

Design and realization of a two axis system designated for mini solar tower

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Abstract—In this work, we present a design of a mathematical model used in the simulation of the behavior of a two-axis solar tracking system (heliostats). This system is used as part of a project of a mini solar tower installed in the region of Ghardaïa. Then we start with the mechanical design of heliostats using SolidWorks software. After that, we went ahead with the realization of this system.

Keywords—solar tracking, solar tower, heliostats, SolidWorks

I. INTRODUCTION

The solar power tower (SPT) is one the systems to produce electricity by use concentrated solar radiation to generate high temperatures, which are later employed to drive a conventional power cycle and produce electricity [1]. In SPT the concentration of the solar radiation performed by mechanical systems namely heliostats. Heliostats are mirrors positioned around the tower, every one of them carried by metallic structure and oriented by two drives.

Heliostats typically contribute about 40% to the total cost of the solar power tower plants [2],[3]. Therefore, the choice of the structural design of the heliostats is important for the low-cost SPT installation.

Our work consists of designing a mathematical model that allows the calculation the position of heliostat field and conception realization the systems (heliostat).

II. MATHEMATICAL MODEL

The position of the sun relative to a point on Earth's surface is defined by two angles:

The sun altitude (h) is the angle between the direction of the sun and the horizontal plan on earth (3).

$$\sin(h) = \cos(\delta) \cos(\varphi) \cos(\omega) + \sin(\varphi) \sin(\delta) \quad (1)$$

δ : declination angle.

φ : location latitude.

ω : hour angle.

The sun Azimuth (a): This is the angle between the projection of the direction of the sun on the horizontal plane and the south (3).

$$\sin(Az) = \frac{\cos(\delta) \sin(\omega)}{\cos(h)} \quad (2)$$

The sun position vector Sun is presented by the following equation:

$$\vec{sun} = \begin{bmatrix} Sun_S \\ Sun_E \\ Sun_Z \end{bmatrix} = \begin{bmatrix} \cos(Az) * \cos(h) \\ \sin(Az) * \cos(h) \\ \sin(H) \end{bmatrix} \quad (3)$$

A. Radiation reflected by the optical system

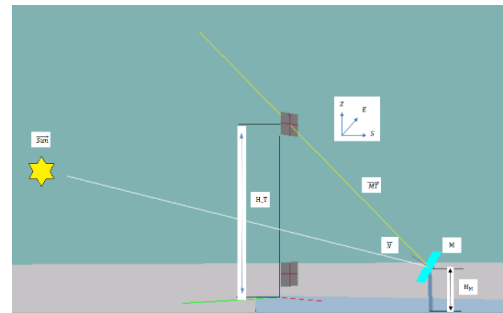


Fig. 1. The different vectors of the optical system

According to Figure 1. Calculating the MT vector is possible if the coordinates of the points M and T are known, with:

$$Cord_M = (S_M, E_M, H_M) \quad (4)$$

$$Cord_T = (0,0, H_T) \quad (5)$$

$$H_M=1.5m, \quad H_T=7.5 m$$

M : Represent the center point of the heliostat

T : Represent the fixed point in the solar tower

The MT vector will be calculated from the expression

$$\vec{MT} = (-S_M, -E_M, H_T - H_M) \quad (6)$$

The normal Vector of the heliostat

The normal vector of a heliostat must be the sum vector of the reflected sunrays unit vector and a unit vector that is from the center heliostat toward the fixed-point (the solar tower).Fig.2.

This vector is given by the following expression:

$$\vec{N} = U_{Sun} + U_{MT} \quad (7)$$

U_{Sun} : Unit sun vector

U_{MT} : Unit vector of the direction of MT

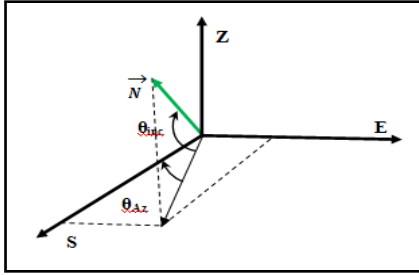


Fig. 2. Component of the N vector

In a system, SEZ fixed to the Earth, the components of the vector N is given by the following formula:

$$\vec{N} = \begin{bmatrix} N_s \\ N_e \\ N_z \end{bmatrix} = \begin{bmatrix} \cos(\theta_{Az}) * \cos(\theta_{inc}) \\ \sin(\theta_{Az}) * \cos(\theta_{inc}) \\ \sin(\theta_{inc}) \end{bmatrix} \quad (8)$$

From this expression the calculation of angles of rotation of vector N is given by the following relation:

$$\theta_{Az} = \arctan(N_s, N_e) \quad (9)$$

$$\theta_{Az} = \arctan(N_z, \sqrt{N_s^2 + N_e^2}) \quad (10)$$

θ_{Az} : azimuth rotation angle of heliostat.

θ_{inc} : incline rotation angle of heliostat.

III. BOUNDARY OF THE HELIOSTATS FIELD

A C++ code has been developed to obtain a preliminary distribution of the land efficiency available on a 460 m surface with a latitude of 32° N [5]. The main parameters used are given in Table 1.

TABLE I. DISCRPTION OF THE FIELD.

Design irradiance, W/m ²	1000
Dimension of heliostat, m	1.2x1.2
Number of heliostats	17
Height of heliostat support, m	1.5
Height of tower, m	7.5
Receiver aperture, m	1x1

IV. CONFIGURATION OF THE HELIOSTATS FIELD

The designed heliostats field for the scale of 25kW solar power tower plant is shown in Fig.3.

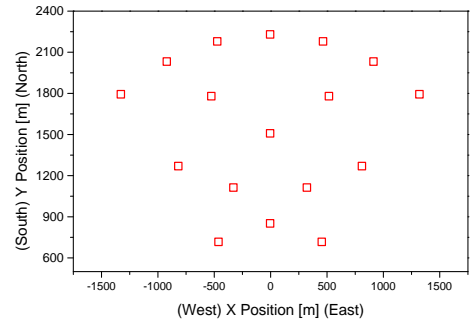


Fig. 3. Layout of the heliostats field

V. PERFORMANCE OF SYSTEM

Using the SolidWorks software [4], we have carried out the design of a prototype heliostat (height of 1.5 m and mirror of 1,2 x 1,2m). The purpose of this design achieved an autonomous system to a motorized support by two direct current motors has two degree of freedoms of type (Azimuth/Altitude), having the function to guide and align a mirror facing the sun while in the long run of the day. This system been manufactured to the unit of applied research for renewable energies (URAER), Ghardaïa, in Algeria. Fig.4.

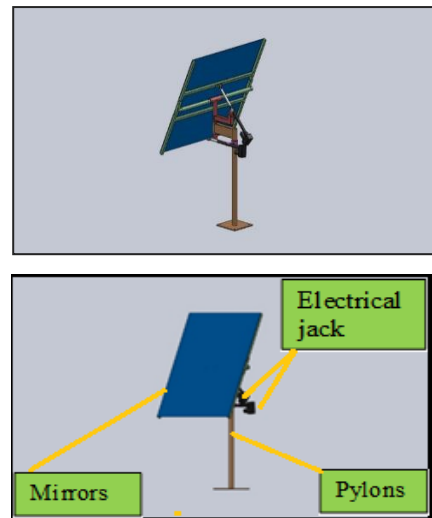


Fig.4. Conceptions of Heliostat

Based on the results of the design and simulation, we have made of this system. Fig.5 After the installation of the heliostat in the solar field (solar tower) and the application of the electronic control system, the heliostat showed a remarkable degree of accuracy and a good functioning.



Fig. 5. The realized design heliostat.

- The Heliostats have been designed and manufactured for the mini test installation of the tower of solar power the unit of applied research for renewable energies (URAER), Ghardaïa, in Algeria. The field of heliostat is newly built; it has 17 heliostats and a tower height of 7.5 m, as shown in the Fig. 6. The heliostats are described below.



Fig. 6. Installation of the heliostats and test

VI. CONCLUSIONS

The heliostats and small reflective zone were designed and manufactured for a mini solar power test tower installation of the Applied Research Unit for Renewable Energies (URAER), Ghardaïa, Algeria. We use a mathematical model to position the heliostats on the terrain with a surface area of 460 m and a tower height of 7.5 m. The main objective of this article is the design and realization of the 17 heliostats for the Ghardaïa zone.

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