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AN ANYWHERE WORKING HELIOSTAT

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Thank you.

Authors

ZIDI Abdelkadeer / LAAKAB Tahar

Dedication

Tahar

I dedicate this work:

To my dear mother and father,

To My dear brothers and sister especially Abderahman, and Ayoub for their patience, their love, their support and their encouragement to them all Lakab and Zidi family.

Dedication

Abdelkader

I dedicate this work:

To my dear mother and father,

To My dear brother Redouane and sister Randa, Alaa and Elaf

And to the family of my mother and father, my aunts and uncles, and to my uncles and aunts, and to all the great Zidi family

For their patience, their love, their support and their encouragement, to them all and to Lakab family.

To Our Friends Mohammed daher , Moad Abdelbasste, Guendouz mohammed laid, lachheb senna, yacine bitour , mourad serbah, najib and My uncle djamel polic and Abdellah 23

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Abbreviations

CSP: Concentrated Solar Power.

PV: Photo-Voltaic

PTD: Parabolic Trough

LFCP: Linear Fresnel

ST: Solar Tower

UNFPA: United Nations Population Fund.

Introduction

Renewable energy is the energy of today and tomorrow and the future. It is more and more widespread in the world due to its advantages compared to fossil resources. According to the International Energy Agency, these energies accounted for only 10% of the energy consumed globally in 2017.

Algeria is one of the countries that have a large climate averages in favor of renewable energies, including solar energy, and the use of this can cover the country's electricity needs or even export it to other countries outside the homeland. Despite all the drawbacks and above all the environmental risk posed by fossil fuels, as well as the advantages of solar energy, the latter represents only 0.7% of world energy production; this comes down mainly to the relatively very high production cost.

This problem pushes several researchers towards studies whose goal is to minimize the costs of carrying out such projects, for example, we find in literature works whose goal is to improve the performance of photovoltaic cells, others have worked on improving the absorbers of solar receivers, and there is also works carried out in order to optimize the heliostat fields.

In heliostat fields as well as solar tower heliostats fields, the cost of building heliostats can exceed 40% of the overall cost of a renewable energy project. The reduction in the cost price of these elements (heliostats) has become a necessity to promote the use of solar energy, hence the idea of this work to contribute into cost reduction of the solar fields, a contribution based on the proposal for a design of a simple and efficient heliostat, the production costs of which must be considerably minimized using a new technique based on the placement of the two axes relatively to each other.

For this, we have structured this thesis in three chapters, the first two represent bibliographically research on solar energy, the first is devoted to the presentation of concentrated solar technologies, we also present in this chapter state of the art of heliostats and the different types of heliostats, its movements, the parameters influence their performance ... and any type of exploitation of this energy as well as projects already carried out. The second chapter explain to us the presentation of the Sun and the importance of the energy received by this star on Earth, such as solar radiation at ground level and Solar field.

The third chapter is devoted to the study and we have done the best design of the heliostat so that it has been confirmed that there is no similar design at all. and using a computer-aided, Therefore, we have created several pieces, each piece differs from another according to its performance and its location in the body, and we did this using the Solidworks program., followed for resistance verification, From the next step, we assembled the parts to get a complete device, and by this, we explained how the heliostat work and its transmission movement in a cinematic diagram, and from it, we knew that the new heliostat has good performance and a larger reflective surface. Thanks to the study of the transitional movement of heliostat and the development of schematic drawings, and at the last stage we had to create an applied study, and through the simulation of the design done at the level of the pylon, we reached the important points of the simulation, whose goal was the strength that the pylon bears and the maximum value that it bears, and we concluded that it is the strength that We applied it, but it did not affect pylon, and thus the simulation results were generally acceptable. Thus, we only had to finish our work with a general conclusion.

Chapter I

SOLAR POWER TECHNOLOGIES & STATE OF THE ART OF HELIOSTAT

I.1 Introduction

Energy is the basis for the current development of the entire world in all areas, which, unfortunately, consists primarily of coal, oil and nuclear energy, they are non-renewable energies, one of their main disadvantages, with serious environmental implications, and hence the emergence of renewable energies as an alternative to non-renewable energy.

Global energy and electricity consumption is increasing rapidly due to population growth, industrialization and urbanization. The world faces enormous challenges in providing a clean and sustainable energy supply to the population at present, with 80% of the global primary energy supply coming from fossil fuels (for example, coal, liquid oil, and natural gas), which now exist.

It is a source of depleted energy and is classified as non-host energy and responsible for major greenhouse gas emissions such as CO_2. (Fig I-1) shows global CO_2 emissions from the misuse of raw materials for conventional energy.

Fossil fuel energy sources are also a major cause of climate change, and developing countries must seek alternative energy sources for their respective energy sectors to avoid carbon emissions in the near future.

In order to eliminate this catastrophic scenario, global renewable energy is the best solution to this resilience, as it could contribute to the elimination of 30% by 2050 compared to 2012.

Technologies have become the top priority for energy satisfaction society's demand and contribution to a greater effort to reduce CO_2.

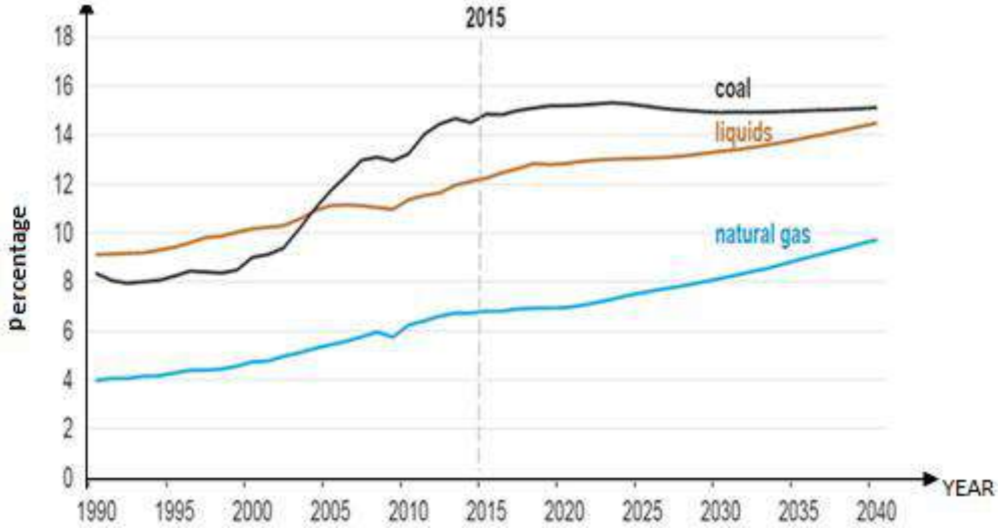

Figure I-1 : *Global energy-related CO_2 emissions.*

Due to the features of being green, low-cost and renewable, solar energy is widely recognized as one of the most competitive alternatives among all the renewable.

Today, solar energy has become a fundamental need for economic development and environmental preservation at the same time. Thanks to the light captured on Earth from this star (which is the only star in the solar system close to Earth), it is possible to produce clean electricity from a renewable source. [1]

I.2 Solar Technology

More energy from the sunlight strikes the earth in 1h than all of the energy consumed by humans in an entire year. In fact, solar energy dwarfs all other renewable and fossil-based energy resources combined.

We need energy – electrical or thermal – but in most cases where and when it is not available. Low cost, fossil-based electricity has always served as a significant cost competitor for electrical power generation. To provide a durable and widespread primary energy source, solar energy must be captured, stored and used in a cost-effective fashion.

Solar energy is of unsteady nature, both within the day (day– night, clouds) and within the year (winter–summer). The capture and storage of solar energy is critical if a significant portion of the total energy demand needs to be provided by solar energy.

Fig.I-2 illustrates the world solar energy map. Most of the countries, except those above latitude 451N or below latitude 451S, are subject to an annual average irradiation flux in excess of

1.6 MW h/m², with peaks of solar energy recorded in some ‘‘hot’’ spots of the Globe, e.g., the Mojave Desert (USA), the Sahara and Kalahari Deserts (Africa), the Middle East, the Chilean Atacama Desert and North-western Australia.[2].

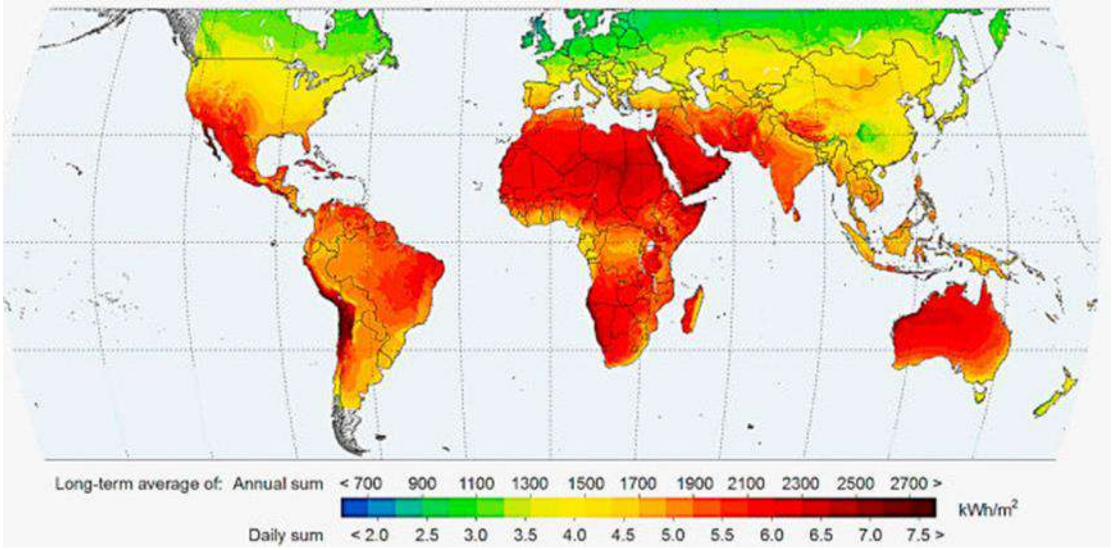

Figure I-2 : *World solar energy map*

I.3 Solar Conversion to electricity

Solar energy is converted into electrical energy by producing electrical energy. Sufficient heat at the temperature required to generate electricity from heat engines. Because it is common to call electricity "energy", these solar systems are called Concentrated Solar Thermal Power energy (CSTP, or CSP without the word "thermal"). It can also benefit from generating electricity from PV modules in sites usually free of the cloud, so authors may distinguish between them CSTP (concentrating solar thermal energy) and CSPP (concentrating solar energy Photoelectric power), although these abbreviations are not uncommon. As shown in (Fig I-3), the different components of CSTP are next:

- Climate with clear skies prevailing, hence the radiation of sunlight concentration.
- The solar field of collectors to concentrate the solar beam radiation.
- Receptor uptake. Heat transfer fluids.
- Heat exchangers.
- Turbine.
- Generators
- Cooling systems
- Optional auxiliary power / power bank.
- Electrical substation.

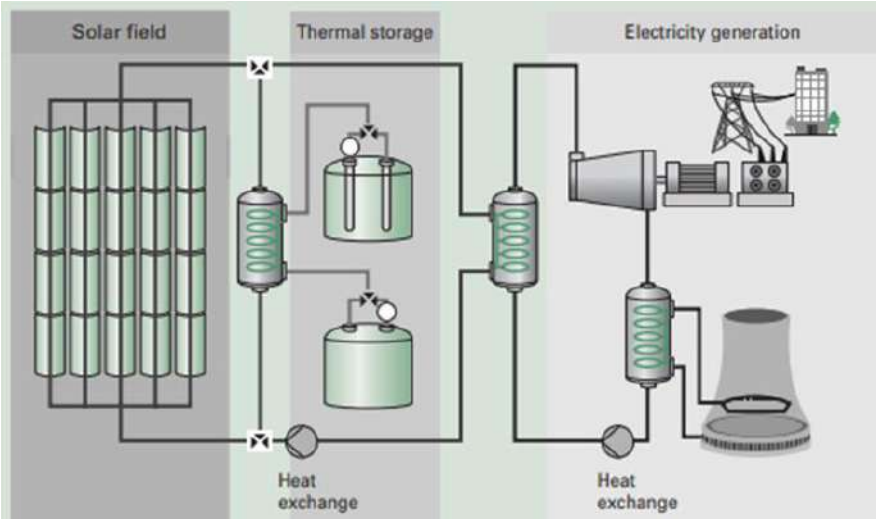

Figure I-3 : *Subsystems for solar capture heat exchange, heat storage and electricity generation*

The presence of integrated thermal storage is an important feature of CSTP plants; most of them also have backup fuel capacity. With these additional features, CSTP can generate power continuously and as required in a utility distribution network (e.g., balancing outputs from other renewable sources, such as variable photovoltaic power and wind power).[3]

I.4 Photovoltaic technology

Solar Photovoltaic allows the direct recovery and transformation of sunlight into electricity through photovoltaic panels. It is a direct conversion of solar energy into electricity via semiconductor material. The photovoltaic cell is an electronic component which is the basis of the installations producing this energy. It works on the principle of the photoelectric effect.

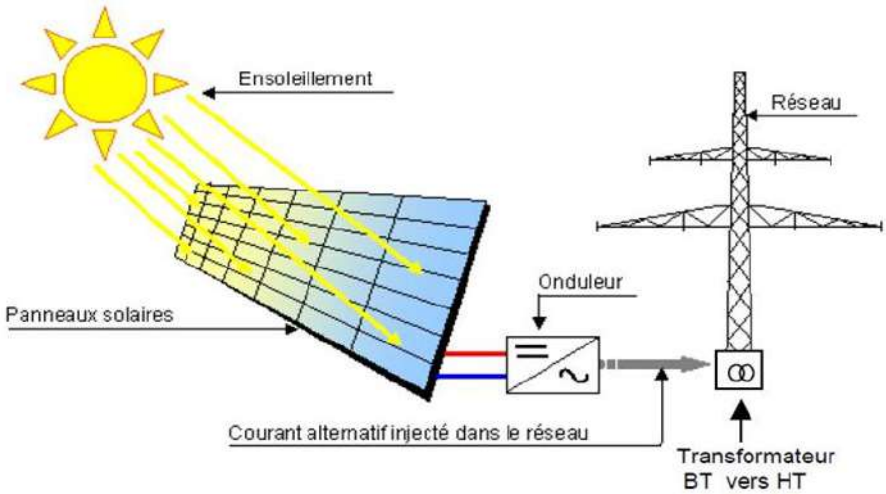

Figure I-4 : *Schematic diagram of a photovoltaic installation*

Several cells are interconnected to form what is called a photovoltaic solar module. Subsequently, several modules are to form a solar facility. This facility generates electricity that can be consumed on-site or supplied to a distribution network. The power of a photovoltaic solar power plant is proportional to the area of modules installed. [4]

I.5 Concentrating Solar Power Technologies

I.5.1 Cylindro-parabolic Technology

The structure uses curved mirrors to concentrate sunlight on a tube filled with fluid. A liquid collects thermal energy and transports it to the "factory block" where it is converted into steam and then into electricity through a turbine.

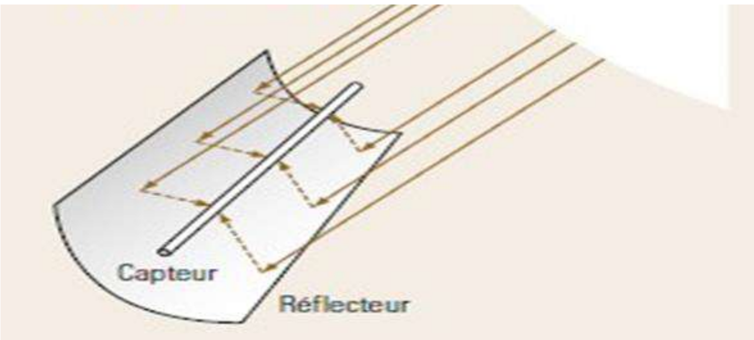

Figure I-5 : *Cylindro parabolic system*

I.5.2 Solar towers Technology

A tower supports a collector dominated by a field equipped with hundreds of heliostat mirrors (directional mirrors), which each follow the sun. As with cylindro-parabolic mirrors, a liquid carries energy to the power plant. [3]

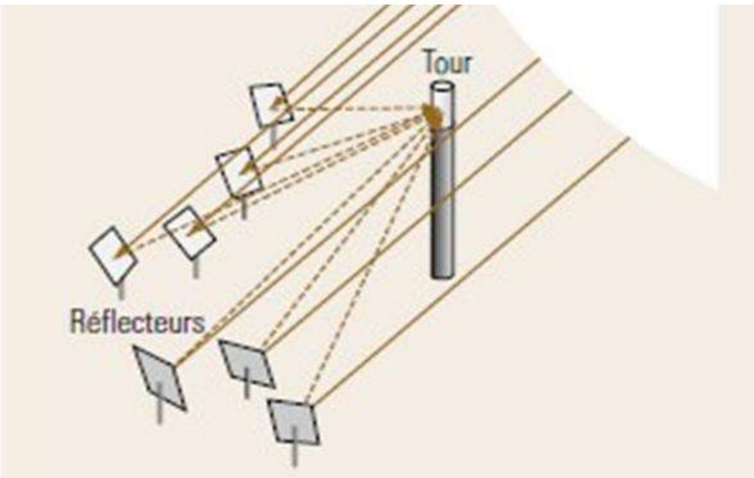

Figure I-6 : *CSP Solar tour system mirrors*

I.5.3 Parabolic Trough Design

These solar collectors use mirrored parabolic troughs to focus the sun's energy to a fluid-carrying receiver tube located at the focal point of a parabolically curved trough reflector (see Fig.I-7).

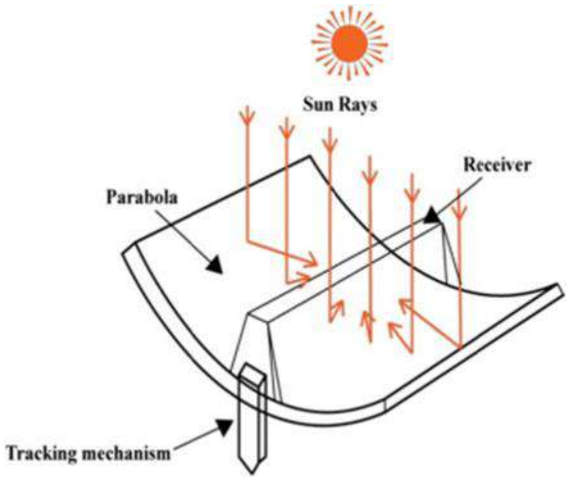

Figure I-7 : *Schematic of a parabolic trough*

The energy from the sun sent to the tube heats oil flowing through the tube, and the heat energy is then used to generate electricity in a conventional steam generator.

Many troughs placed in parallel rows are called a "collector field." The troughs in the field are all aligned along a north-south axis so they can track the sun from east to west during the day, ensuring that the sun is continuously focused on the receiver pipes. Individual trough systems currently can generate about 80 MW of electricity.

Trough designs can incorporate thermal storage—setting aside the heat transfer fluid in its hot phase—allowing for electricity generation several hours into the evening.

Currently, all parabolic trough plants are "hybrids," meaning they use fossil fuels to supplement the solar output during periods of low solar radiation. Typically, a natural gas-fired heat or a gas steam boiler/re-heater is used. Troughs also can be integrated with existing coal-fired plants. [5]

I.5.4 Linear Fresnel CSP

A linear Fresnel collector is a type of solar concentrator that uses flat mirrors concentrating solar radiation on a single collector tube, thereby reducing problems of construction and cost. The system consists of long parallel rows of mirrors that rotate around their longitudinal axis, concentrating solar radiation on a linear receiver suspended at a certain height above the plane of symmetry, (Fig I-8). [6]

The geometry of this type of collector makes it possible to have one or more receivers in parallel, to minimize mirror blocks.

Figure I-8 : *Linear Fresnel Solar Concentrator*

The absorption pipe has the same characteristics as that used in cylindro-parabolic mirrors. Good surface operation, lightness, simplicity of construction and low costs are the promotion of rapid development of this technology, even though its low concentration limits its effectiveness. One of the installations currently in operation since March 2009 is the 1.4 MW FresnelplantPE1 by Novatec Biosol, located in Murcia (southern Spain). [7]

I.5.5 Stirling Dish Engines

Dish systems use dish-shaped parabolic mirrors as reflectors to concentrate and focus the sun's rays on to a receiver, which is mounted above the dish at the dish center.

A dish/engine system is a stand-alone unit composed primarily of a collector, a receiver, and an engine (see Fig.I-9).

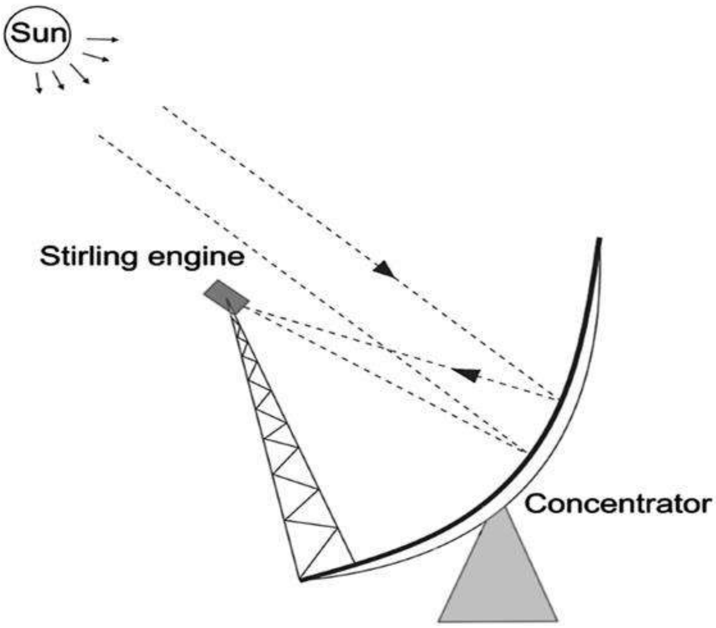

Figure I-9: *A Stirling Dish Engines system*

It works by collecting and concentrating the sun's energy with a dish-shaped surface onto a receiver that absorbs the energy and transfers it to the engine.

The engine then converts that energy to heat. The heat is then converted to mechanical power, in a manner similar to conventional engines, by compressing the working fluid when it is cold, heating the compressed working fluid, and then expanding it through a turbine or with a piston to produce mechanical power.

An electric generator or alternator converts the mechanical power into electrical power. Dish/engine systems use dual-axis collectors to track the sun. The ideal concentrator shape is parabolic, created either by a single reflective surface or multiple reflectors, or facets.

Many options exist for receiver and engine type, including Stirling cycle, microturbine, and concentrating photovoltaic modules. Each dish produces 5 to 50 kW of electricity and can be used independently or linked together to increase generating capacity. A 250-kW plant composed of ten 25-kW dish/engine systems requires less than an acre of land. Dish/engine systems are not commercially available yet, although ongoing demonstrations indicate good potential. Individual dish/engine systems currently can generate about 25 kW of electricity. More capacity is possible by connecting dishes together.

These systems can be combined with natural gas, and the resulting hybrid provides continuous power generation. [4]

I.5.6 Beam-Down CSP

The Beam-Down Solar Thermal Concentrator (BDSTC) is a point focus concentrator of around 280 m^2 of primary reflective area. The primary reflector system comprises of 33 2-axis tracking heliostats.

Figure I-10: *Beam Down Solar Thermal Concentrator*

As shown in (Fig I-10), the heliostats focus sunlight on one imaginary upper focal point. The radiation gets intercepted however, by a secondary Central Reflector (CR) on top of the tower, and is then redirected to a lower focal point close to ground level. [8]

The BDSTC is a central-tower like system but instead of collecting solar energy in the heat transfer fluid on top of the tower as is done in conventional tower plants, the receiver is located at the lower focal point close to ground. This is accomplished by a set of secondary optics of CR.

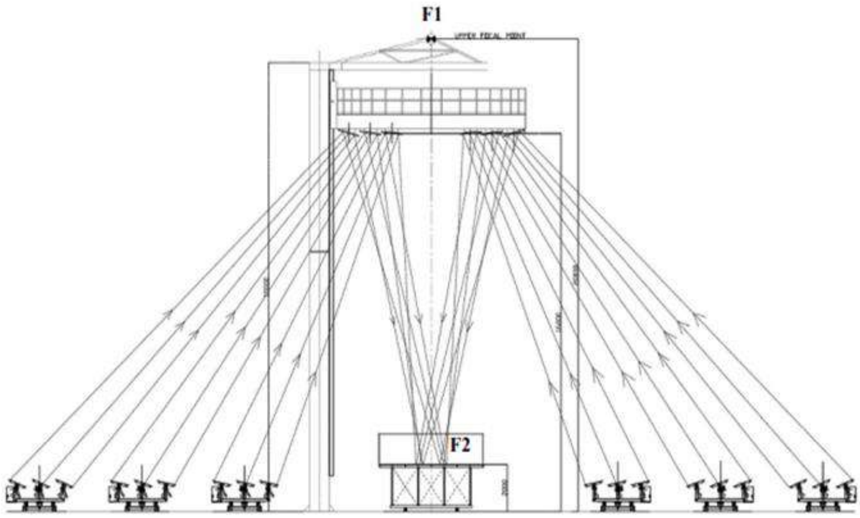

Figure I-11: *Vertical cross-sectional view of 100kW pilot plant.*

As shown in (Fig.I-11), when solar radiation is focused on the first focal point (F1) it will be redirected towards the lower focal point (F2). [9]

The aim point at height (H) serves as one focus (F1) for both the ellipse and the hyperbola, the other focus being at the receiver located near the ground at (F2). There are three configurations that can be implemented as

- Case 1: elliptic secondary reflector. This requires placing the reflector even farther than the focal point which not only increases cost but also increases images size with no added value**.**
- Case 2: hyperboloid secondary reflector placed between (F1) and (F2).
- Case 3: a flat reflector which can be also used as shown in (Fig.I-11) but it might have tube wider than the reflector in Case 2.

In the BDSTC, a set of flat mirrors tracing the profile of a hyperbola are used as a secondary reflector (Case 2). They reflect the radiation back to the lower focal point as shown in (Fig.I-11).

The use of mirror segments instead of a continuous hyperbolic mirror have the advantages of reducing the manufacturing costs, lowering wind load on the tower structure and providing natural cooling for the mirrors hence reducing thermal stresses. However, the use of flat mirrors in the secondary receiver poses some optical restrictions on the heliostats aiming and focusing capability, since each heliostat is restricted to focus its radiation to a single facet otherwise, it will be reflected off center.

This imposes premature focusing of heliostat image to prevent radiation spillage and results in a reduction in the overall concentration on the target plane. The Beam-Down concept faces several obstacles to realization namely: the loss due to the extra reflection, the mechanical integrity of central reflector against wind load compared to the slender conventional towers, the dilution of beam concentration at receiver aperture due to the extra travel distance in addition the heliostat field configuration.

Besides the advantages outlined by Tamaura et al. related to having heavy receivers placed near ground level, perhaps the most attractive feature of the Beam-Down configuration is the possibility of using cavity receivers.

Since all the radiation falls on the target from a narrow angle of less than 20° cavity receivers are well suited for such configuration. Compared to open receivers commonly used in conventional tower plants, cavity receivers have a smaller aperture, which means that thermal losses are strongly reduced and consequently higher temperature can be realized. This advantage has to compensate for the previously mentioned difficulties for the concept to be attractive in the end. [10]

I.5.7 Solar Tower

Solar tower technologies use a ground-based field of mirrors to focus direct solar irradiation onto a receiver mounted high on a central tower where the light is captured and converted into heat. The heat drives a thermo-dynamic cycle, in most cases a water-steam cycle, to generate electric power.

The solar field consists of a large number of computer-controlled mirrors, called heliostats. Current solar towers use water/steam, air or molten salt to transport the heat to the heat-exchanger/steam-turbine system. Depending on the receiver design and the working fluid, the upper working temperatures can range from 250°C to perhaps as high 1 000°C for future plants, although temperatures of around 600°C.

In the form of a (Fig.I-12) below, there are different solar tower in all regions of the world the main advantages are that:

- The higher temperatures can potentially allow greater efficiency of the steam cycle and reduce water consumption for cooling the condenser.
- The higher temperature also makes the use of thermal energy storage more attractive in order to achieve schedulable power generation and
- Higher temperatures will also allow greater temperature differentials in the storage system, reducing costs or allowing greater storage for the same cost.[11]

Figure I-12: *Different solar tower projects*

I.5.7.1 *Heliostats Field*

The Beam Down heliostat field consists of 33 group-type heliostats of 8.505 m2 reflector area. Heliostats are arranged in a surrounding field configuration in three main sectors of equal size, North, East and West. Depending on their distance from the origin the heliostats are labeled (A, B or C) as shown in (Fig.I-13). 6 heliostats are in the A line 17.48 m away from the origin, 15 heliostats are in the B line 20.08 m away from the origin and 12 heliostats in the C line 36.68 m away from the origin. [12]

Heliostats should continuously change their elevation and azimuth angles so that solar radiation can be redirected towards the focal point. To do so, there are two tracking modes for heliostat positioning; one is the open loop or ephemeris mode.

In this mode the heliostat controller calculate the azimuth and elevation angles required at each point of time based on its location in the field, position of the sun and focal point. The sun position is calculated using well-known astronomical equations that require precise knowledge of time, latitude and longitude.

The heliostat control system can use a GPS to acquire the needed information. This open-loop control mode is used to roughly position the heliostat to the correct position. Fine adjustment can be achieved by the feedback tracking sensor (see Fig.I-14) on which the second tracking mode is based. [13]

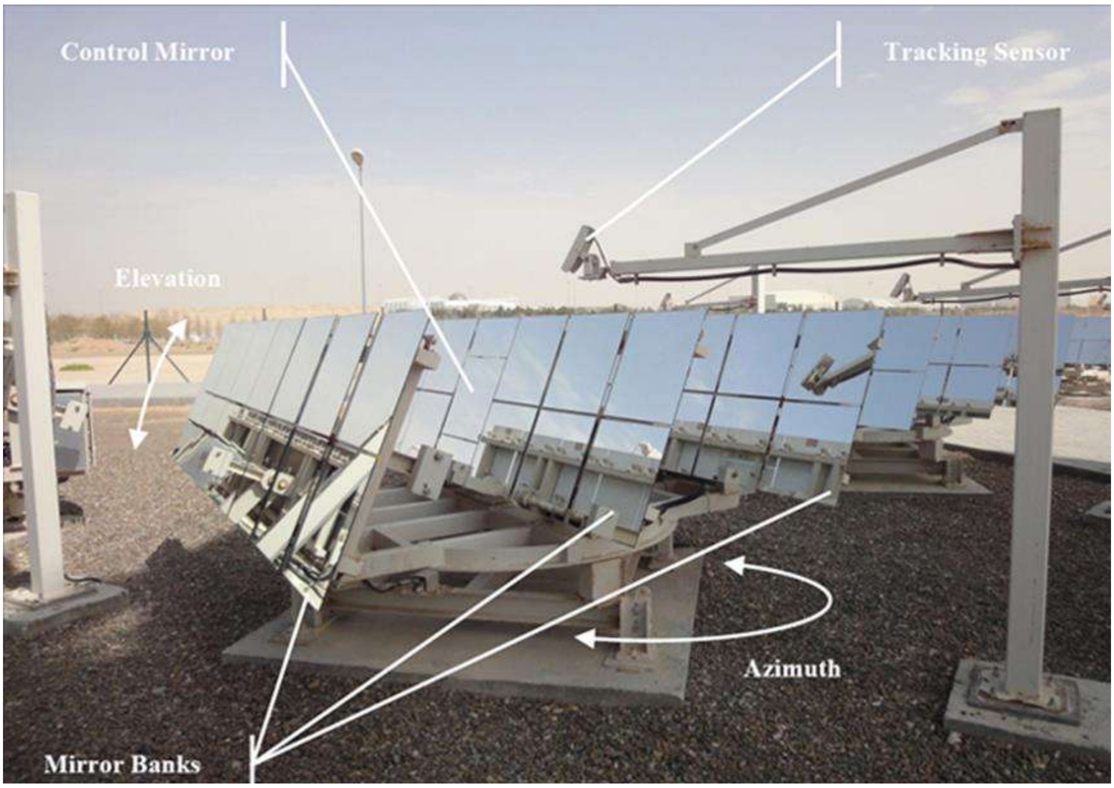

Figure I-13: *Typical ganged type heliostat and tracking sensor*

I.5.7.2 *Receiver*

The receiver is one of the most important parts of tower plants, there are two types of receivers: tubular and volumetric. Tubular receivers are used for liquid HTF such as water, molten salt, thermic oil, liquid sodium and Hitec salt, and volumetric receivers use air or supercritical CO_2 as HTF.

The type of receiver depends on the type of HTF and power cycle (Rankine or Brayton) used in the system. And receiver is one of the most important parts of tower plants. There are two types of receivers: tubular and volumetric. Tubular receivers are used for liquid HTF such as water, molten salt, thermic oil, liquid sodium and Hitec salt, and volumetric receivers use air or supercritical CO_2 as HTF. The type of receiver depends on the type of HTF and power cycle (Rankine or Brayton) used in the system. A brief description of the receivers is discussed in the following section. [14]

I.5.7.3 *Power Cycle*

The powers block is also a very important component of the plant as it is here that the solar energy collected by the receiver is converted to a more usable form which is electricity. The two main power cycles used in ST plants are role of the power cycle is to convert the thermal energy into electrical energy .and A power tower plant can be modelled with either a Rankine cycle or a supercritical carbon dioxide (sCO_2) Brayton cycle. Recent research has shown that sCO2 cycle is an attractive alternative to Rankine cycles for CSP and nuclear. [14]

I.6 Comparison of various CSP Technologies

Table I-1 : *comparison of different CSP technologies.*

	Relative Cost	Land Occupancy	Cooling Water (L/MWh)	Thermo-Dynamic Efficiency	Operating Temperature Range (°C)	Solar Concentration Ratio	Outlook for Improvements
PTCs	Low	Large	3000 or dry	Low	20-400	15-45	Limited
LFRs	Very low	Medium	3000 or Dry	Low	50-300	10-40	Significant
SPTs	High	Medium	1500 or dry	High	300-565	150-1500	Very significant

Although efficiency values are similar between stations, there are differences in application, cost and storage capacity.

- **Application:**

These kinds of stations require large areas of land in addition to solar radiation, and thus there are limited areas in the world that meet the requirements for building power plants. For example, in North Africa, the country of Algeria, Ghardaia, there is a thermal zone with large scans where this application can be achieved.

- **Cost:**

Photovoltaic power systems are low-cost compared to concentrated solar energy systems and always achieve a cost level and provide the required equations for concentration.

According to the International Renewable Energy Agency (IRENA), the installed capacity for central solar power plants was 5 GW at the end of 2016, while the installed capacity for photovoltaic plants reached 291 GW.

The cost of these plants is expected to decrease over time due to their increased prevalence in a manner similar to that of photovoltaic power plants.

- **Storage capacity:**

One of the most important advantages for central solar power plants to outperform photovoltaic plants is the ability to store energy, because the heat er liquid used in transport is able to retain heat for a period of time. What it means is that these stations can be neglected at night after the absence of the Sun, whereas photovoltaic stations do not operate after the absence of the Sun without batteries.

- The considerable proliferation of the central solar technology, as well as the photovoltaic solar technology, is evidence of the importance of the energy in solar radiation and of the many ways to harness this spectrum to meet our energy needs.
- Two Arab solar-focused electricity-generating states, Morocco and the United Arab Emirates, have so far succeeded, we may also show the difference in the above table. [11]

I.7 Heliostats

I.7.1 Definition

An optical instrument consisting of a plane mirror driven by a clockwork mechanism that, in spite of the apparent motion of the Sun, ensures the projection at a fixed point of the reflected solar rays. Large installations such as solar thermal power plants include heliostats with many mirrors. Normally, all the mirrors in the field are controlled by one computer.

Heliostats may be categorized either as serial or parallel, depending on the mounting of the actuators. In a serial type of heliostat, the actuators are mounted serial, as in a serial robot. The azimuth elevation (Az-El) drive is of this type (Fig.I-15A), as well as the novel target aligned heliostat (Fig.I-15B).

The benefit is a simple design and simple control, and disadvantages include reduced stability. Another approach is a parallel type of heliostat, where at least two actuators are in contact with both mirror module and ground at the same time (Fig.I-15C).

The benefit with this type of drive is increased stability. It is one of the most important studies for every heliostat design used in a solar power tower plant:

- High reflectivity
- High optical precision
- High tracking accuracy

- Resistant structure

The presence of wind loads radically increases the costs of the heliostat, since its structure must be stable enough to withstand these forces. [21].

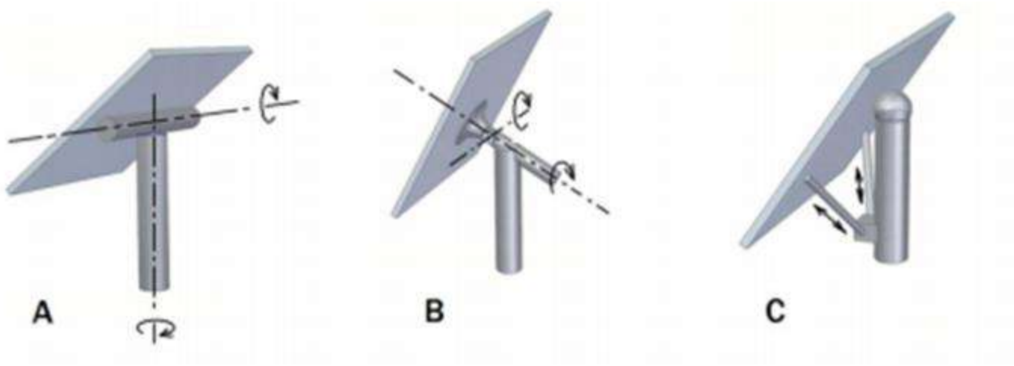

Figure I-14: *heliostat mechanism concepts A) Azimuth-Elevation; B) Target aligned heliostat; C) Parallel heliostat.*

I.7.2 Heliostat dimensioning

following, the main decisive aspects for heliostat dimensioning considering wind loads are discussed Heliostat is a mechanically operated mirror used in solar power tower systems. It could be heliostats Classified as either series or parallel, depending on the mounting triggers. In a sequential type of heliostat, actuators are sequentially installed, as in a serial robot. The height of the azimuth (Az-El) and the dimensions of the heliostats differ from one shape to another. That is why the design plays a big role in the dimensions of heliostats It was decided that the heliostat dimensioning tools should be applied to demonstrate the development process of one 25 m² heliostat and one 49 m² heliostat. [15]

The requirements of these heliostats are shown in table below. However, also huge heliostats are realized (e.g., Titan-tracker) at comparably low weight and cost. The reason is that for larger heliostats more complex structures with low specific weight like frame work cantilever arms can be realized.

Table I-2 **:** *Requirements of the example heliostats*

Mirror area	25 m²	49 m²	Verification Methods
Mirror facet size	2.5m x 2.5m	1 m x 1 m	CAD-model
Pedestal height	3.5 m	5 m	CAD-model
Mirror glass and thickness	AGC Solar mirror 4 mm		CAD-model
Drive type	Azimuth-Elevation		CAD-model

Degrees of freedom	2	CAD-model
Elevation range	195 deg	CAD-model
Azimuthal range	360 deg	CAD-model
Main structural material	Steel	CAD-model
Central tower height	120 m	N/A

We can see advantages when size is reduced to a scale equivalent to other volume manufactured commodity items regarding the following aspects:

- Production volume.
- Use of common-off-the-shelf (COTS) components.
- Use of low-cost manufacturing processes.
- Use of standard assembly processes.
- Transport and logistics.

I.7.3 Heliostat components

Heliostats are composed of several parts, one of which is static and the other is rotational.

I.7.3.1 *Mirror (reflecting sunlight)*

The reflectivity of solar rays can be achieved by glass mirrors, reflective films, plastic mirrors and polished metals. Regardless of the type of reflector used, the reflectivity rate (reflectance) is less than 100%, according to the study of Coventry et al. the first two types of mirrors are the most appropriate current options for the reflectors of the heliostats, because they currently have adequate reflectance compared to other. [16]

I.7.3.2 *Mirror support structure (fixing mirror)*

The torque tube and the pylon together form a ‘‘T” and are connected to each other by the drive system for azimuth and elevation movement. Glass and steel have different thermal expansion ratios. Therefore, the mirrors are often connected to the support structure via pins which are flexible in both directions of the mirror plane.

The glass mirrors reinforced by stamped support structures offer increased stiffness. Thus, thinner glass mirrors can be used. Openings in the metal sheet reduce weight. The adhesive’s flexibility compensates the differences in thermal expansion of glass and steel. However, temperature changes lead to geometry changes which impact the beam quality. By optimizing the geometry set at the moment of bonding, this effect can be minimized with respect to the annual energy yield

Advantages of the facets are:

- 1% higher reflectivity due to 3 mm instead of 4 mm thick glass mirrors.
- Less parts and lower weight of the support structure.
- Mounting simplified because of better handling of the facets.
- Fabrication can be highly automated. [16]

I.7.3.3 *Pylon and foundations (ground connection)*

The pylon is made of steel tube and secured to the ground by a concrete foundation. This fixing solution is the most answered especially for large heliostats.

I.7.3.4 *Control (offset determination)*

Control systems are electronic boards and control algorithms that are used to provide signals to drive motors to maintain the position of concentration relative to the sun. A solar reflection system ideally should make the concentration point on the target without error. In reality, the reflection systems are not perfect, and will not always point the solar image exactly at the desired point on the target. This concentration error usually and due to several parameters for example the effect of wind and temperature on the whole heliostat structure and the play of joints and engines and mathematical calculations. This error can be controlled by cameras. These cameras can capture the errors then transform them to the control board to correct the final position. [16]

I.7.4 Heliostat designs and their types

There are many different types of design of heliostats and they differ from one type to another and differ according to their work, physical characteristics and geometric shape.

I.7.4.1 *Bengoa heliostat (ASUP 140)*

Given the current trend of reducing the cost of electricity production and reducing the cost of the limit on the construction of solar power plants, Abengoa has developed a 138.7 m2 hydraulic heliostat with sandwich facets (Abengoa, 2017), (Fig.I-17). By the patented hydraulic drive mechanism complete azimuth rotation is possible. The bearings of the elevation axis are below the continuous torque tube to avoid large size of the bearings. The elevation axis is shifted from the center of gravity to achieve pre-tensioning of the elevation drive to eliminate back lash, New heliostat installed at Khi Solar commercial tower solar power plant in South Africa.[17]

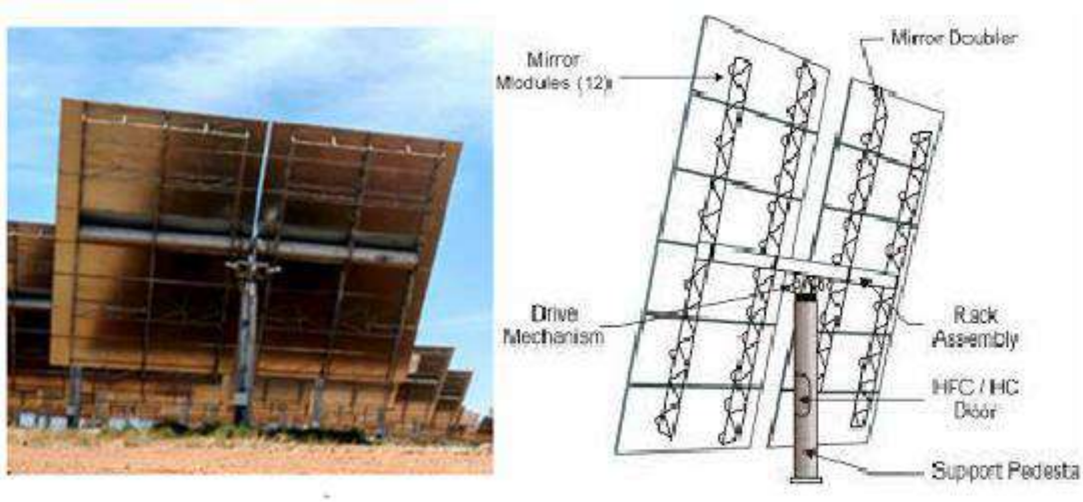

Figure I-15: *Abengoa's 180 m2 hydraulic heliostat with sandwich facets.*

I.7.4.2 *AORA heliostat solar*

AORA Solar's heliostat has a dual-layer grid structure formed from metal sheets as mirror support structure, a square torque tube and an unusually long linear actuator for elevation. [18]

Figure I-16*: AORA Solar heliostat with grid support structure and square torque tube.*

I.7.4.3 *Google heliostat*

Google Corporation carried out its own heliostat development project in 2010 with the aim of finding new innovative solutions for their own solar power plant. The project was shut down in 2011, and they released their results. Their proposal was a 6m² heliostat, powered by two stainless steel wires, driven by worm motors. [21]

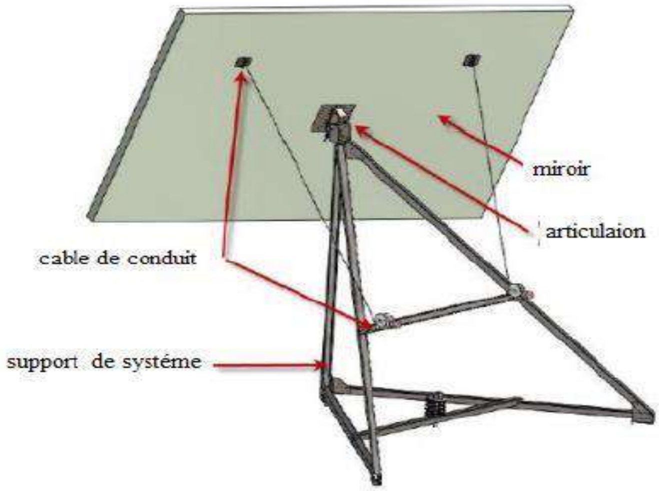

Figure I-17: *Google concept of a heliostat with wires.*

I.7.4.4 *Heliostat CSIRO*

The heliostat of CSIRO is based on a single facet and two linear actuators (Fig.I-20). The original size of the CSIRO heliostat was 4.5 m² (2.44 m 1.84 m) but today can be up to 7.22 m² size, representing the largest manufactured sheet of glass that is still transportable by shipping container, but flexible to supplier options. The maximum design wind speed is 40 m/s, and operating wind speed 15 m/s. The first axis of rotation is horizontal to achieve a required angle range of less than 120. Hence, for this heliostat type cost effective linear drives can be used for both axes. [19]

Figure I-18: *CSIRO heliostat with single facet and horizontal primary axis which enables the usage of linear actuators for both axes (CSIRO).*

I.7.4.5 *Helio systems (PATH)*

Helio systems has built 8 targets aligned heliostats of 12 m² (PATH03). The current design was developed in 2015 (Fig.I-21). A former version (PATH01) was developed in 2011 and tested with over 650 heliostats. The reason for building target aligned heliostats is that parabolic shapes reflect rays to a small focal point – but only if the rays are parallel to their optical axis. For other directions the focal spotis widened. This optical error, called ‘‘astigmatism”, can be reduced by an optimised canting of the mirror facets for all heliostat types, and especially for target aligned heliostats (Zaibel et al., 1995)where incoming and reflected rays are always in a plane fixed relative to the mirror plane. [20]

Figure I-19: *Target aligned 12 m² heliostat of Heliosystems*

I.7.4.6 *Kraftanlagen München*

The heliostat of Kraftanlagen München (KAM) has a size of 14 m² the mirror facets are connected to the cross beams by pins and pads. 28 prototypes were built in 2016 In Morocco, it is the first and final I have no faults in it design are in operation. [20]

I.7.5 Disadvantages of heliostats

In general:

- Rotary engine can be expensive.
- Wires are used to move the reflective surface.
- A large structure is used, which causes it to occupy a large area, so large motors are used to move the reflective surface
- The protection system is not available if the wind exceeds a specified speed

.

- Inability to track celestial objects with a single drive motor. For long pauses the alta zimuth mount must be controlled by a computer or be placed on an equatorial base, but here again the pause time is limited to around 1h25mint.
- Lack of precise steering precision due to the use of a cylinder (jack) as it relates to the ratio of the movement of the stem, which makes the heliostat body move at a certain angle.

I.8 Conclusion

Heliostats have different types of geometry and design, the best in terms of performance (round-height).The location of the heliostat varies according to geometric coordinates and from location to location depending on the physical characteristics of the area, specific to each site. In this chapter we have identified all the elements needed to compute at the power plant, it remains for us to design a suitable design with the least cost and the least quality accuracy and with the greatest energy yield. For the Heliostat movement, this problem will be dealt with in Chapter III, and as we mentioned in this chapter, the types of heliostats are different from each other. After we studied some of the heliostats, we found that they had some physical and technical defects, and they created flaws that couldn't be ignored, so we had to create a design.

Chapter II
SOLAR FIELD

II.1 Introduction

Energy is the source of evolution of our time and cannot be discarded, and it is the energy of its sources, unfortunately, that is non-renewable energy, which is the enemy of the environment, hence renewable energies as an alternative solution, which is solar energy. The Sun is one of the stars of our galaxy, thanks to its light captured on Earth, which is the only planet in the near-Earth solar struggle that can produce clean electricity. Solar radiation binds Earth to the Sun and the Earth's atmosphere controls this energy flow. The aim is to exploit the energy from the sun available, such as input to a solar device in position, direction, and time together. Solar radiation reaches the surface of the Earth at a maximum density of. And from it, it extracts the energy of stages and is stored for investment or export.

II.2 The solar resource

The most important basic resource for all energy potential renewable energy is solar energy. The earth receives a significant amount of solar energy in during the year. Radiation is attenuated when it passes through the atmosphere by absorption and dissemination, depending on weather conditions. To exploit this energy resource, it is necessary to know the number of available flows to a specific region. Or this we present in this part a notion the geographical coordinates, as well as the energy captured on a given surface, and the different relationships between hourly values. [22]

II.2.1 Characteristics of the Sun

The sun is the only star in the solar system closest to Earth, its light takes about 8 minutes to reach us. The sun is pseudo-spherical in shape comparable to a huge ball of very hot gas which consists of 80% hydrogen and 19% helium, the remaining 1% being a mixture of more than 100 elements, virtually all known chemical elements on Earth Although the sun is a medium-sized star, its alone accounts for 99% of the solar system’s mass.

The sun is not a homogeneous sphere, it consists of:

- The nucleus contains 40% of the mass of the sun, that is where 90% of its energy is created in the form of gamma rays and X, its zone extends over a thickness of 25 km,
- The irradiative zone where the heat produced propagates by diffusion;
- The convection zone where the heat produced propagates by turbulent convection;
- The photosphere is an opaque layer, the gases forming it are strongly ionized and capable of absorbing and emitting a continuous spectrum of radiation; it emits 99 % of the radiation visible;
- The chromospheres, which a thickness of 2000 km;
- The crown is the last layer of the sun. [19]

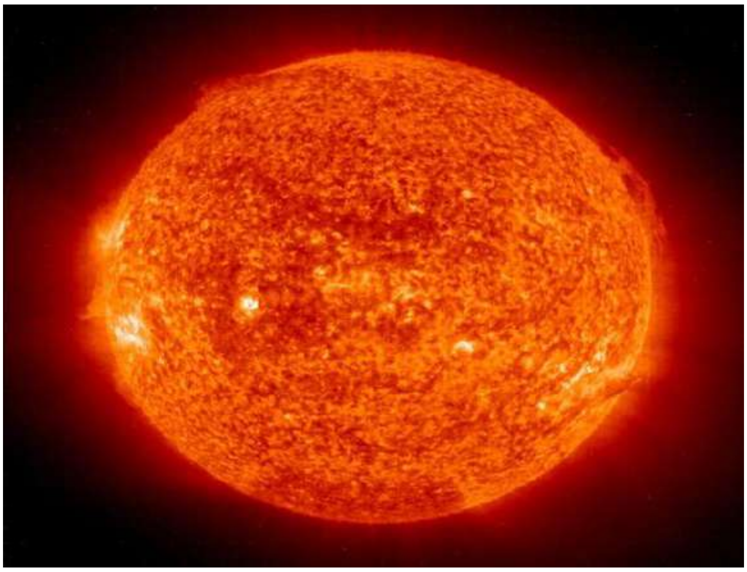

Figure II-1: *The sun seen from earth.*

II.2.2 Earth-Sun ring systems

The Earth describes around the Sun an almost circular trajectory, called the plane of the ecliptic, with an average distance of 149.6 million km, and over a period of 365.25 days.

The earth rotates on itself with a period of 24 hours, its axis of rotation (pole axis) is inclined relative to the plane of the ecliptic of 23° 27’ (– 23°27’ at the winter solstice, + 23°27’ at the summer solstice) and zero at the equinoxes.

At the winter solstice (21 December) the earth is the closest to the sun, and at the summer solstice (22 June) it is the most distant.

The value of the decline for the days of the year is calculated as follows:

$$\text{Sin}(\delta) = 0{,}4.\sin(t) \qquad \text{(II-2)}$$

t: refers to the angular coordinate of the earth taking the spring equinox as its origin.

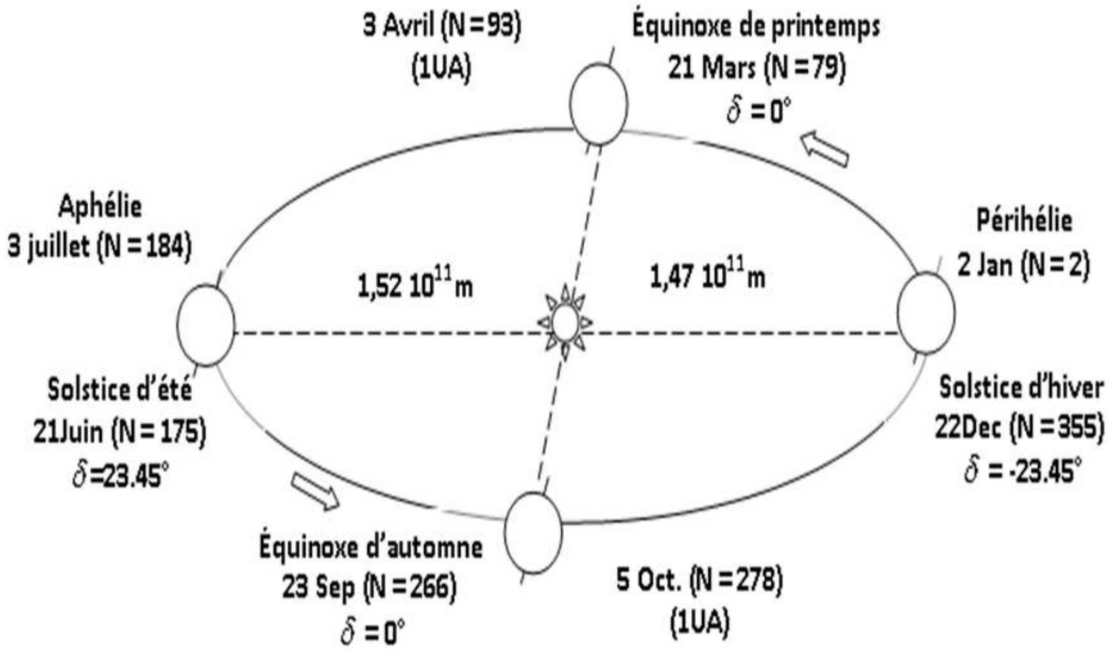

Figure II-3: Motion of the globe *earth* in relation to the sun

The sun continually discharges a huge amount of radiant energy, of which the earth intercepts a very small part. An average of 1,367 watts reaches every square meter of the outer edge of the Earth's atmosphere (for an average Earth-Sun distance of 150 Million km).

The amount of solar energy received on the Earth's surface depends on the thickness of the atmosphere to be passed through. [23]

II.2.3 Celestial sphere

The celestial sphere is an imaginary sphere of an immense diameter, which admits for center the earth, and for radius the distance (earth – sun). All objects visible in the sky are considered to be on the surface of the celestial sphere. The various Characteristics on the sphere itself can be summarized as shown in the (Fig.II-3) [23].

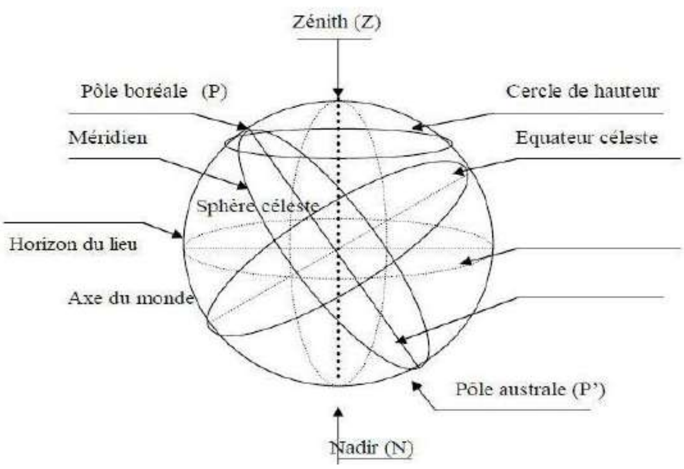

Figure II-4: *The Celestial Sphere*

II.2.4 Position of the Sun in relation to the Earth

The position of the sun in the celestial vault can be determined according to the position of the observer on earth (geographical coordinates) and local time.[23]

II.2.5 Geographical coordinates

II.2.5.1 *Latitude (θ)*

The value θ represents the angle made by the vertical of the place (site) with the equatorial plane, so if the site is located in the northern hemisphere the value θ>0, and when the site is in the southern hemisphere θ < 0.

II.2.5.2 *The longitude (φ)*

The φ value represents the angle formed between the original meridian (Greenwich in England) and the meridian of the site under consideration.

The longitude φ is between -180 (towards the west) and +180 (towards the east), and since the earth takes 24 hours to make a turn on itself (360°) we deduce that each hour represents 15° of difference in longitude.

II.2.5.3 *Altitude (h)*

This is the vertical value expressed in meters between the site under consideration and the sea level (taken as the reference surface).

II.2.6 Equatorial coordinates

The movement of the Sun is marked in relation to the equatorial plane of the Earth by two angles (δ,ω).

- The declination of the sun (δ):The angle that the plane of the Earth's equator makes with the direction of the earth-sun is called declination, this angle varies throughout the year symmetrically from – 23° ,26′ to +23°,26 its value can be calculated by the formula [25]:

$$\delta = \frac{23.24 \times \pi}{180} \sin(2\,\pi\,(284 + j)/365) \qquad (\text{II-}2)$$

Where **j** is the number of the day of the year from 1 January.

- The time angle of the sun (ω): This is the angle between the passing origin Meridian from the south and the projection of the sun on the equatorial plane, it measures the sun's course in the sky.

$$\omega = 15(TSV - 12) \qquad (\text{II-3})$$

TSV: is the true solar time in hours and each hour is equal to 150 of longitude [25].

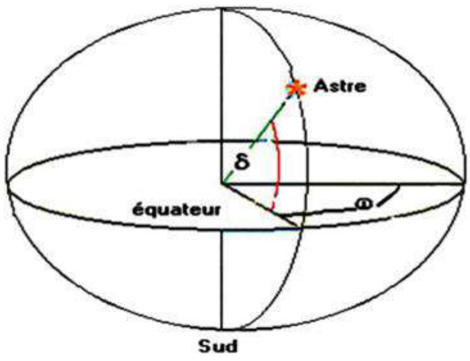

Figure II-5: *Equatorial coordinates*

II.2.7 Horizontal coordinates

The horizontal marker is formed by the plane of the astronomical horizon and the vertical of the location. In this landmark, the coordinates are height **h** and azimuth **a**. [26]

- **The height of the sun (h):** It is the angle formed by the direction of the sun and its projection on the horizontal plane, it is particularly equal to:

$$\sin(h) = \sin(\varphi)\sin(\delta) + \cos(\varphi)\cos(\delta)\cos(\omega) \qquad \text{(II-3)}$$

- **Azimuth of the Sun (a):** The angle between the projection of the direction of the Sun on the horizontal plane and the direction of the South

$$sin(a) = \frac{\cos(\delta)\sin(\omega)}{\cos(h)} \qquad \text{(II-4)}$$

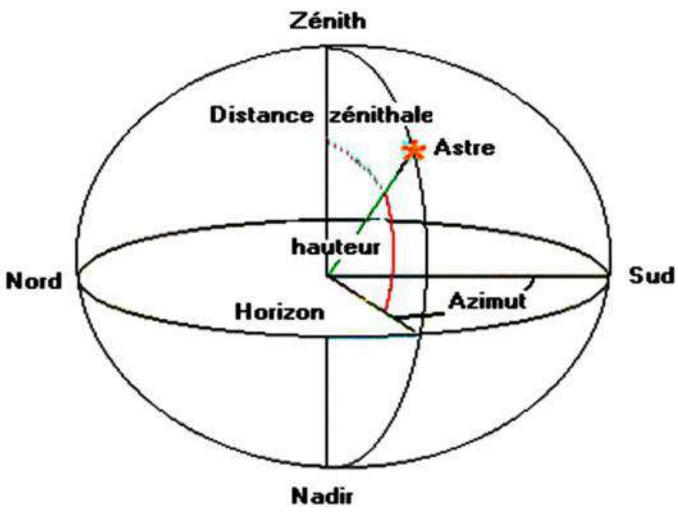

Figure II-6: *Horizontal coordinates*

II.2.8 Solar times

The earth has two types of rotation, one on the axis of the poles and the other around the sun:

- The rotation of the earth on itself defines the concept of a solar day, a complete rotation in24 hours and each hour corresponds to an angular deviation of 15°.

- The rotation of the earth around the sun defines the four seasons and distinguishes time true solar [26].

II.2.8.1 *True Solar Time (TSV)*

It is given by relationship [26]:

$$TSV = 12 + \frac{\omega}{15} \quad \text{(II-5)}$$

$$TSV = 12h \; Si \; \omega = 0° \quad \text{(II-6)}$$

ω: is positively counted in the afternoon.

II.2.8.2 *Average Solar Time (TSM)*

Average solar time differs little from true solar time, this difference is defined by the equation of time **E_t**.

$$E_t = TSV - TSM \quad \text{(II-7)}$$

E_t: being the correction of the **TSV** relative to or **TSM** is expressed in minutes and decimal fraction of minutes.

$$Et = 9.87 sin 2.\frac{360}{365} - 7,53 cos\frac{360}{365}(J - 81) - 1,5 sin\frac{360}{365}(J - 81) \quad \text{(II-8)}$$

II.2.8.3 *Universal Time (TU)*

In a given longitude place, universal time is related to the mean (local) solar time by the relation:

$$TU = TSM \pm \frac{l}{15} \quad \text{(II-9)}$$

(+) for longitudes EST and (-) for longitude OUEST.

The universal time is therefore calculated by:

$$TU = TSv + Et \pm \frac{l}{15} \quad \text{(II-70)}$$

II.2.8.4 *Legal time (TL)*

This is official state time:

$$TL = TU + \Delta H \quad \text{(II-81)}$$

ΔH: being the time difference between the meridian of Greenwich and the state considered, (**ΔH** =1 hour for Algeria).

II.3 Solar radiation at ground level

Only the energy captured on a given surface is of interest, the quantities will be expressed in kWh/m² of receiving surface [22].

Solar radiation undergoes a number of alterations and random attenuation as it passes through the atmosphere: reflection on atmospheric layers, molecular absorption, molecular diffusion and diffusion by aerosols.

At ground level, because of diffusion, some of the radiation is diffused, that is, isotropic. The other part, called direct, is anisotropic. Solar radiation reaching the ground is subdivided into three main components

II.3.1 Direct solar radiation

Direct radiation is received directly from the sun, without diffusion through the atmosphere. Its rays are parallel to each other, so it forms shadows and can be concentrated by mirrors [22].

II.3.2 Diffuse solar radiation

Diffuse radiation consists of photons diffused by the atmosphere (air, nebulosity, aerosols). Its structure varies with weather conditions. In overcast weather, it is assumed to be isotropic, that is, to receive identical radiation from all directions of the celestial vault [22].

II.3.3 Reflected solar radiation

Albedo is the part reflected by the ground. It depends on the environment of the site. Snow, for example, emits a lot of light rays, whereas asphalt emits practically none. This will have to be taken into account when evaluating radiation on inclined planes [22].

II.4 Solar Field

The desert areas, located in latitudes close to the equator, are the most favorable for solar energy [27]. Some developed countries near these areas of sunshine are beginning to exploit this energy through different processes, including solar concentrators. The areas in which solar radiation is particularly important will allow the creation of a large-scale power generation site, as is the case in California, where currently a solar power plant with an output of 354 MW, (Fig.I-2).

II.4.1 Geographical location of Algeria

Algeria is one of the largest countries in Africa with an area of 2381741km² over the 30 million km² of the African continent, or nearly 1/12 of the total surface area of Africa, it is the largest of the African states, and extends between the latitudes 18° and 38° North and between the longitudes 9°West and 12°East, whose main dimensions would be:

- 1900 km from North to South,
- 1800 km from West to East,
- 2100 km from the North-East to the South-West,
- 1200 km of coastline on the Mediterranean.
- The Sahara, which covers 5/6 of the country's surface area.

The various studies undertaken so far on the solar energy potential in Algeria show considerable and very appreciable amounts of energy for development. Algeria with more than two million km². This is equivalent to about 30 times the energy consumed in the world.

This high availability makes Algeria an inexhaustible reservoir of energy. In terms of insolation, the national daily average is more than 5 kWh/m², and the duration of sunshine in the national territory exceeds 2500 hours/year. [28]

II.4.2 Solar deposit in Algeria

The solar deposit is a dataset describing the evolution of solar radiation available in a given period. It is used to evaluate the operation of a solar power plant and to check the demand to be met [29]. Due to its geographical location, Algeria has a huge solar deposit as shown.

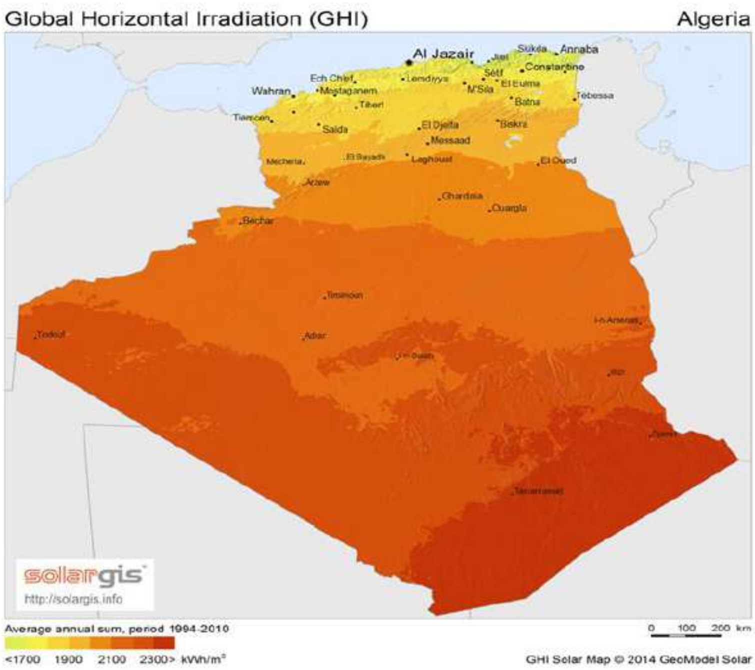

Figure II-9: *A study of thermal regions in Algeria.*

Following an assessment by the German Space Agency (ASA) concluded that Algeria represents the largest solar potential of the entire Mediterranean basin, namely 169000 TWh/year for solar thermal and 13.9 TWh/year for solar photovoltaic. [30] The distribution of solar potential received annually over the regions of Algeria is represented in the table below:

Table II-1 : *Solar Potential of Algeria.*

Region	Coastal region	highlands	Sahara
Area(%)	4	10	86
Average duration of sunshine (hours/year)	2650	3000	3500
Average Energy received (KWh/m²/year)	1700	1900	2650

Knowledge of temperature is crucial for the study and use of any solar system. Data of the temperatures of the Wilaya of Ouargla calculated over ten years of observation (from 2004 to 2014) are represented in (Table .2), the latter shows the year in two seasons, one cold with a minimum average in January (5.11°C), and the other hot with a maximum average in July (43.71°C) [31].

Table II-2 : *The temperatures of Ouargla.*

month (°C)	*Tmax(°C)*	*Tmin(°C)*	*(Tmax+Tmin)/2 (°C)*	*(Tmax-Tmin)(°C)*
Jan	18.77	5.11	11.94	13.67
Feb	21.08	6.83	13.96	14.25
Mar	25.81	10.99	18.4	14.81
Apr	30.38	15.26	22.81	15.12
May	34.89	19.75	27.32	15.13
Jun	40.28	24.81	32.54	15.47
Jul	43.71	28.21	35.96	15.5
Aug	42.84	27.54	35.20	15.3
Sep	37.75	23.51	30.63	14.23
Oct	32.18	17.61	24.89	14.57
Nov	24.16	10.46	17.31	13.7
Dec	19.23	6.02	12.62	13.21

II.5 Conclusion

The use of solar energy is one of the priority research axes in Algeria, which has a large solar field. such that the Earth receives a large amount of solar energy during the year. Our work has two main titles: The first title covers the theoretical study on Solar resources and the position of the sun is identified at each moment of the day and of the year by two systems of different coordinates and the second title on the study reflects the qualifications of Algeria in the field of energy.

Chapter III
STUDY AND DESIGN OF THE NEW HELIOSTAT

III.1 Introduction

In this chapter we propose a new heliostat design, as this design contains simple parts, more resistant, easy to maintain, and less expensive than other heliostats in the market, which at the same time ensures accuracy in the direction of the photovoltaic panel or the reflective surface, thus improving the yield of solar fields.

III.2 Computer Aided Design

In most of the design cases, we use software with the help of the computer, the new products are usually designed using many of them: AutoCAD; Catia; 3DS Max; ANSYS; Revit; Sketchup; … And in our work, we're going to use the computer-aided SolidWorks design software.

SolidWorks is one of the most outstanding engineering design programs in the three-dimensional mechanical design of pieces and mechanical machinery is that you can simulate loads and their impact on the mechanical piece, as well as move, install and test mechanical pieces, analyze and easily modify their data before they are produced on the ground. And we found that the most popular class that uses Solidworks are mechanical engineers and professors to design mechanical pieces and help implement them at the lowest cost. We also had to use them in our design.

we can say that SolidWorks is a parameterized solid modeling design tool based on features, in fact, a SolidWorks model is made up of individual elements called features such as bosses, cutouts, holes, fillets, chamfers Created in 1993 by the eponymous American publisher, SolidWorks was purchased on June 24, 1997, by the company Dassault Systems. Some of the largest organizations

Using SolidWorks include Michelin, AREVA, Patek Philippe, Mega Blokes, Axiome, ME2C, SACMO, Le Boulch and Robert Renaud. 3D modeler using parametric design, SolidWorks generates 3 types of files relating to three basic concepts: part, assembly, and drawing. These files are related. Any modification at any level is reflected in all the files concerned. A complete file containing all the data relating to the same system constitutes a digital model. In the (Fig.III-1) below, we put an image of the user program in our study.

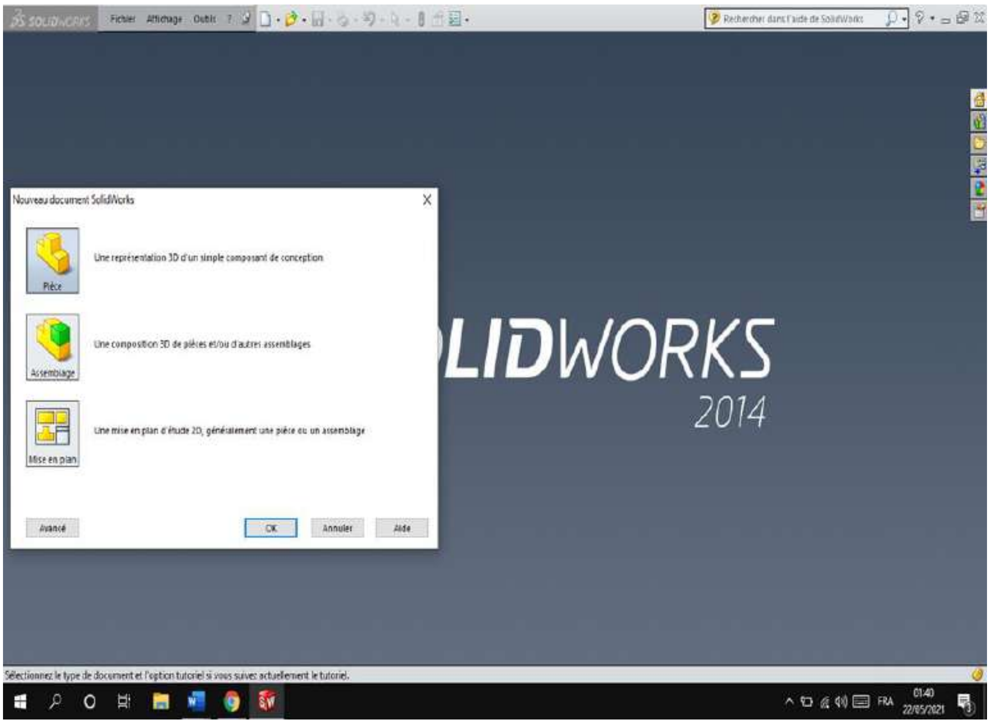

Figure III-1: *The three basic SolidWorks concepts*

III.3 New design proposed

III.3.1 Specifications

The first thing that heliostats have to be able to direct the sun's rays towards a known fixed point with maximum accuracy, and the second thing that must graze the bearer's endurance now is responsible for carrying different elements of the heliostat and the force with which the wind affects as it is considered a basic base for heliostat.

In such a case, the reflection surface (with a surface area of at least 1 m ²) must at best be in a horizontal position to reduce or eliminate wind forces. This will be taken into account once the wind speed exceeds 40 km/h.

It must then be ensured that heliostats can reach this "horizontal" position when the wind speed exceeds a specified value; we consider it to be 50 km/h to make sure that heliostats will stand that force.

To simplify the process of cleaning and/or maintaining reflective surfaces, their position must be changed to "vertical." So, we have two situations: horizontal (associated with the safe state of high wind velocity) and vertical (associated with cleaning and maintenance).

III.3.2 Main ideas of the proposed design

Our idea is based on movements of the heliostat as it covers all the angles, it has two movements according to two different axis, the first is vertical while the second forms an angle of 45° with the first, on the other hand the normal to the plane of reflection also forms an angle of 45° with the second axis (inclined).

Driving in rotation the elements of the heliostat around these axes is ensured by means of two worm gear motors and roller chains engaged on one side to a pinion integral with the gear motor, and on a toothed wheel integral with the axis on the other side.

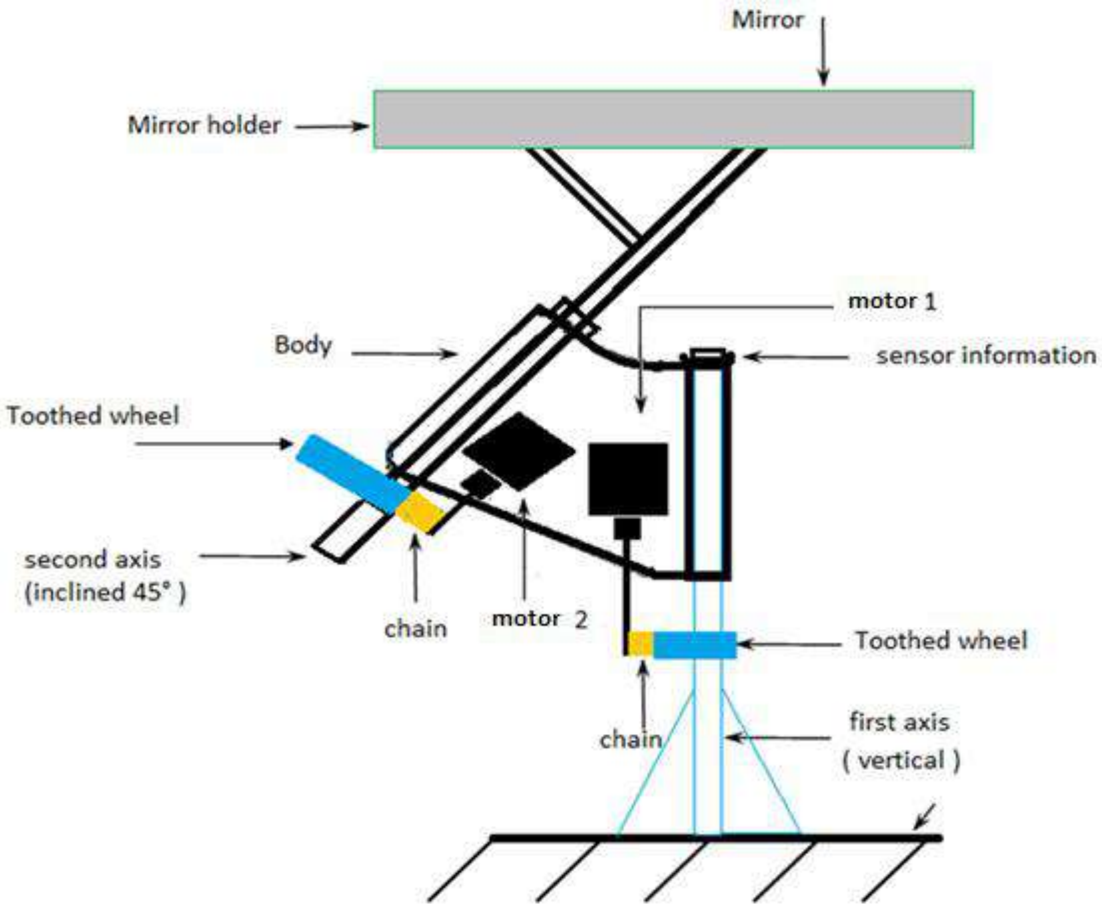

Figure III-2 : *Sketch explaining the proposed design.*

When the first worm gear motor (1) operates, it moves the entire body around the first axis through the chain attached between the first axis (1) and the first worm gear motor (1). This rotation can be endless covering 360°.

By actuating the second worm gear motor (2), the angle of elevation of the normal to the reflecting surface will vary between 0 ° and 90 °, in this way, the heliostat can be oriented in any direction wanted, as well; it is functional any where over the world.

To vary the angle of elevation of the normal to the reflecting surface between 0° and 90°, and because of the 45° angle between the normal to the plane of reflection and the second axis, the axis must turn 180° instead of 90° (like in T model), this will help to get more control and better accuracy of elevation angle.

The control will be guaranteed by the Arduino board that will ensure the correct orientation of the heliostat according to the position of the Sun, the position of the receiver and the real-time readings of the two angle values from sensors linked to the rotations of the heliostat

III.3.3 Great feature and remote range

Our goal is that the heliostat system that respects this design will be able to work in any region of the world because it can cover an angle of 360° degrees, and it can even rotate without limits. Covering the 90 ° angle of elevation movement also contributes to this feature. Sure, the reflection surface is small, but this will make it possible to better control the reflection of the sun's rays, the small size of the sunshade helps in its maintenance. Maintaining the support of the mirror, which is in the shape of the letter "Y", contributes to supporting the holder to resist wind and reduce pressure, and it is also free from defects.

III.4 Drawing of the different parts in SolidWorks

III.4.1 Foundation and Pylon

Based on previous work, we estimated in advance that the building should have a diameter of around 40mm due to the size of the parasol we offer and especially the size of its reflective surface. Of course; This value will be verified by simulation.

At the upper end, an angle sensor is attached to the body in the same plane, and the role of the building is to indicate the rotational movement of the building and to allow it to simultaneously rotate around the azimuthal axis. The cogwheel at the bottom of the column’s saga will help guide the body around the upright posture. And this cogwheel (epic in an axis) that is the transmission cogwheel has 41 teeth.

Fig.III.3 shows all these parts with a more detailed view; It suffices to point out that all these parts are fixed concerning the base and are constant.

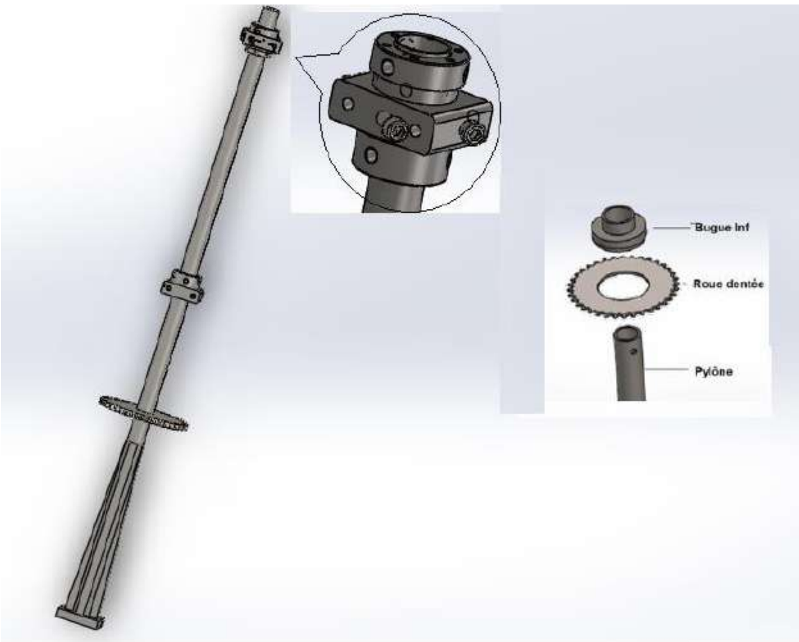

Figure III-3 : *The Pylon assembly with an exploded view.*

III.4.2 The Body

From our point of view, we believe that the use of a standardized profile in the design of the various elements of the heliostat will reduce the overall cost of the heliostat, given their availability on the market, that is why that a simple round tube was chosen for the Pylon, in the same way; the body design is based on the use of angles of the same profile The body structure is based like the shape of the trapezoid Isosceles ensuring rigidity as the trapezoid Isosceles is undeformable elements.

Fig.III-4 shows the assembly of the different parts of the body look-alike in an exploded view. Two main parts form the body; the first (in the form of a trapezoid) is used to drive the Support of the mirror in rotation around the azimuth, the time that the second protected is necessary for the maintenance of the elements ensuring the movement of elevation namely and carrying two motors and other components.

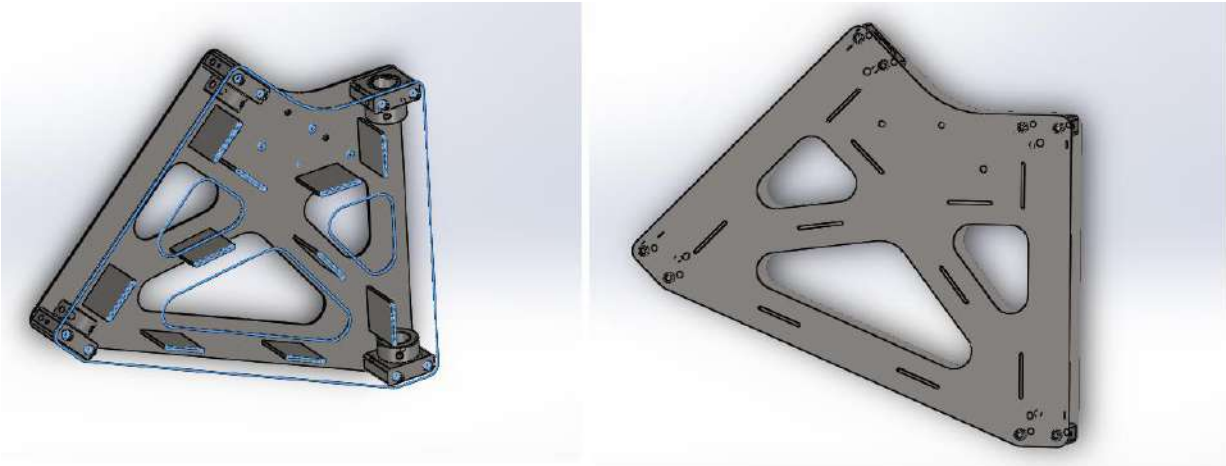

Figure III-4 : *The different parts of the body in exploded view.*

III.4.3 The mirror supports

Shaped 0.71m x 0.71m square and constructed at an angle of 20x20, the mirror stand will be able to rotate horizontally around two axes, one of which is a fixed sub-loader and a second in the upper part of the body. As for the mirror, it comes in the form of an octagon, and the reason for its choice is a substitute for a square shape to have the advantages of its physical properties.

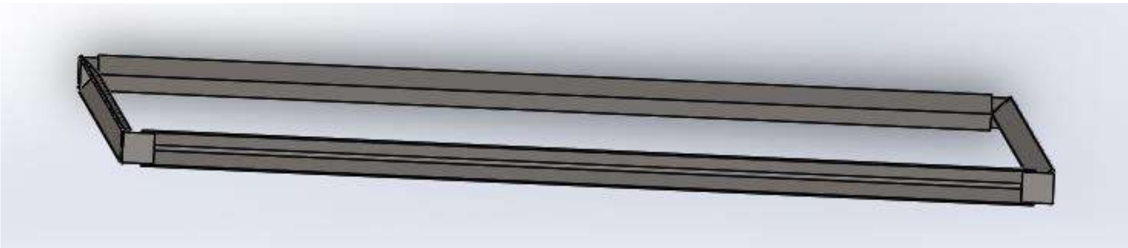

Figure III-5 : *Mirror Support.*

III.4.4 Auxiliary parts

In addition to these four main countries, additional parts necessary for the operation of the heliostat are shown in the following figures:

- A Ring for guiding the Body in relation to the Pylon and inclined ax (Fig.III-6A).
- Two small pinions, one for guiding the drive axes of the mirror support and the second for guiding the body (Fig.III-6B).
- two toothed wheels for guiding the Body in relation to the Pylon and the other for rotating the support (Fig.III-6C).
- The parts are placed inside the body where these small parts are of support (Fig.III-6D).

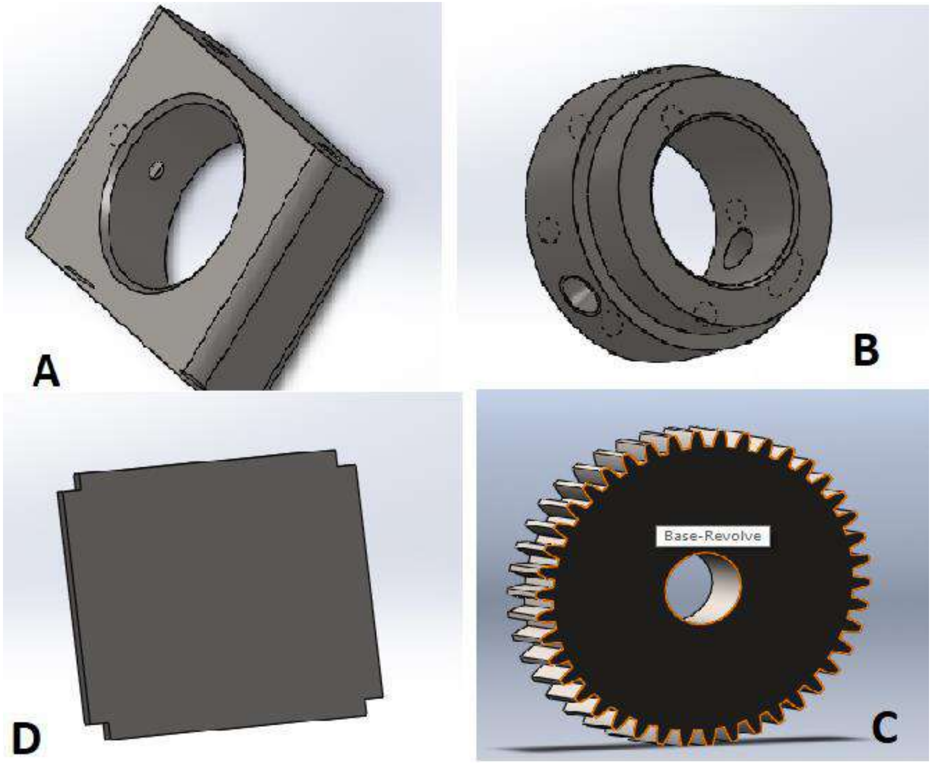

Figure III-6 : *Auxiliary body parts.*

III.4.5 Global assembly of the heliostats

The figure represents a solid bottom in which all the basic and binary parts of the heliostat components have been assembled, and the obtained result is represented in Fig.III-7 in a number of poses and a different number of points of view.

No. ARTICLE	the parts.	the simulation study parts	QTE
1	Pylon	in this area we will do the study	1
2	TRGL		2
3	CarreRfrt		10
4	LogmtBague		4
5	ISO 4762 M10 x 20 --- 20N		16
6	BagueSupport		4
7	BagueMaintient		.
8	Tube		1
9	TubeMin		1
10	PorteMirr		1
11	Prmd		8
12	Corniere		4
13	Miroire		1

Figure III-7: *Heliostat parts*

Figure III-8 : *Global assembly.*

III.5 Mathematical Model of the Heliostat Field

The heliostat field consists of a few to hundreds of heliostats installed around the tower. A single heliostat consists of a set of mirrors, a tracking system, a frame, a structure foundation, and a control system. The designed heliostats are used to follow the course of the sun, generally to direct the sun's rays all day long to a point or a small fixed surface called a receiver which is placed at the top of the tower. The reflected sun's rays maintain the focus of energy on the receiver during operation to generate high temperatures. Then, the generated heat is used in convent.

III.5.1 Heliostat rotation angles

Designed heliostats are mechanically actuated optical reflectors that continuously track the sun's rays and reflect the irradiation onto the receiver. This applies that the heliostat normal must be oriented in the direction that bisects the unit vectors to the sun and to the receiver. Due to the daily and seasonal movement of the sun, the heliostat requires two degrees of freedom. The specific configuration of these two degrees of freedom is known as the tracking mechanism as depicted in (Fig.III-8 and 9).

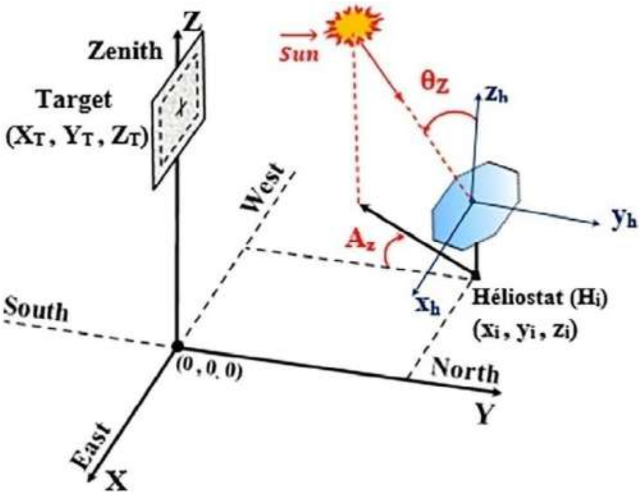

Figure III-9 : *The solar position*

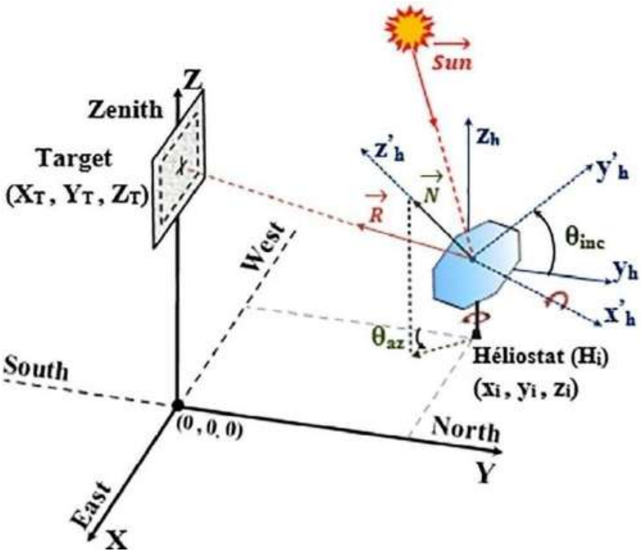

Figure III-10 : *Redirected sun vectors toward the receiver (target) in the optical system considered.*

III.5.2 Sun vector position

At the first stage of the optimization process, and at any heliostat field location and any moment of the day, the coordinates of the sun should be known. Generally, the sun's coordinates can be defined by the azimuth and zenith angles. The orientation of each individual heliostat can be controlled based on three parameters, that is, the heliostat position, the incident sun vector, and the reflected vector to the targeted receiver. To define the sun vector, the solar azimuth angle AZ and the zenith angle θZ are calculated as presented in Fig.III-8.

where the sun unit vector can be defined as:

$$\vec{U}_S = \frac{\vec{s}}{s} \qquad \text{(III-11)}$$

III.5.3 Heliostat-tower vector

In the chosen system of coordinates, the positive X axis is the West direction, the positive Y axis is the North direction and the z axis is orthogonal to the ground. Where ($\mathbf{X}_i$,$\mathbf{Y}_i$,$\mathbf{Z}_i$) and ($\mathbf{X}_T$,$\mathbf{Y}_T$,$\mathbf{Z}_T$) are the coordinates of the heliostat i and target T, respectively. It is assumed that all the heliostats have the same height.

The redirected sun vectors toward the receiver (target) in the optical system considered are presented in Fig.III-9. The target vector named also the Heliostat-Tower vector $\vec{R}$= ($\mathbf{R}_X$,$\mathbf{R}_Y$,$\mathbf{R}_Z$)is the reflected sunray by the heliostat can be obtained as:

- $\mathbf{R_X = X_T - X_i, R_Y = Y_T - Y_i, R_Z = Z_T - Z_i}$ (III-2)

The target unit vector can be defined as:

$$\vec{U}_R = \frac{\vec{R}}{R} \qquad \text{(III-3)}$$

III.5.4 Heliostat normal vector

The heliostat normal vector N of a flat heliostat can be computed from the sun and the target vectors $\vec{U}_S$and $\vec{U}_R$ expressed previously in Equations. can be defined as:

$$\vec{N} = \vec{U}_S + \vec{U}_R \qquad \text{(III-4)}$$

where, the components of $\vec{N}$= (N_X,N_Y ,N_Z); are defined as, The normal ray equation can be deduced by multiplying three 4×4 matrices extracted from the cinematic diagram.

III.6 Cinematic diagram

III.6.1 Definition of cinematic diagram

One calls a minimal cinematic diagram that represents a mechanism with at most one mechanical connection between two parts or a class of equivalence. We can also say that it is a representation of a mechanism that highlights the possibilities of relative movements between kinematically linked groups. And in the figure below it represents cinematic diagram.

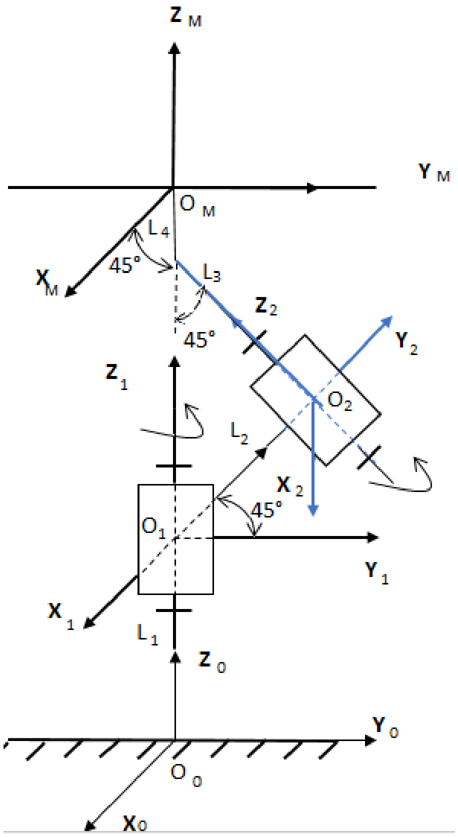

Figure III-12 : *cinematic diagram of heliostat*

III.6.2 Displacement matrix

$$T01 = \begin{bmatrix} \cos(\theta az) & \sin(\theta az) & 0 & 0 \\ \sin(\theta az) & \cos(\theta az) & 0 & 0 \\ 0 & 0 & 1 & L_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T12 = \begin{bmatrix} \cos(\theta inc) & \sin(\theta inc) & 0 & 0 \\ k.\sin(\theta inc) & k.\cos(\theta inc) & -k & 0\ \ KL_2 \\ k.\cos(\theta inc) & 0k.\sin(\theta inc) & k & KL_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T2M = \begin{bmatrix} \cos(\theta inc) & \sin(\theta inc) & 0 & 0 \\ k.\sin(\theta inc) & k.\cos(\theta inc) & -k & 0\ \ KL_2 \\ k.\cos(\theta inc) & 0k.\sin(\theta inc) & k & KL_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$T0M = T01 \times T12 \times T2M \qquad (III\text{-}4)$$

It is the direct geometric model In order to extract the normal ray, the following product must be performed, N=T01×I0 From it we find the components of the normal vector N=T01×I0

$NX = \sin(\theta inc) \times \sin(\theta az)$; $NY = -\sin(\theta inc) \times \cos(\theta az)$; $NZ = \cos(\theta inc)$

where θinc and θaz are the inclination rotation and the azimuthal rotation angles of the heliostat, respectively, and can be expressed as:

$$\theta inc=\arctan\left(\frac{\sqrt{{N_X}^2+{N_Y}^2}}{N_Z}\right);\theta az=\arctan\left(\frac{N_X}{N_Y}\right) \quad \text{(III-5)}$$

III.6.3 Analysis of the resistance of the structure

We first need to determine the dimensions and the area of the heliostats and the different pressures on our structure that affect our structure, then we can check the resistance of the heliostats by simulation, and this takes into account the most unfavorable situations. We can say that such a situation is equivalent to that in which the following pressures act on the heliostats:

- The force generated by the pressure of winds whose speed is equal to 40 km / h, and the orientation is completely normal to the reflection surface
- The Weight of the Mirror
- The weight of the structure with the geared motors and all the parts of the heliostat.

When designing in SolidWorks the material can be defined as shown in the example of the lower ring presented with these properties in the figure below. Thus, the weights of the different parts are known by the simulator and taken into account in the stresses during the simulation, so it is not necessary to calculate them; it remains only to determine the force of the wind which can be calculated by the following equation:

$$F_{\text{wind}}=\frac{\rho SC\alpha}{2}\cdot v^2 \quad \text{(III-6)}$$

Or :

- ρ: the density of the air.
- S: the section opposing the winds.
- Cα: coefficient depending on the direction of the wind in relation to section S.
- V: Wind speed.

According to the specifications, the wind speed can reach 40km / h in "tracking" operating mode, if the speed exceeds 40 km / h, the heliostat switches to "storm" mode where the mirror takes a horizontal position eliminating thus all the forces of the winds. We will consider a wind speed equal to 50 km / h just to be sure of the resistance of the structure if a heliostat does not go into "storm" mode, this will correct any problems before the wind speed exceeds. the 50 km / h. So, we have to convert the values of 50km/h to m/s where we find:

$$V=50km/h=\frac{50\times1000}{60\times60}=13.89\cong 14m/s \quad \text{(III-7)}$$

Concerning the coefficient $C\alpha$, the most unfavorable case arises when the wind applies a normal pressure to the surface of the mirror when the latter is in a vertical position for maintenance, or close to the vertical in "tracking" mode, in this case the coefficient $C\alpha = 1$.

The section opposing the winds is that of a mirror, so $S = 1.864\ m^2$. So:

$$F_{\text{wind}}=\frac{1.146\times1.864\times1}{2}\cdot 14^2=209.34\ \text{N} \qquad \text{(III-8)}$$

III.7 Simulation study

After definition of this force, one proceeded to the static simulation of the resistance of the model starting by imposing a null displacement on the level of the foundation to fix this one.

First, a study must be carried out according to the following stages and in order:

1- Study
2- Body and material
3- Interactions
4- Mesh and execute
5- Results

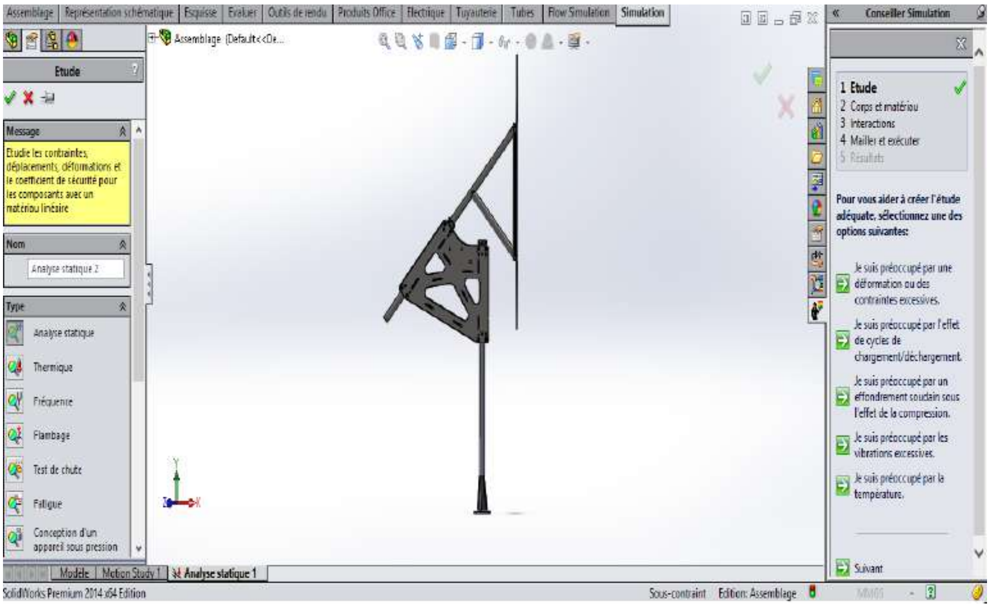

Figure III-13: *Static analysis study*

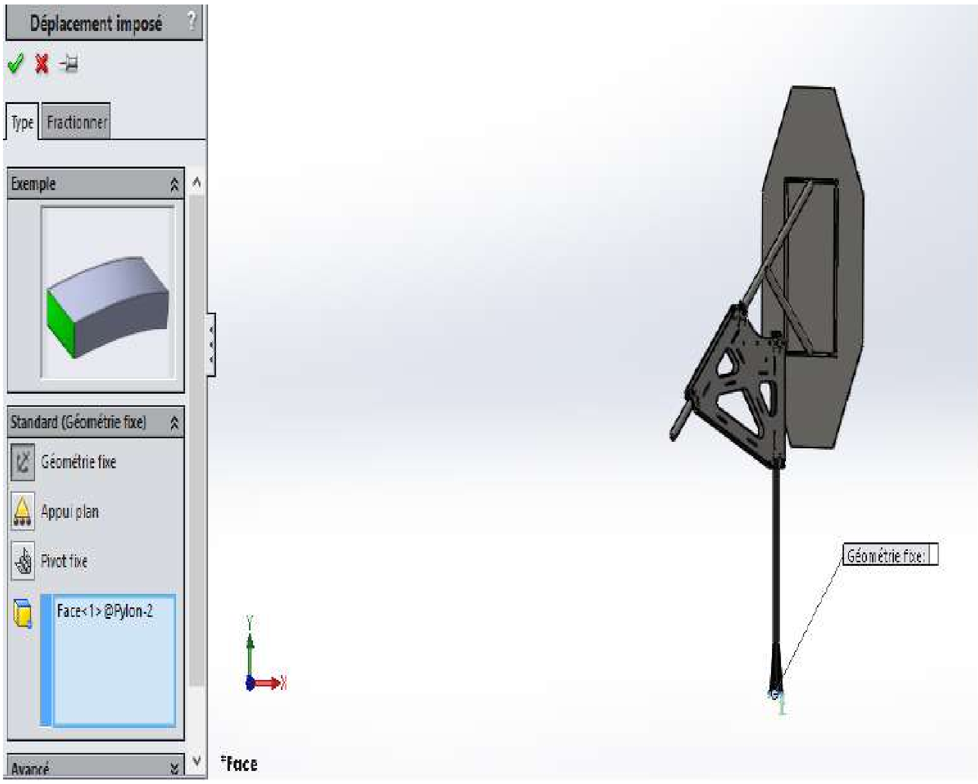

Figure III-14: *Imposing displacement*

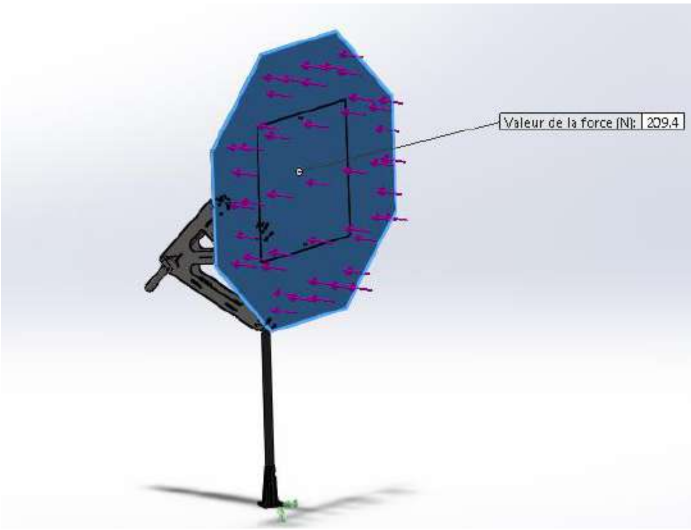

Figure III-15: *Applying load*

After studying and applying the force on a (mirror) face exposed to the force of the wind, we found that it is not possible to study the entire body, and from it we have come to study the important element, which is more influential in the components of heliostats.

At the beginning of the study, all special conditions for international units must be observed

The first step in the analysis is to create a pylon study

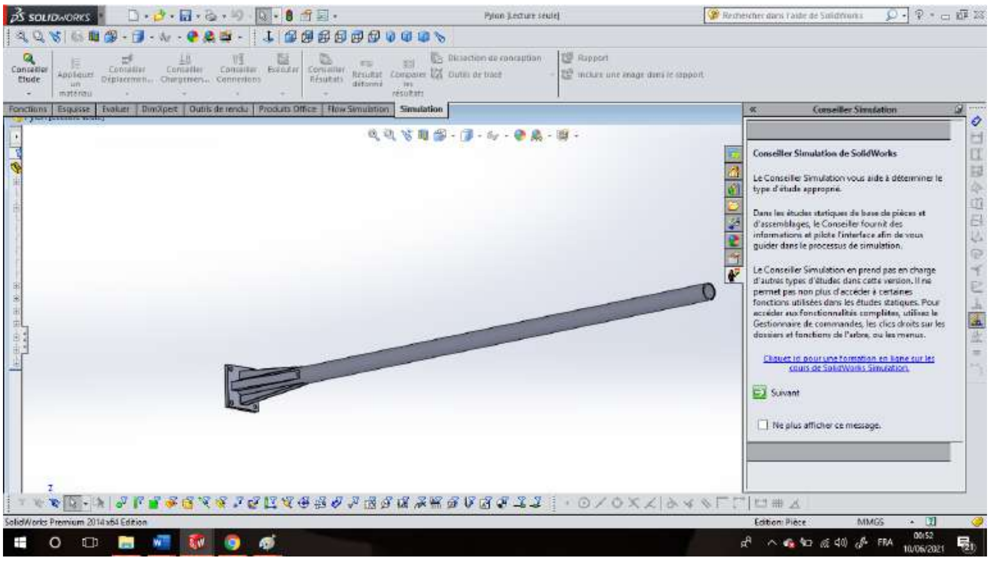

Figure III-16: *Loading the part*

after this step, choose the type of construction steel material (1.0035 s185) It is characteristic:

- **module d'young:** $2.1e^{+011}\ \frac{N}{m^2}$
- **elasticity limit:** $1.75e^{+008}\ \frac{N}{m^2}$

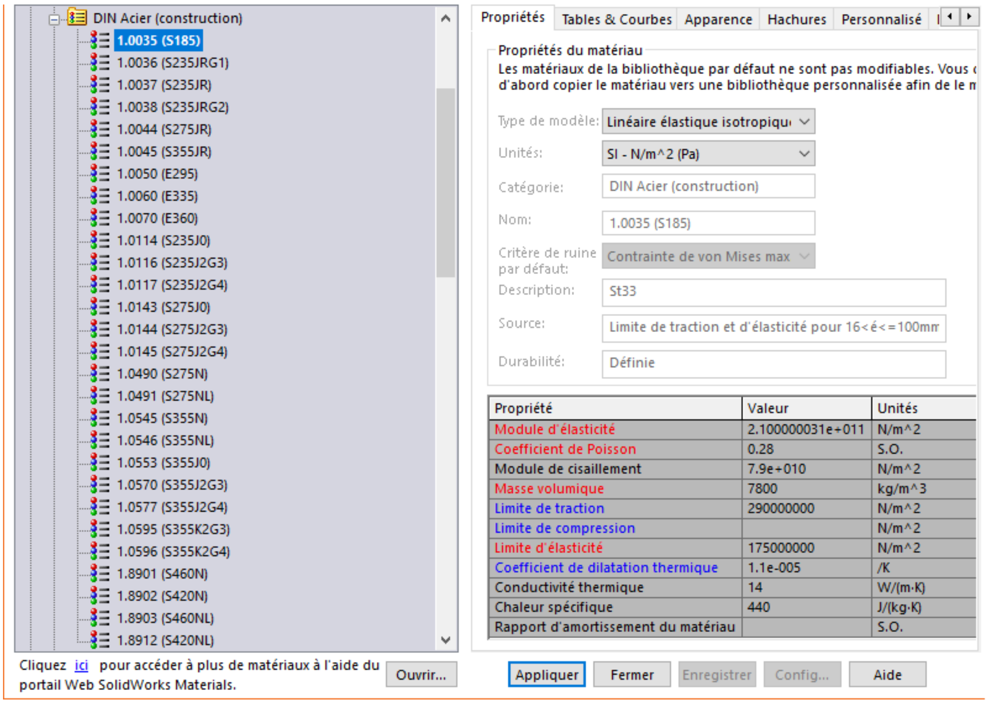

Figure III-17: *Material allocation.*

The next step consists in imposing zero displacements to embed the part. A simple right clicks on imposed displacements / fixed geometry will be sufficient in this case

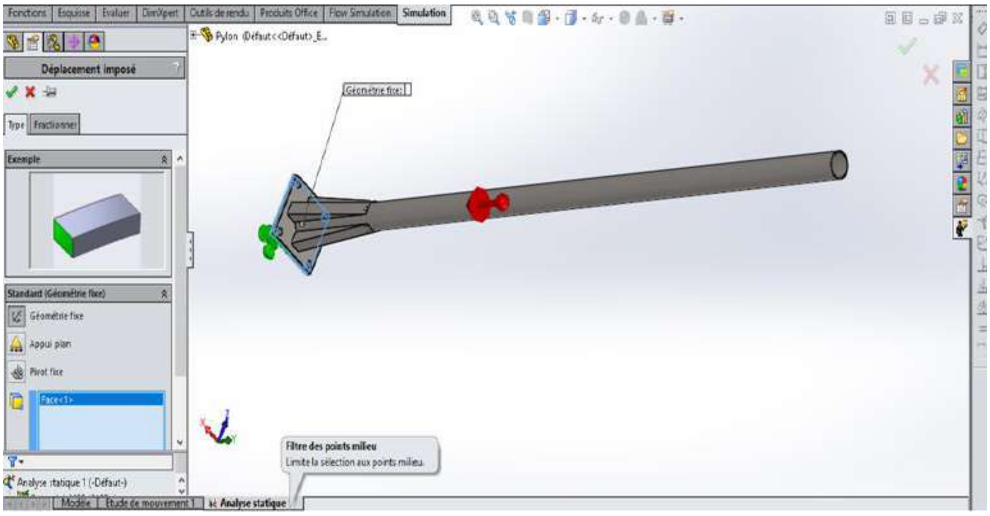

Figure III-18: *Fixing part*

Then, we apply the forces and start the calculations after the creation of the mesh.

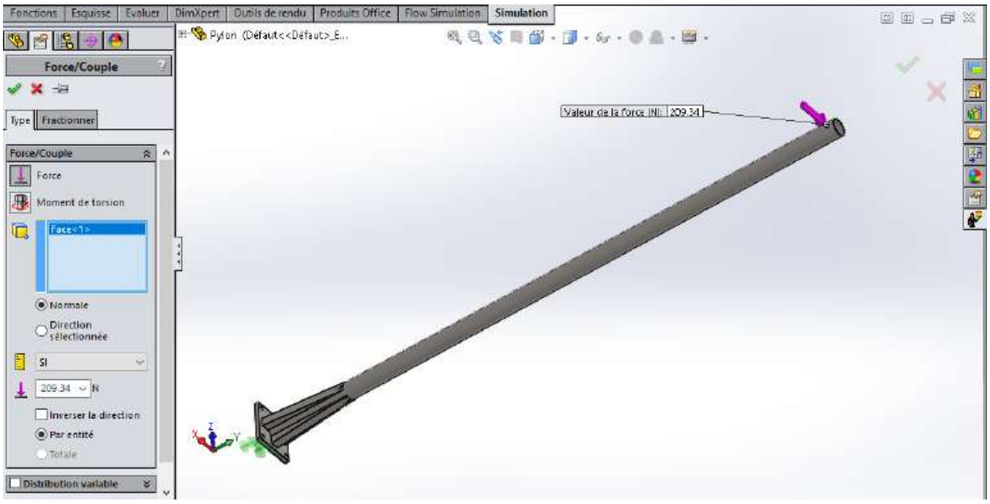

Figure III-19: *applied Loads*

At this point we have applied a force that is valued 209.34 N

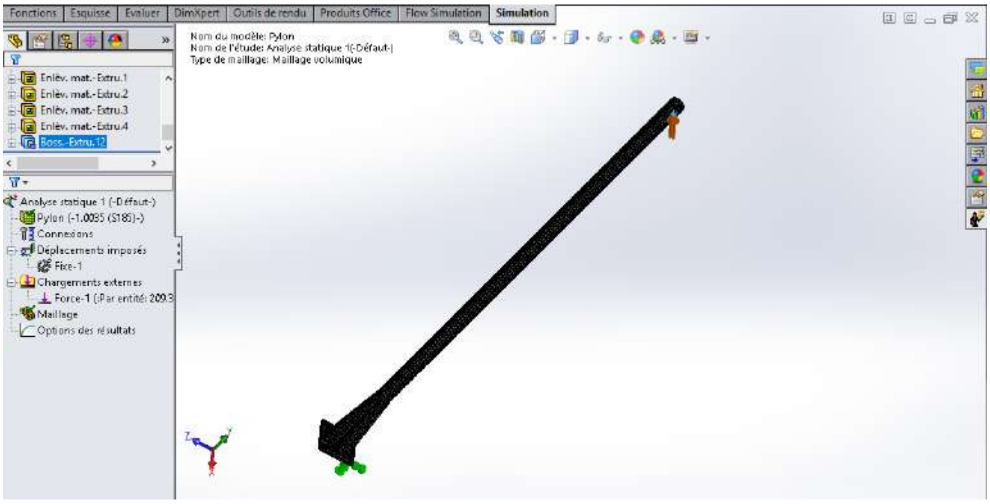

Figure III-20: *meshing*

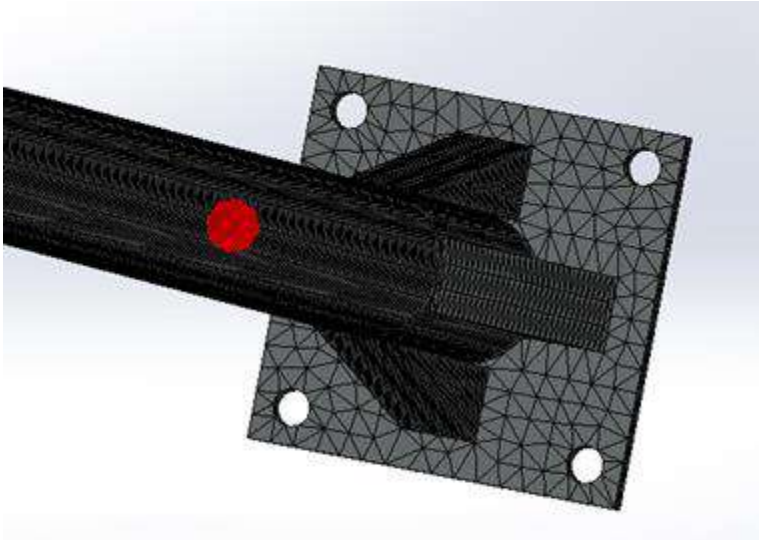

Figure III-21: *Zoom on the mesh*

After exciting the simulation, we get the results shown in the next figures. Fig.III-21 below shows the stress in the pylon, we notice that the maximum is reached near the embedding just above the ribs. It is also clear that the elastic limit isn't reached, for that the pylon will resist the forces indicated above.

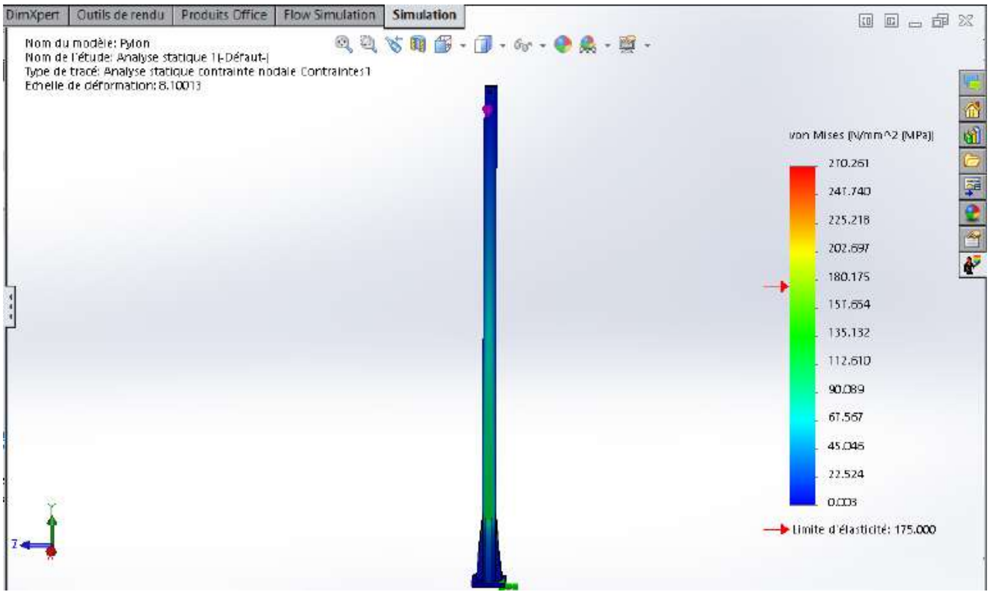

Figure III-22: *Stresse simulation results*

Fig.III-22 shows the displacements; we notice that the maximum is reached the top of the pylon where the load was applied; we can say that it is a small displacement compared to the dimensions of the heliostat and will not decrease the heliostat efficiency and performance.

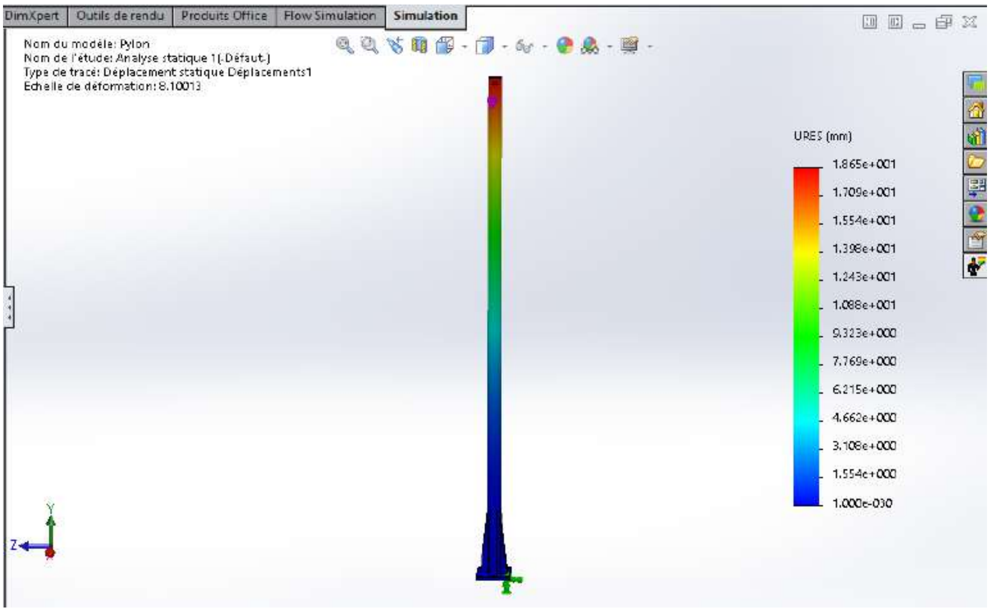

Figure III-23: *Displacement simulation results*

Fig.III-23 shows the strain results, it is clear that the pylon is out of danger since the maximum strain is less than 7e-004.

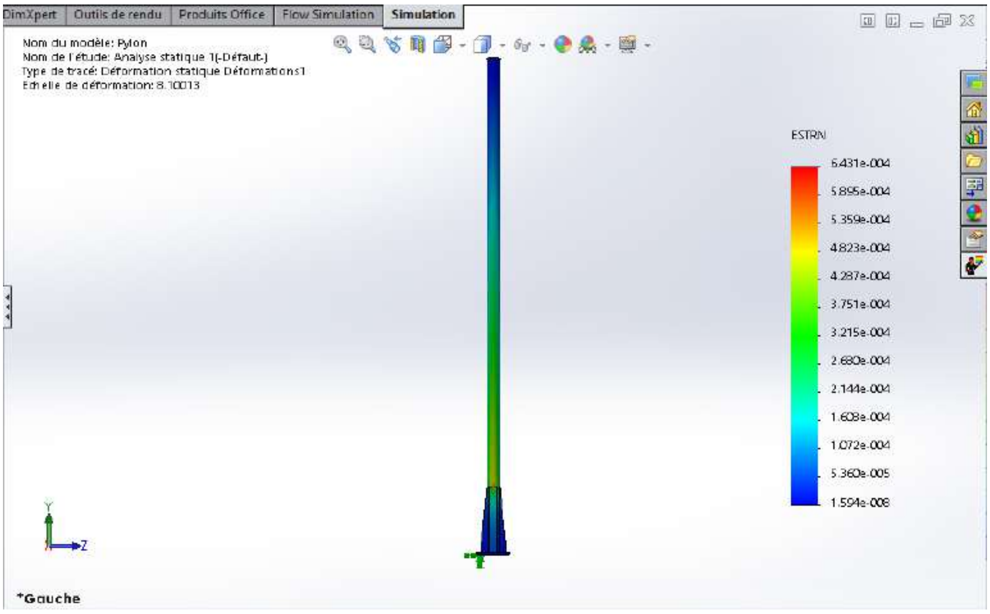

Figure III-24: *Strain simulation results for the static reaction force.*

III.8 Conclusion

In this chapter, we have presented the different stages of the study that we carried out to complete a design that meets the specifications and a comprehensive study on the design of heliostats in terms of the effects of the external force of wind, where we used the SolidWorks software, which helped us a lot in determining the stresses, strain and displacement of the design, as we mentioned its specifications accurately and how it works through two engines responsible for its horizontal and vertical movement in addition to calculating Sun position beam and structure resistance to various problems.

In addition, the cost price is estimated to be compared to other models since it uses simple and low-stress components, unlike actuators known in this field which are precision elements.

Conclusion

Solar energy is one of the renewable energies that mainly provides heat and electricity. We have seen that with the help of new technologies, photovoltaic or thermal solar panels, heat can be obtained through reactions transforming light into heat as well as electricity.

Algeria has many advantages in terms of climate and its important location, and it has the advantage of being located in an area where the annual solar radiation is very high. Therefore, we have explained the risks of non-renewable energy on humans and the environment and avoiding its over-exploitation. We have also explained the advantages of renewable energy on humans and nature, and one of the most important of this energy is solar energy, as solar energy fields are among the best resources in our desert climate.

Reducing the cost of these elements (heliostats) has become a necessity to enhance the use of solar energy. The desert of Algeria, with its sunny climate and its vast desert expanse, is a fertile ground for such projects and technologies, from which the idea of contributing to reducing the cost of solar fields is based, a contribution based on the design proposal. Heliostat is simple and effective; its production costs should be greatly reduced.

The design is well described in Chapter 3 where the assembly, as well as the parts, are represented in different shapes. The pylon resistance was checked during diameter selection and even validated by simulation. All of this work was done in SolidWorks.

Finally, due to time constraints, the study of helicopters is not well detailed, so it is recommended to continue studying the cost and test the prototype to prove its effectiveness and find its actual performance.

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Abstract

At the present time, renewable energies are considered the energy of the future, and it is called the energy of today and tomorrow, but solar energy, which is one of the most important of these energies in terms of its returns, and it is called green energy because it is clean for the environment and for the human being.

We note that it registers a low rate of application despite the development it is witnessing, but we also note that recently it has been given consideration. The main reason behind this is due to the high investment value required for such projects. As a solution to this problem for solar tower projects, which focus the sun's rays towards a thermal future to be exploited in the production of electricity.

Therefore, we propose, through this study, the first design of a solar tracking device model, which, through its simplicity and efficiency, will contribute to reducing the costs of field completion by a percentage that cannot be despised from the total cost of a solar energy project. Also, this design is very simple and inexpensive as there is no similar in the market.

Key words: *heliostat, renewable energy, reflective panels, tower, design, rays, SolidWorks*

ملخص

في وقتنا الحاضر، تعتبر الطاقات المتجددة هي طاقة المستقبل، والطاقة الشمسية هي واحدة من أهم هذه الطاقات من حيث مردودها، فهي طاقة خضراء نظيفة تحافظ على للبيئة والإنسان.

كما نلاحظ أنها تسجل نسبة استغلال منخفضة رغم التطور الذي تشهده ولكن نلاحظ أيضا انه في الآونة الأخيرة قد أعطي لها اعتبار. السبب الرئيسي خلف هذا يعود إلى قيمة الاستثمار المرتفعة اللازمة لمثل هذه المشاريع والحل لهذا الإشكال بالنسبة لمشاريع الأبراج الشمسية والتي تركز أشعة الشمس نحو مستقبل حراري لاستغلالها في إنتاج الكهرباء يكمن في تخفيض ثمن الاستثمار بقدر الإمكان.

لذلك نقترح من خلال هذه الدراسة تصميم نموذج لجهاز تتبع الشمس والذي سيساهم من خلال بساطته وكفاءته في خفض تكاليف إنجاز الحقل بنسبة مئوية لا يمكن تجاهلها وبالتالي خفض التكلفة الإجمالية لمشروع طاقة شمسية. كما يعتبر هذا التصميم انه بسيط جدا وغير مكلف حيث لا يوجد مثله في سوق.

الكلمات المفتاحية: الطاقة المتجددة، الألواح العاكسة، برج، تصميم، أشعة.

Résumé

De nos jours, nous trouvons les énergies renouvelables sont considérées comme l'énergie du futur, et on l'appelle l'énergie d'aujourd'hui et de demain, mais l'énergie solaire, qui est l'une des plus importantes de ces énergies en termes de rendements, et on l'appelle l'énergie verte parce qu'elle est propre pour l'environnement et pour l'être humain.

On note qu'il enregistre un faible taux d'application malgré l'évolution qu'il connaît, mais on note aussi qu'il a été récemment pris en considération. Cela s'explique principalement par la valeur d'investissement élevée requise pour de tels projets. Comme solution à ce problème pour les projets de tours solaires, qui concentrent les rayons du soleil vers un avenir thermique à exploiter dans la production d'électricité.

Par conséquent, nous proposons, à travers cette étude, la première conception d'un modèle de dispositif de suivi solaire, qui, par sa simplicité et son efficacité, contribuera à réduire les coûts d'achèvement du champ d'un pourcentage qui ne peut être méprisé, ainsi qu'à réduire le total coût d'un projet d'énergie solaire. En outre, cette conception est très simple et peu coûteuse car il n'y a pas de similaire sur le marché

Mots clés: *héliostat, énergie renouvelable, panneaux réflecteurs, tour, design, rayons. Solidworks 3D*