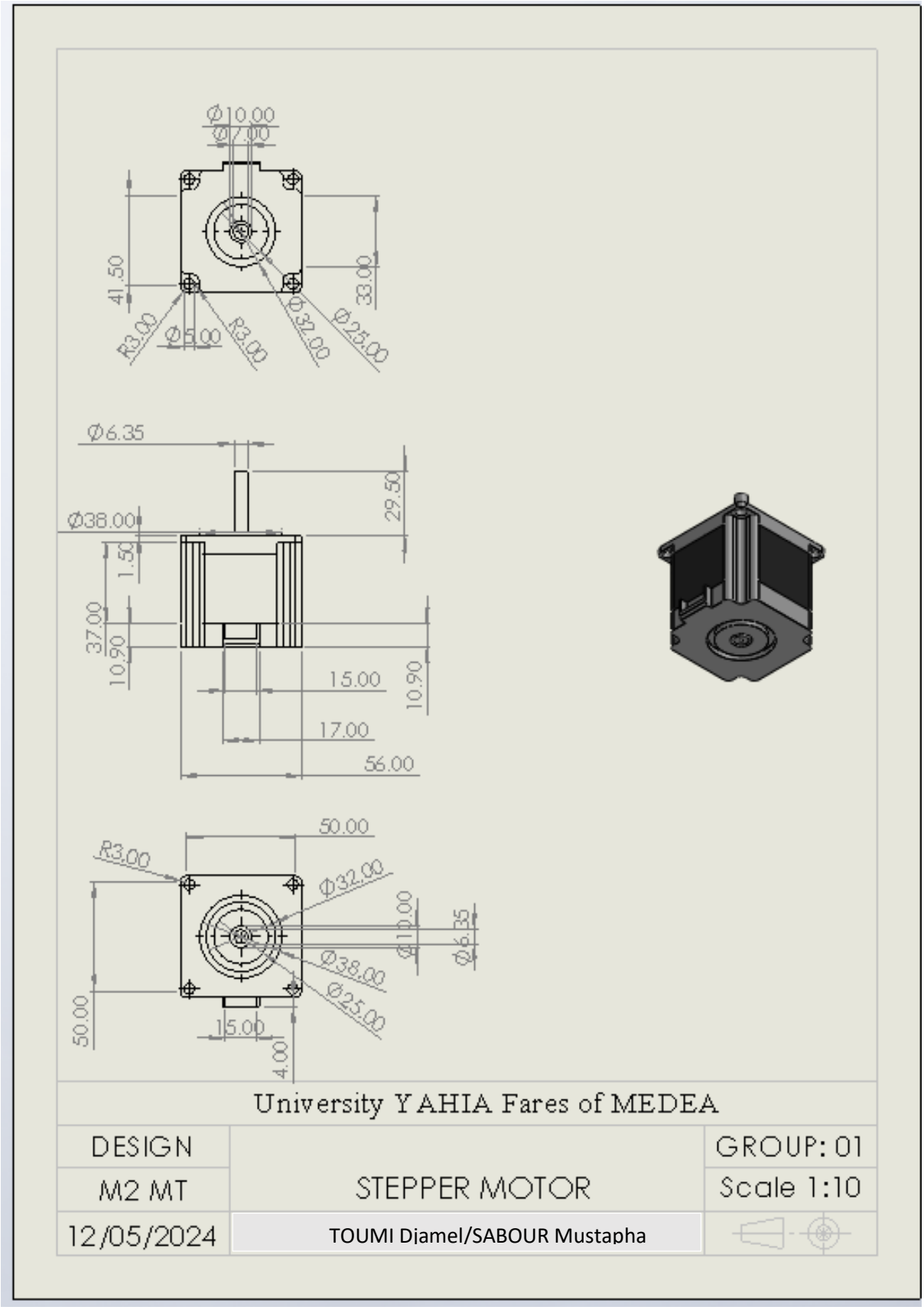
[32]Adafruit.com, 2024. https://cdn-learn.adafruit.com/assets/assets/000/016/270/medium800/components_IMG_4799.jpg?1398813268 (accessed Jun. 09, 2024).

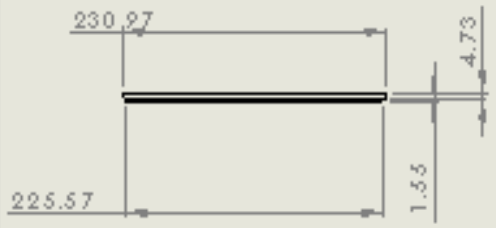
[33] Els-cdn.com, 2024. https://ars.els-cdn.com/content/image/1-s2.0-S2213138819307040-gr4.jpg (accessed May 21, 2024).

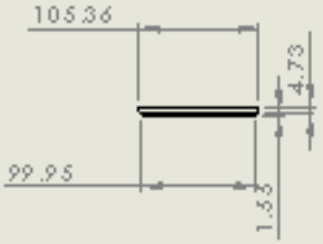
[34] S. Sahu, S. Tiwari, and R. N. Patel, “Analysis and Testing of Dual Axis Solar Tracker for a Standalone PV System,” Jan. 2020, doi: https://doi.org/10.1109/icpc2t48082.2020.9071451.

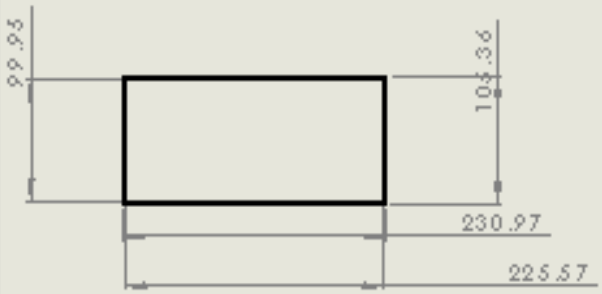
# Appendix

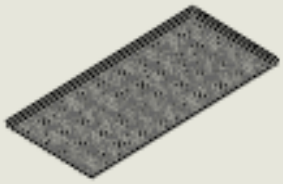
# Appendix A:


Ø10.00
Ø7.00
41.50
33.00
R3.00
Ø5.00
R3.00
Ø32.00
Ø25.00
Ø6.35
29.50
Ø38.00
1.50
37.00
10.90
15.00
10.90
17.00
56.00
50.00
R3.00
Ø32.00
Ø10.00
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Ø25.00
50.00
15.00
4.00
University YAHIA Fares of MEDEA
DESIGN
GROUP: 01
M2 MT
STEPPER MOTOR
Scale 1:10
12/05/2024
TOUMI Djamel/SABOUR Mustapha

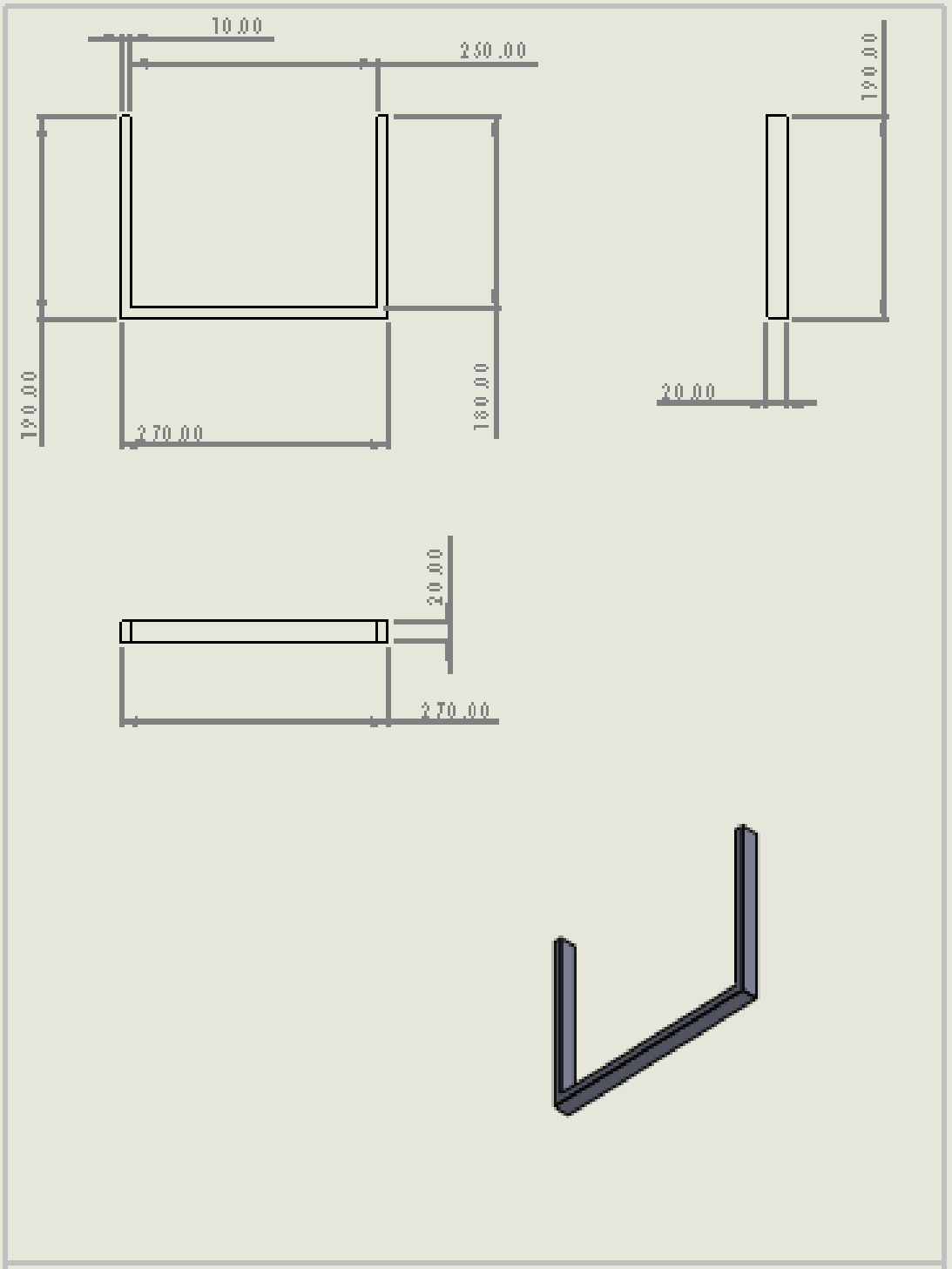


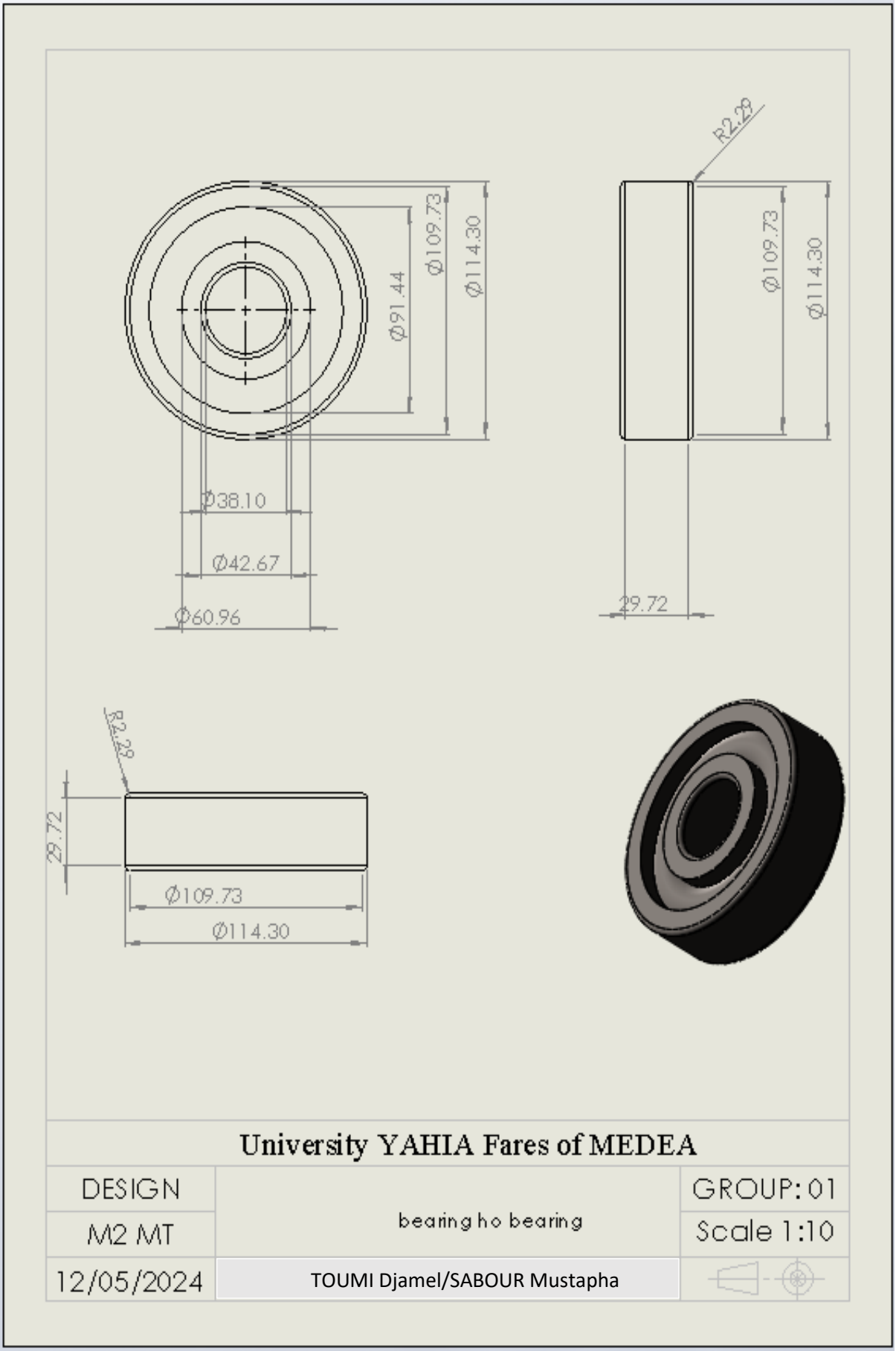



| | | |
|---|---|---|
| University YAHIA Fares of MEDEA | | |
| DESIGN | solar | GROUP: 01 |
| M2 MT | | Scale 1:10 |
| 12/05/2024 | TOUMI Djamel/SABOUR Mustapha | |




| | | |
|---|---|---|
| University YAHIA Fares of MEDEA | | |
| DESIGN | Frame | GROUP: 01 |
| M2 MT | | Scale 1:10 |
| 12/05/2024 | TOUMI Djamel/SABOUR Mustapha | |




| University YAHIA Fares of MEDEA | | |
|---|---|---|
| DESIGN | bearing ho bearing | GROUP: 01 |
| M2 MT | | Scale 1:10 |
| 12/05/2024 | TOUMI Djamel/SABOUR Mustapha | |

# Appendix B:

## Arduino code :

```
#include <AFMotor.h>

// Define LDR pin connections
#define LDR_TopLeft A0
#define LDR_TopRight A1
#define LDR_BottomLeft A2
#define LDR_BottomRight A3

// Create instances for the stepper motors
AF_Stepper stepperX(200, 1); // 200 steps per revolution for motor on port 1
AF_Stepper stepperY(200, 2); // 200 steps per revolution for motor on port 2

// Define the threshold value for light difference
int threshold = 50;

void setup() {
  Serial.begin(9600);
  // Set the speed of the motors (RPM)
  stepperX.setSpeed(10);
  stepperY.setSpeed(10);
}

void loop() {
```

```
// Read the LDR values
int topLeft = analogRead(LDR_TopLeft);
int topRight = analogRead(LDR_TopRight);
int bottomLeft = analogRead(LDR_BottomLeft);
int bottomRight = analogRead(LDR_BottomRight);

// Calculate the average light intensity on each axis
int avgTop = (topLeft + topRight) / 2;
int avgBottom = (bottomLeft + bottomRight) / 2;
int avgLeft = (topLeft + bottomLeft) / 2;
int avgRight = (topRight + bottomRight) / 2;

// Calculate the difference in light intensity
int diffVertical = avgTop - avgBottom;
int diffHorizontal = avgLeft - avgRight;

// Adjust the position of the solar panel based on the light difference
if (abs(diffVertical) > threshold) {
  if (diffVertical > 0) {
    stepperY.step(1, FORWARD, SINGLE);  // Move motor Y forward
  } else {
    stepperY.step(1, BACKWARD, SINGLE); // Move motor Y backward
  }
}

if (abs(diffHorizontal) > threshold) {
  if (diffHorizontal > 0) {
```

```
      stepperX.step(1, FORWARD, SINGLE);  // Move motor X forward
    } else {
      stepperX.step(1, BACKWARD, SINGLE); // Move motor X backward
    }
  }

  // Delay to allow the motors to move
  delay(10);
}
```