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Design and construction of a solar tracking system for linear fresnel concentrator

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ABSTRACT

An open circuit solar tracking system has been designed, manufactured, simulated and implemented for a handcrafted prototype of a small scale linear Fresnel reflector with a single axis of motion. The electronic control system is governed by an Arduino UNO R3 board and two main auxiliary systems; a Microstep Driver TB6600 and an RTC DS1302 module. Further, a mechanism was implemented that joins the reflectors to a stepper motor that executes a single movement per sequence, to move the set of reflector mirrors that make up the reflection system of the device. The positioning angles of the reflectors determined by the control algorithm models for solar tracking, allowed to feed the TONATIUH software to evaluate the path of the solar rays through the 3D modeling of the Linear Fresnel reflector on a real scale. The software was designed to follow the path of the sun by means of astronomical equations. In this way, the mirrors of the Linear Fresnel reflector can follow the solar path on a single axis from 7 am to 5 pm, making changes in the position of each element in 15-minute intervals. The percentage of position deviation of the reflectors does not exceed 1% between the location of the full-scale system mirrors and the position angles provided by the control algorithm. The efficiency of the implemented automatic solar tracking system increased by more than 50% compared to the manual tracking system.

Keywords: Performance, Linear Fresnel Reflector, Control, Renewable, Algorithm

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1. Introduction

Authors are suggested to present their articles in the section The use of solar energy as a renewable energy source in recent years has been increasing, due to its abundance and sustainability [1] [2]. Among the technologies for the use of this resource, are the Fresnel linear concentration or reflection systems. (LFC) [3] [4], candidate within the subgroup of solar thermal technologies as the one with the highest degree of future projection at the research and technological development level [5] [6]. Its applicability is based on the simplicity of the LFC system compared to others, because it presents: ease of maintenance, operation and manufacture at a low cost [7] [8].

LFC systems are composed of rows of reflector mirrors that form a reflection area, which is responsible for redirecting the sun's rays and concentrating them in a focal point or absorption area smaller than the reflection area. [9] [10]. The focal point is made up of one [11] or a series of tubes through which a fluid [12] circulates and absorbs the concentrated solar radiation, converting that energy into thermal heat [13]. Generally, the absorber system is made up of a second reflection system with a trapezoidal shape, to avoid heat transfer losses and increase the absorption capacity of incident solar radiation, improving the performance of the device [14] [15].

LFC technology is applied centrally in electricity generation plants [16] [17] and large-scale thermal energy consumption processes in industrial processes, while small-scale linear Fresnel reflectors (SSLFR) or decentralized are used in the residential sector in urban and rural areas [18] [19] [20].

By its nature, the efficiency of an SSLFC depends on the precision of its optics and the presence of small errors in the solar tracking path [13] [21], so evaluate the optical characteristics and implement solar tracking systems , allows to increase the performance of the device [22] [23]. Other factors that can influence the efficiency of SSLFC systems can be: estimation of the shape of the sun for simulation processes [24], physical properties of materials [25], errors in geometric design [26], manufacturing errors and assembly [27], installation and operating conditions[21].

For optical analysis of LFC systems, there are three basic methods: numerical simulation, CFD Modeling[28] [29] and Monte Carlo ray tracing methodology. The latter stands out for the development of very useful computational tools to evaluate the solar tracking system, since they allow to evaluate the position of the mirrors at different angles, throughout the day, that is, by varying the solar position [30] [31]. Within this method, the TONATIUH software stands out, which allows 3D modeling of the geometry of the SSFLC system, including optical parameters of the device components, defining the direct solar radiation (DNI) incident on the system and the solar position [32] [33].

On the other hand, in large-scale linear Fresnel reflectors, the rows of mirrors and the absorber tube have very long extensions and are not provided with longitudinal movement, forming an angle of 0 (°) with the horizontal plane. For these cases, generally the rows of mirrors are configured to rotate on the North-South axis, in order to track the sun during the day (transversal movement), but there are applications in which the configuration is made in the West-east axis due to its geographical location. In these types of configurations, LFC systems do not usually consider the losses of reflected light to determine the power absorbed by the receiver tube [22] [34].

There are several configurations for possible longitudinal movements of mirrors for solar tracking. The movement of the mirrors can be continuous throughout the day or only at specific times of the day. In the first configuration, the design ensures that for any moment of the day the rays reflected by the mirrors are always directed to the absorption point, while in the second configuration, the location of the mirrors is equal to the latitude of the place, corrected by declination and does not fully guarantee the reflection between the mirror area and the absorption point [35].

In other configurations, the absorption system becomes a secondary reflection system, forming an angle with the horizontal plane without longitudinal movement [35]. In order to improve the efficiency of the linear Fresnel concentrator, we developed a solar tracking system on one axis and studied its behavior. Developing an experimental analysis, to determine the performance of the device from field tests and an analysis of fluid in motion (Hydro-dynamic), subjecting it to a manual and automatic reflector field monitoring. Subsequently, the results of the Hydro-dynamic tests were evaluated, with the performance data of the initial system by the developers of the prototype who analyzed it with a static flow (Hydro-static) [20] [36]. The details are organized as follows.

In section two, the methodology, the implemented materials and the control system developed for the development of the solar path tracking system will be presented. In section three, the results are presented, highlighting a simulation of the device's ray tracing behavior by applying the TONATIUH tool, evaluating the positioning angles of the mirrors delivered by the code developed for solar tracking. At the same time, the experimentation process carried out is highlighted, by means of field tests analyzing the behavior of the implemented system, determining the percentage of deviation of the mirrors and the efficiency of the SSFLC. Finally, in section 5, the most relevant conclusions of the work developed are presented.

2. Material and methods

2.1. Initial Prototype LFC

For the development of the solar monitoring system, the prototype of the Linear Fresnel concentrator was used, developed by the Research Group in energy, automation and control systems GISEAC, of the Technological Units of Santander, Bucaramanga, Colombia, dimensioned and manufactured. In order to experiment with alternative thermal systems for water heating and steam production, applying the Appropriate Technology concept, that is, a device with the following characteristics: low cost of construction, maintenance and operation, use of human resources and local materials for its manufacture and the use of direct solar radiation, incident in the experiment city [20].

- The LFC craft prototype is based on 6 components (See Figure 1):
- Reflector Mirrors “1” Receiver tubes “2”
- Secondary reflection system. Made of 20 gauge Galvanized Sheet, Length 1.2 m, height 0.035 m and width 0.12 m. “3”
- Preheating system (flat artisan collector, made up of 18 serpentine tubes, with a diameter of 0.00635 m) “4”
- Gravity water supply system (Natural Shot) “5”
- Structure “6”

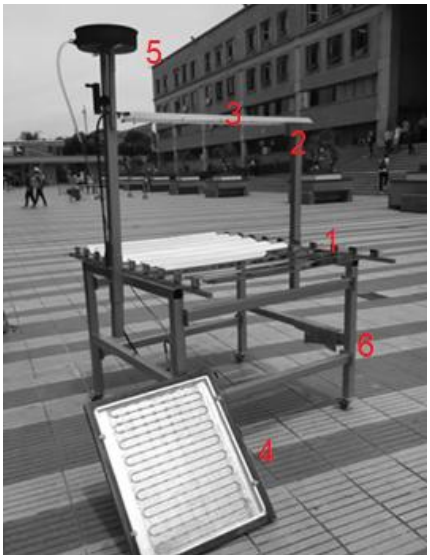

Figure 1. LFC Prototype without manual tracking

Solar tracking is carried out manually and individually for each mirror by one person. Figure 1 shows the full-scale model of the initial LFC device without solar tracking and Table 1 presents relevant dimensions of system components. Additionally, the LFC device presented an experimental optical efficiency value of η = 11.65% in hydro-static conditions, under the meteorological conditions of Bucaramanga, Colombia [20].

Table 1. LFC Device main component parameters without solar tracking

Parameters	Values
Total number of reflecting mirrors	10
Mirror’s length	100[cm]
Mirror width	10[cm]
Total number of absorber tubes	2
Focal distance	75[cm]

2.2. Elements of the transmission mechanism

2.2.1. Movement transmission mechanism

Table 2 shows each of the mechanical components used in the design and implementation of the solar tracking system. Figure 2 shows the base of the mirrors and the rotation system; the mirrors “1” of the primary reflection system can rotate on the north-south axis, to carry out solar tracking during the day. For them, a pin “2” attached to a bearing “3” is used at each end of the mirrors for their structural fixation to a tracking mechanism. This process was carried out for each of the mirrors of the device.

Table 2. Mechanical Components of the Solar Tracking System

Parameters	Values
Total number of reflecting mirrors	10
Total number of bearings	20
Total number of pedestal bearings	20
Total number of connecting rods	10
Total number of stub shafts right	10
Total number of left stub shafts	10

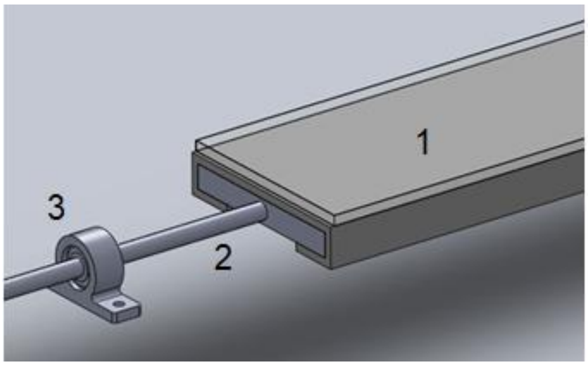

Figure 2. Reflector shaft and bracket

Each movement unit has been designed with SolidWorks and manufactured, separating the mirrors according to the initial design of the LFC prototype as shown in Figure 3. Fixing the mirrors on the device support structure, fixing the bearing prisons , allowing an acceptable angular slip and a maximum inclination of 72 (°) by each reflector, guaranteeing a low coefficient of friction. It should be noted that each mirror will be connected to a single mechanism, but they will not have the same inclination.

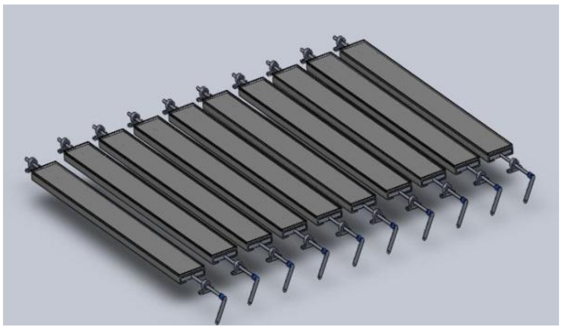
Figure 3. Mirror Bracket Location

The mirror attachment mechanism is shown in Figure 4. The connecting rods “1” connect through one end of the mirrors, a single link “2” with all the reflectors and a stepper motor “3”, installed on a metal structure “4” attached to the prototype base structure. In this way, the angular velocity and the displacement of the

reflection area are obtained, carrying out the movement of a single connecting rod, directly connected to the motor and the link, transmitting the movement to each of the mirrors.
Finally, Figure 5 shows each of the mechanical components described in Table 1 that are part of the solar tracking system implemented and tested in the device.

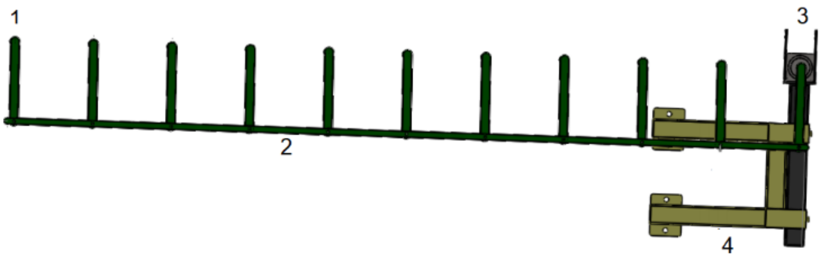

Figure 4. Tilt adjustment mechanism and solar tracking

Figure 5. Full-scale mechanical system of the implemented solar tracking system

2.2.2. Electronic components of the system

Table 3 shows the components used in the articulation of the electronic solar tracking system, while Table 4 shows the energy consumption of each component, evidencing a low electricity consumption, because the system was dimensioned under the concept Appropriate Technology (AT).

Table 3. Electronic Components of the solar Tracking System

Parameters	Values
Arduino UNO R3	1 UND
Microstep driver TB6600	1 UND
RTC DS1302 module	1 UND
NEMA23 STp-59D3 Stepper Motor	1 UND
Cooler	1 UND
LED diode	1 UND
Electric Resistance	1 UND
Voltage adapters	2 UND

Table 4. Consumption of the electronic elements of the system

Item	Amperage (A)	Voltage (V)	Power (W)
Arduino UNO R3	0,046	5	0,23
Microstep driver TB6600	4	12	48
RTC DS1302 module	0,0002	5	0,001
NEMA23 STp-59D3 Stepper Motor	2,8	12	33,6
Cooler	0,12	12	1,44
LED diode	0,0105	12	0,126
Total			83,397

Figure 6 resents the connection diagram of the electrical components shown in Table 3: Arduino R3 “1” board with Atmel Atmega328 microcontroller chip, RTC DS1302 “2” or “Real Time Clock” module, Microstep Driver TB6600 “ 3 "coupled to develop the control in the NEMA23 STp-59D3" 4 "stepper motor, Cooler to dissipate the temperature of the connections" 5 ", Led diode" 6 ", resistor" 7 ", voltage adapter 12 VDC for power NEMA23 STP-59D3 stepper motor, Microstep Driver TB6600 and Cooler, and 5 VDC Voltage adapter to power Arduino UNO R3 and LED diode.

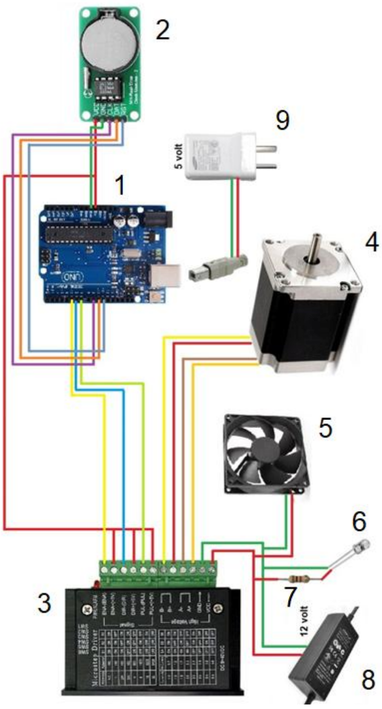

Figure 6. Electronic Control System Connection Diagram

2.3. Control Algorithm

2.3.1. Reflector Position

To determine the location of each of the mirrors in a given time interval during the day, the use of a series of mathematical models is required, which make the prediction of the theoretical location of the reflecting mirrors, inclination and location in the plane. Cartesian. There are GENERAL answers and variables that directly intervene in the position of all the reflectors.

The fixed values correspond to the width of the mirrors "W" of 0.1 m, the focal length "F" between the primary re-reflection system and the concentration point equivalent to 0.75 m and the distance between the center of mirrors of 0.15 m. To determine the general variables, the following equations apply.

First, the calculation of solar declination is determined, equation 1 is used, where Nd corresponds to the day of the year.

$$\delta = 23.45\sin\left(360^* \frac{284+Nd}{365}\right) \tag{1}$$

Subsequently, the hourly angle is determined by applying equation 2, where Nh is the value of the hour of the day in which the Angle is to be determined.

$$\omega=15(Nh-12) \tag{2}$$

With the solar declination and solar inclination data, and knowing the latitude (φ) value of the experimentation site, the solar incidence angle is calculated by means of equation 3.

$$\cos(\theta) =[\sin(\varphi) * \sin(\delta)]+[\cos(\varphi) * \cos(\omega)* \cos(\delta)] \tag{3}$$

In turn, the value of the solar height angle is determined by applying equation 4.

$$Y=90- \theta \tag{4}$$

Once the values of solar declination, hour angle, angle of incidence and angle of solar height have been determined, the variables that directly define the positioning of each mirror are determined. Initially, the angle of reflection is calculated by applying equation 5 and later the angle of declination is determined by applying equation 6.

$$\phi= \tan^{-1}\left(\frac{Li}{F}\right) \tag{5}$$

$$\beta=\left(\frac{\theta-\phi}{2}\right) \tag{6}$$

Where, Li is the distance between the center of each mirror and the center of the area of reflection.
The process of applying equations 5 and 6 must be developed with each of the mirrors of the system, for the specific time in which it is desired to know its positioning. For the development of this study, positioning calculations were carried out in 15-minute intervals, in an hourly range from 7 am to 5 am. These values feed the algorithm designed to control the solar tracking of the device during the day.

2.3.2. Control algorithm

The control algorithm of the solar tracking system has been developed to determine the characteristics to be followed by each of the mirrors to follow the path of the Sun in an hourly range from 7 am to 5 pm.
The mirrors of the first reflector system move freely. This movement is provided by a stepper motor used to rotate the mirrors of the primary reflector system both clockwise and counterclockwise. The calculation of the positioning was carried out following three steps. In the first step, the solar angles have been determined from the estimation of the solar time, the geometric characteristics of the device, the geographical latitude and other parameters such as the solar declination, the solar time and the hour angle. In the second step, the solar angles were used to determine the solar reflection and declination angles.

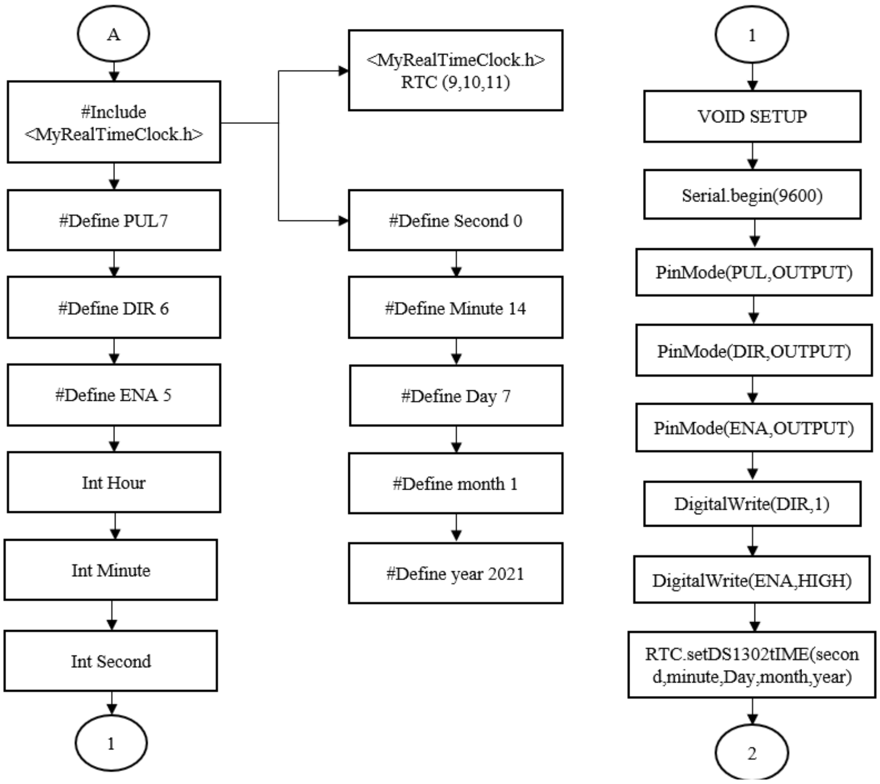

Figure 7. Part 01 and 02 solar tracking system control diagram

In the third step, a code is developed applying the Arduino tool, for which a series of mathematical models intervened that allowed to predict the position of each of the mirrors during the solar trajectory. Figure 7 shows a flow chart that dynamically represents the first part of the code developed, consequently and presents the second part and Figure 8 the third part of the code.

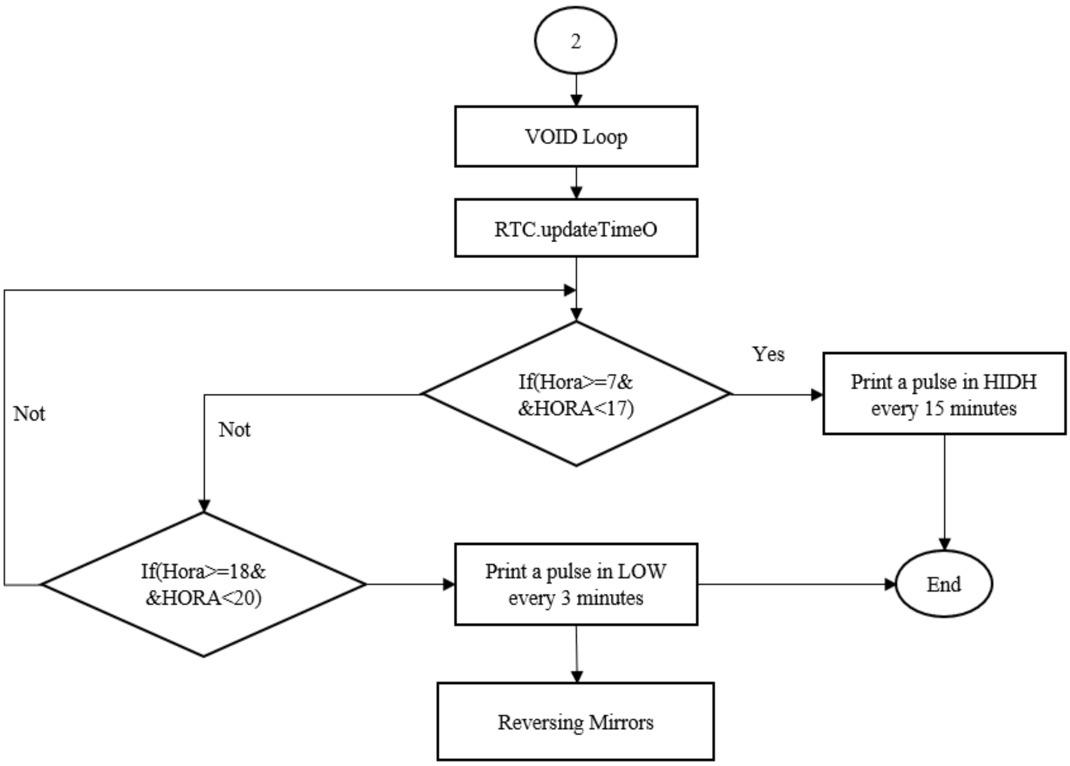

Figure 8. Part 03 solar tracking system control diagram

The tracking system automatically aligns the mirrors to the solar path based on the information from the database supplied in the code, in a time interval of 15 minutes and records the positioning data of each of the reflectors, time and date.

2.3.3. Tonatiuh simulation

TONATIUH is an open access tool, developed by the National Renewable Energy Center (CENER) (Download: https://iat-cener.github.io/tonatiuh/). TONATIUH allows the development of optical and thermal simulations of concentrating solar systems (CSP). The method used for the development of the tool is Monte Carlo's ray tracing (MCTR), simulating the optical behavior of different geometries of solar concentrating systems (CSP).

The software was developed in a C ++ programming language, easy to use and apply. It allows the development of real-scale 3D models of centralized or decentralized CSP systems, allowing the user to include optical characteristics of the elements that make up the device to be studied in the development of simulations.

TONATIUH tool was used to evaluate the path of the solar rays between the reflection point (Reflector field) and the concentration point, applying the angular positioning values of each reflector, supplied by the control algorithm. developed, for the process of tracking the solar path. Thus, through the application of TONATIUH, it is possible to visually evaluate the trajectory of each solar ray used in the simulations.

2.3.4. SSLFC system performance

The performance of the SSLFC system is a fundamental parameter to know the improvement of the device, once the solar tracking system has been implemented. To determine the efficiency of the system, the parameters presented in Table 5, are used, corresponding to those taken by the manufacturers of the initial SSLFC model[20] [36] and applying equation 6.

Table 5. Parameters to Determine the Performance of the SSLFC System

Parameters	Magnitude
Stefan-Boltzman constant	5,67*10^-8 [W/m^2*k^4]
Concentration factor	18,8
Average direct radiation	900 [W/m^2]
Receiver tube emissivity	0,9
Receiver tube surface area	0,0532 [m^2]
Receiver tube length	203 [cm]
Overall loss coefficient	49.88 [W/m^2*k]
Collector efficiency	0.9157
Heat renoval factor	0.907

3. Results and discussion

3.1. Case study

We have considered a specific geographical location: Bucaramanga (Santander, Colombia), with latitude 7.1, longitude -73.12 and altitude of 930 meters. The geometric parameters of the SSLFC system are those described in Table 1 and remain constant during all tests. Additionally, the analysis will be carried out in a hydro-dynamic way using a pumping system, a data acquisition system for Pressure, Temperature and Level variables and a direct solar radiation meter (DNI W / m ^ 2), which They will make it possible to evaluate the

performance of the system from an experimentation process of the SSFLC with the implementation of the solar monitoring system. The average DNI during the test days was 774.6 W / m ^ 2.
Although the study focuses on a specific site and a specific SSLFC model, it can be extended to other sites and to other SSLFCs with totally different parameters.

3.2. Experimentation

The experimentation process was based on the development of a series of field tests that allowed to evaluate the performance of the SSLFC system in general in a Hydro-dynamic way with solar tracking and without solar tracking. The solar tracking mechanism was disabled to perform the hydro-dynamic tests manually and later the solar tracking system was enabled, to carry out the hydro-dynamic tests with the system implemented. These data were compared with the experimental results previously carried out by means of the Hydro-static analysis developed in the same SSLFC system[20].
Figure 9 presents a graph of the behavior of the position of the mirrors as a function of the solar declination angle. This process of movement of each reflector is carried out in 15 minute intervals, gradually modifying the positioning of the Angle β of each element.

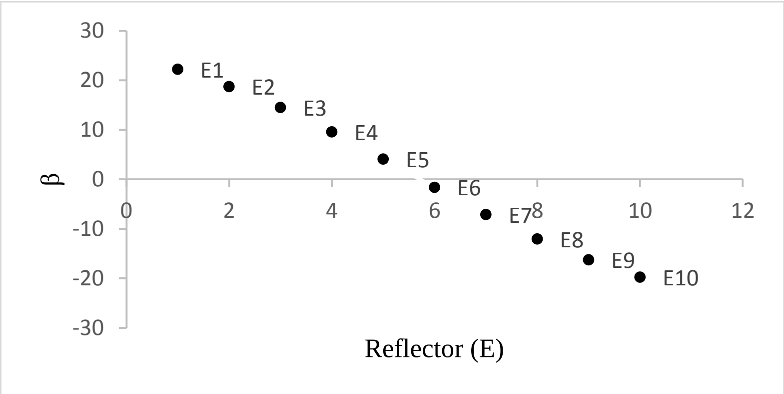

Figure 9.Graph Declination Angles (β) of Mirrors (E) at 12 m

Figure 10 presents the average percentages of Deviation of the angular positioning of each mirror. The process was developed by comparing the angle values calculated by means of the control algorithm and the information provided by the digital tool called Protractor360, with which the position value of each mirror, it was tabulated manually and later, the data were processed offline. The angle of variation of each mirror per hour was 7.4 degrees. Based on Figure 10 it is concluded that:

- The average deviation percentage between the prediction values of the control algorithm and the real position
- of each reflector element, differs by a percentage of less than 1%, evidencing the adequate design and implementation of the mechanical control system, as well as the selection of each of its components.

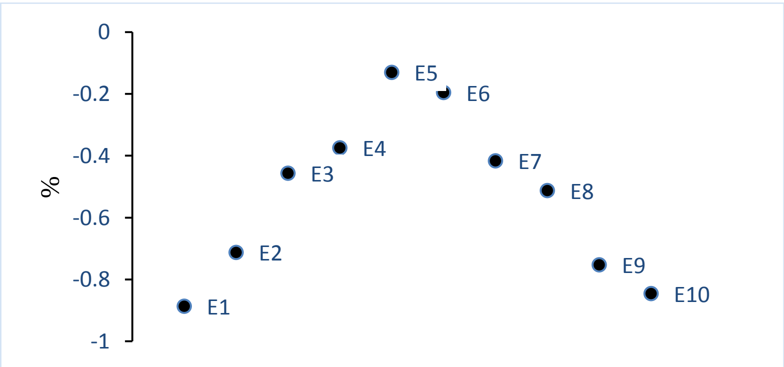

Figure 10. Graph of the average percentages of angular deviation of the mirrors comparing the positioning value of the control algorithm and the actual positioning of the system

Figure 11 shows the development of the ray tracing simulation process under the Monte Carlo method and the application of the TONATIUH Software, in order to predict the path of the solar rays, using the angular values for the positioning of each one of the reflectors supplied by the control algorithm.
The process was developed evaluating the angular position during a time interval from 7 am to 5 pm, varying the position of the reflectors every 5 minutes. Figure 11 a show the position of the sun and the mirrors at 7:00 a.m., reflecting the solar radiation in the concentration zone, in turn Figure 11 b y c, show the same process at 12:00 m and 5:00 pm, respectively. From this simulation stage applying TONATIUH it is concluded:

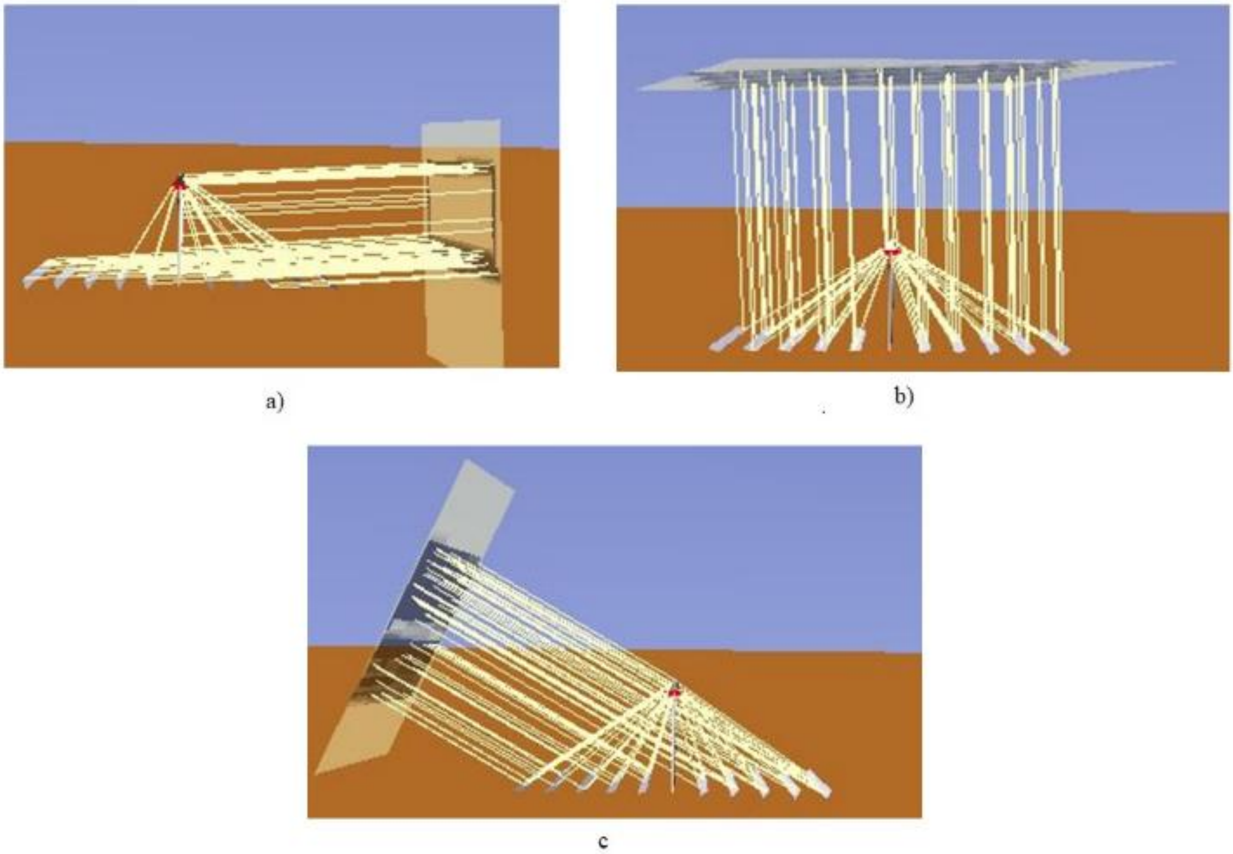

Figure 11. Tracing Sun Tracking Rays Under Tilt Angles of Control System Predictions

- The positioning angles of the reflectors supplied by the control algorithm, for the process of monitoring the solar path, are adequate, due to the graphs of ray traces of the simulations, where an adequate reflection towards the area is evidenced. concentration. This process is visual and when the reflector angles are wrong, the reflectors do not project the solar rays. For the present case study, Figure 11 presents a graphical sample of the graphical interface of the TONATIUH Tool and the adequate projection at three different times, of the solar radiation towards the point of concentration.

Figure 12 shows the average inlet and outlet temperature data of the experimental process developed for the hydrodynamic SSLFC system and without solar tracking. In turn, it presents the final average value of temperature reached by the device for Inlet and outlet temperature of this experimental configuration. The experimentation was carried out from 9 am to 2 pm, due to the incidence of direct solar radiation in the experimentation area, at times outside this time range, the behavior of solar radiation presents cloudy conditions, preventing the operation of the system. Based on Figure 12 it is concluded that:

- The average temperature values of this experimental configuration do not exceed 32 (°) C and present a minimum value of relation of 28 (°) C, between the inlet and outlet temperature value reached by the SSLFC system

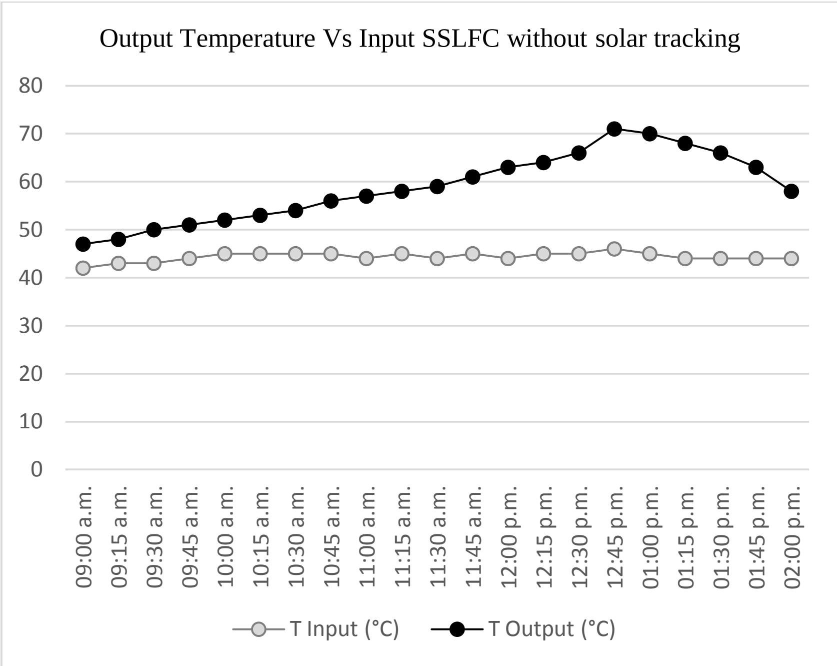

Figure 12. Graph of the behavior of the average input and output temperature of the experimental process of the SSLFC Hydro-dynamic system without solar tracking

Figure 13 shows the average inlet and outlet temperature data of the experimental process developed for the hydrodynamic SSLFC system and with solar tracking. In turn, it presents the final average value of temperature reached by the device for Inlet and outlet temperature of this experimental configuration. Based on Figure 13 it is concluded that:

- The average temperature values of this experimental configuration do not exceed 32 (°) C and present a minimum value of relation of 28 (°) C, between the inlet and outlet temperature value reached by the SSLFC system

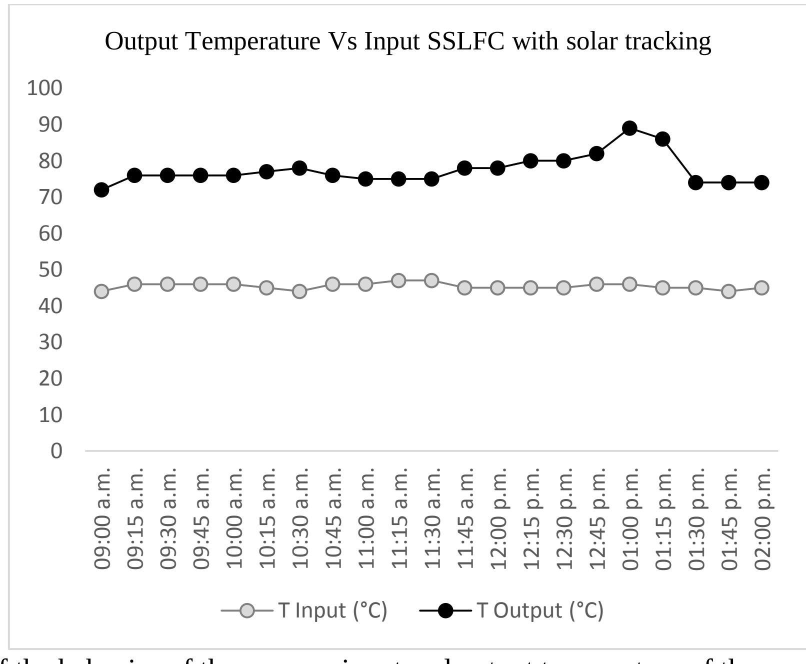

Figure 13. Graph of the behavior of the average input and output temperature of the experimental process of the SSLFC Hydro-dynamic system with solar tracking

Figure 14 shows a comparison between the average output temperature data of the experimental process developed for the hydro-dynamic SSLFC system with solar tracking and the manual solar tracking configuration. In turn, it presents the final average temperature value reached by the device for Outlet temperature in the two experimental settings. Based on Figure 14 it is concluded that:

- The average outlet temperature values of the hydro-dynamic experimental configuration with solar tracking, exceed by 19 (°) C, the configuration of the hydro-dynamic system without solar tracking. This shows a significant improvement in the hot water production process, through the application of process control and automation techniques.

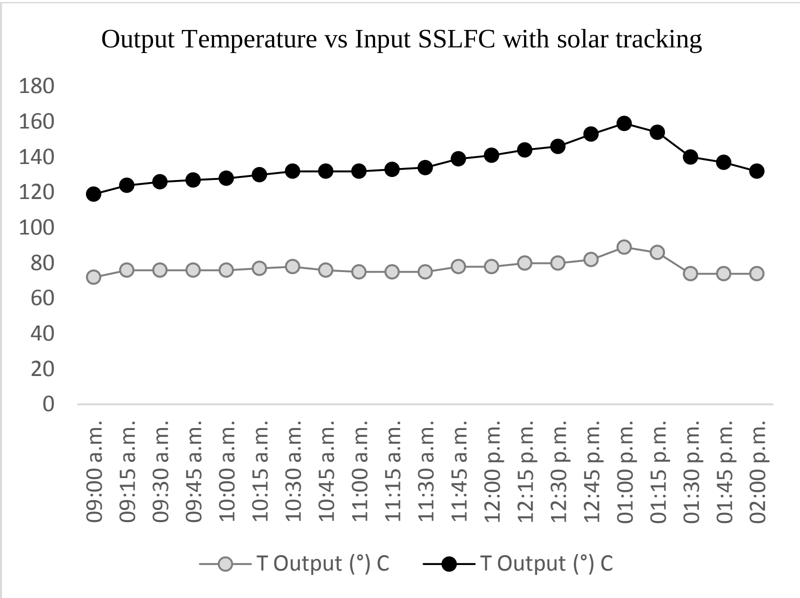

Figure 14. Comparative graph between output temperatures (°) C of the solar tracking system and the manual system

Subsequently, the efficiency values of the experimental processes were determined by applying equation 6 and the parameters of the Table 5. The efficiency calculation of the hydrodynamic system with manual solar tracking is presented below and the average inlet and outlet temperature values of the device presented in Figure 12:

$$\eta \text{ Real}=\frac{Cp(To-Ti)}{AaDNIHdp\eta 0}=\frac{0.032*4206*(58.81-44.33)}{1*774.6.8*0.77}$$

$$\eta \text{ Real}=3.26\%$$

For its part, the efficiency calculation of the hydro-dynamic system with solar tracking is presented below and the average inlet and outlet temperature values of the device presented in the Figure 13:

$$\eta \text{ Real}=\frac{Cp(To-Ti)}{AaDNIHdp\eta 0}=\frac{0.032*4206*(77.48-45.43)}{1*774.6*0.77}$$

$$\eta \text{ Real}=7.16\%$$

Figure 15 shows the comparative graph of the performance percentages of the SSLFC system and concludes:

- The system presented low efficiency values with respect to the two Hydro-dynamic experimentation processes, the efficiency of the system does not exceed 10%.

- The manual solar tracking system presented an efficiency of 3.26%, while the solar tracking system managed to increase the performance of the device by about 50% with respect to the percentage value of the manual tracking system.

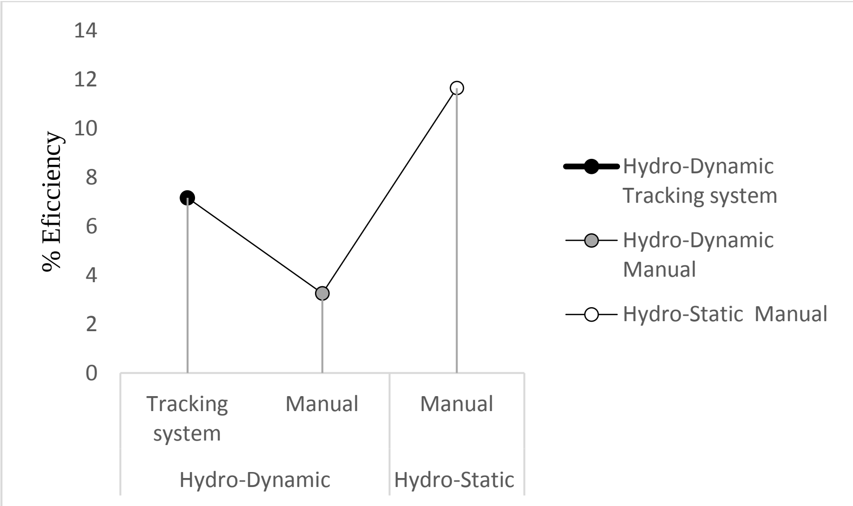

Figure 15. Comparative graph of efficiency of the Hydro-Dynamic experimentation process

Finally, Figure 16 shows the comparison between the experimental analysis developed in the present project and the experimental analysis developed by the Research Group in Energy, automation and control systems GISEAC, of the Technological Units of Santander, Colombia., In the validation of the construction of the Devices. The experimental analyzes differ in aspects of the supply of heat transfer liquid (Water), where the experimental study developed by the manufacturers of the SSLFC was Hydro-static and the present analysis uses a water pumping system (Hydro- Dynamic). It concludes:

- The Hydro-static system presented an efficiency of 11.65%, higher than the values shown by the manual solar tracking system and the automated solar tracking system of 3.26% and 7.16% respectively. This difference occurs because the hydro-static system was evaluated in a fixed way, that is, the flow variable was not controlled for the experimentation, while in the tests carried out with the Hydro-dynamic system, the flow was constant, all the time and was kept at a value of 150 liters / hour.
- The Hydro-static system, despite presenting an efficiency level higher than the hydro-dynamic one, lacks applicability at a centralized and decentralized level, this is because the systems installed on a low, medium or large scale require systems pumping by natural or forced draft, for its applicability and functionality both in residential and industrial areas.

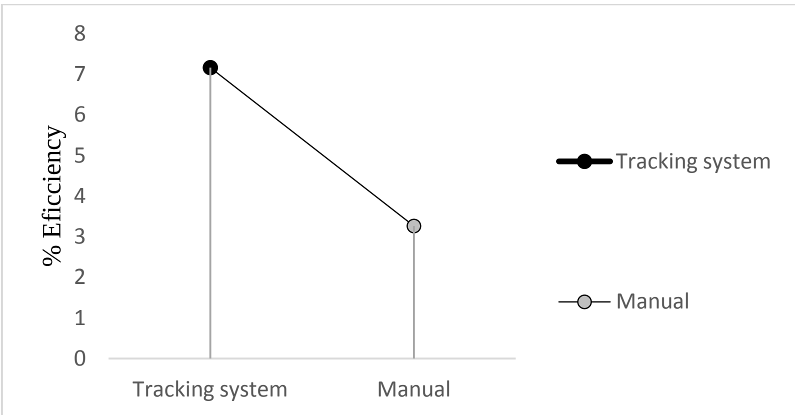

Figure 16. Comparative graph of efficiency of the Hydro-Dynamic experimentation process and the Hydro-Static experimental process

4. Conclusions

The present work dimensioned, implemented, simulated and experimented a single axis solar tracking system for a small scale Linear Fresnel reflector. A control algorithm was developed to follow the path of the open-loop sun. The system can follow the solar position from 7 am to 5 pm, this was projected in order to duplicate the work presented in areas with high incidence of direct solar radiation, in the city of Bucaramanga, the average time of use of this type of radiation was from 9 am to 2 pm, based on the experimentation carried out with the device.

The hardware of the control system is governed by an Arduino UNO R3 board, complemented by a Microstep Driver TB6600 and an RTC DS1302 Module, with specific characteristics that adhere to the functional development of the device under the characteristics of Appropriate Technology, based on a Minimum energy consumption and low cost of implementation, as well as availability of electronic elements in the premises and the operation of the system by anyone, under a simple instruction manual.

The simulation, applying TONATIUH and the Monte Carlo ray tracing method, of the reflection behavior of the solar tracking system, through the values of the inclination angles obtained by the control algorithm, allowed to visually verify the predictions developed, by the mathematical models that made up the control system, ruling out wrong mirror positioning angles.

The performance of the system was evaluated in terms of power absorbed by the absorber tubes, evaluating the results obtained by the Hydro-dynamic experimentation developed under the same conditions for the manual and automatic solar monitoring system, later this data was compared with the initial efficiency of the device determined under Hydro-static tests. Additionally, the tracking errors of the automatic system were analyzed. It is thus, that it is concluded:

- The influence of solar tracking error increases as the mirrors moves away from the focal point or central mirrors.
- Following errors are acceptable, do not exceed 1%, and are the result of mirror loading, shaft friction, resistance of mounting hardware, and wind at the testing site.
- The performance of the automatic solar monitoring system was 7.19%, surpassing the manual monitoring system by a value close to 50% under Hydro-dynamic conditions, evidencing the increase in the values of thermal power absorbed by the absorber tubes when manipulating the Positioning Angle of each reflector element at the same time.

Finally, the low-cost solution proposed presents a good alternative for a one-axis solar tracking system, for a small-scale Linear Fresnel reflector under the Appropriate Technology concept, taking advantage of regional resources and the incidence of direct solar radiation. At the same time. Despite the low efficiency of the system, the technological development of emerging systems is essential for the search for future solutions, in order to offer profitable alternatives, to be implemented in areas with operating conditions similar to those evaluated. in this document.

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