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The new perspectives of solar energy in Algeria, with thermal experimental study of a parabolic trough solar concentrator in several cases

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***Abstract*—In this article which presents a experimental study of parabolic trough collector concentrator. In this work, we propose the practical realization of any concentrator having a 2.88 m2 opening and it is equipped by a solar semi-electronic tracking system with a closed circuit of the heat- transfer fluid. A study on the extensive comparison of three outdoor test methods for determining the thermal performance of parabolic trough solar collectors is presented. These test methods of vertical movement and two other case of bi-axel movement with and without the absorber tube glass envelope, in other review the principles of the work of power plants with a review of the possibility of solar energy in Algeria. There are also important conditions for power generation with economic concentrating solar power provides all the electrical grid requirements.**

The experimental side has studied the influence of the prototype's orientation on the performances of training. Several trials have been carried out in order to have the possibility of attending the temperatures that can ensure the vaporization of water. These trials have been preceded in different conditions of climatic operation. The results are provided and have been discussed. They are discussed in detail and are explained in view of the on-site parabolic trough solar collectors in the real service

***Keywords*—solar energy; experimentation; parabolic trough; solar collector; the realization**

I. INTRODUCTION

Henceforth, the solar energy is an essential solution for the human life's development. The most basic processes surviving in the earth, such as the photosynthesis and the cycle of rain are due to the solar energy.

The recent industrial development and the environmental effects show that the solar energy is the most promising sources of energy which are not convential. The most part of available plants in the solar common trades use the cylindrical- parabolic concentrator.

The parabolic collector contains: receiver pipe, a concentrator, power of transmission, collector's structure, and the receiver is a system on which the solar radiation is absorbed and converted to thermal energy. It contains an absorber pipe, its glass cover and the insulation at its extremity. And on top of it all Algeria is one gas reserves in the world increased by solar and wind energy.

In 1962, Algeria has established renewable energy and put the interests of the most important conditions for the change of hydrocarbons without risk to health and the environment.

The solar systems with concentration offer the ability to produce the electricity through the solar energy, the temperatures that can exceed the **500 °C** and the conversion yield is generally high. By using the direct solar radiation. This one is considered as a principle resource which is very considerable in the planet; these technologies provide a real alternative to the consumption of fossil resources with low environmental impact and high potential for cost reduction, as well as the possibility of the hybridization of these installations.

Today, thousand of captors produce a power more than **674 MW** in the desert of Mojave south California, this power present **90%** of the solar capacity set up in the world. **[1]**

Many researches are carried out in order to study the absorber, the different performances of pipes such as the absorber pipes without glass envelop **[2]** and pipes with glass envelop. It means that our study is based on two different elements in the concentrator parabolic trough solar which are: direction and absorber pipe.

II. SOLAR ENERGY

A. Assessment of the Potential of Concentrating Solar Power Use in Algeria

Evaluated siting parameters for centralized concentrating solar power plants are required before locating a real plant. The potential for CSP implementation in Algeria depends on identifying and analyzing these technical and economical parameters and issues which are listed in **Table 1** and studied, in addition to other parameters.

Due to the nature of CSP technology, only the direct normal insolation (DNI) can be used which limits the high-quality CSP sites to areas with low levels of atmospheric moisture and particulates, little or no cloud cover, and high levels of DNI around the year, deserts thus being the most typical for these conditions **[3].**

Table 1

Main siting factors of concentrating solar power plant [4].

Siting factor	Requirement
Solar resource	Abundant 4(1800 kWh/m2/year) for economical operation.
Land use	20,234 m2/MW of electricity production.
Land cover	Low diversity of biological species, limited agriculture value.
Site topography	Flat, slope upto3%,1% most economical.
Infrastructure	Proximity to transmission-line corridor, natural gas pipeline.
Water availability	Adequate supply, otherwise dry cooling

Further, the required solar field size for CSP is directly proportional to the level of DNI, with the solar field representing about 50%of total project cost; the DNI level will have the greatest impact on

Overall CSP system cost since the CSP systems require high DNI for cost-effective operation. Sites with excellent solar radiation can offer more attractive levelized electricity prices, and this single factor normally has the most significant impact on solar system costs **[3].** It is generally assumed that concentrating solar power systems are economic only for locations with DNI above (1800kWh/m2/year) (circa5kWh/m2/day) **[3, 5].** The geographic location of Algeria, in the Sun Belt region, and the climatic conditions such as the abundant sunshine throughout the year, low humidity and precipitation, and plenty of unused flat land close to road networks and trans- mission grids, have several advantages for the extensive use of the solar energy as enormous potential for power generation compared to global energy demands.

According to a study of the German Aerospace Agency (DLR) based on satellite imaging **(Fig. 4**), Algeria, with1, 787,000 km2, has the largest long term land potential for the concentrating solar power in the Mediterranean basin. In addition, as shown **in Table2 [6**], the value of solar radiation falls between 4.66kWh/m2 and 7.26 kWh/m2; this corresponds to1700kWh/m2/year in the north and 2650kWh/m2/year in the south. The insulation time over the quasi-totality of the national territory exceeds 3000 h annually and may reach 3500 h in Sahara. With this huge quantity of sunshine per year, Algeria is one of the countries with the highest solar radiation levels in the world; this solar potential exceeds **6** billion GWh/year **[6].** The economic potential for solar energy generation in Algeria has been assessed by the DLR and the CDER, mainly from satellite imaging and further processing. The derived economic potential data are gathered in the REs guide report by the MEM [5] and estimated at 169,440 TWh/year for thermal solar system.

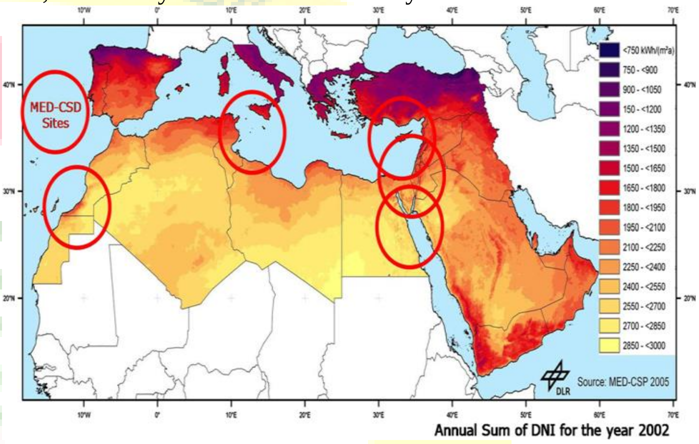


Fig. 4. Solar thermal electricity generating potentials in Algeria [7].

B. Future Parabolic Trough Power Plant Projects in Algeria

Parabolic trough solar thermal power plant (PTSTPP) is one of the attractive technologies to produce electricity from thermal solar energy that use mirrors to focus sunlight onto a receiver that captures the sun's energy and converts it into heat that can run a standard turbine generator or engine. PTSTPP systems range from remote power systems as small as a few kilowatts (kW) up to grid-connected power plants of 100s of megawatts (MW). The process of energy conversion by PTSTPP consists of two main parts:

- The concentration of solar energy and converting it into usable thermal energy.
- The conversion of heat into electricity, which is realized by a conventional steam turbine.

This paper goes on to give a review on the assessment of concentrating solar power (CSP) potential, and PTSTPP projects development in Algeria.

Three further hybrid power plant units are to be completed by 2018, with 70MW parabolic trough solar power plants capacity for each one of them; each one will be scale-ups of Hassi R'mel, and are part of the government's plan to develop electricity production and exports from renewable energies in Algeria **Table 3** lists the new PTSTPP proposed generation projects in the Algerian investment plan under MENA CSP scale-up programme, with a scheduled accumulated CSP capacity of 210 MW.

TABLE 2
Solar potential in Algeria

Areas	Coastal area	High plains	Sahara	Total
Surface (%)	4	10	86	100
Area (km2)	95,270	238,174	2, 048,297	2, 381,741
Mean daily sunshine duration (h)	7.26	8.22	9.59	
Average duration of sunshine (h/year)	2650	3000	3500	
Received average energy (kWh/m2/year)	1700	1900	2650	
Solar daily energy density (kWh/m2)	4.66	5.21	7.26	
Potential daily energy (TWh)	443.96	1240.89	14,870.63	16,555.48

Two options are being considered for the first project, which will be located in Meghaier, in the southeast part of Algeria. Both would include a 270–280 ha solar island using parabolic trough:

Option 1: power production only, total capacity 400MW, of which 70 MW was generated from PTSTPP.

Option 2: integrated desalination/power production, total capacity 480 MW, of which 80 MW PTSTPP (the plant would treat local brackish water) **[8].**

TABLE 3

Three new solar integrated projects under various stages of consideration [3, 9].

Solar–gas hybrid power plant	Location	Installed CSP capacity (MW)	COD
SPP II: Solar power plant	Meghaier	70	2014
SPP III: Solar power plant two	Naama	70	2016
SPP IV: Solar power plant three	Hassi R'mel	70	2018

C. Solar radiation in Algeria

Algeria has a significant solar sink. From its climate, the maximum solar density in any point (clear sky, June) exceeds the 6 kW/m2 and maximum annual received energy in Algeria is close to 2500 kW/m2 [10]. The implantation of solar installations, dictated by the judicious choice of the preferred sites for a better collecting, is conditioned by the sweeping of all the territory (48 Provinces) which will enable us to select the sunniest cities for which the collector efficiency is optimal (figure 1). From its strategic importance, the area of Adrar (South-West of Algeria) is the favorable area for such projects. However, the problem of transport of energy produced could constitute a handicap which one must free oneself.

The history of using solar energy in Algeria backs to 1954 with the solar furnace built by the French for ceramic fabrication purpose. Because of the geographic position, Algeria is considered one of the best places for solar energy usage.

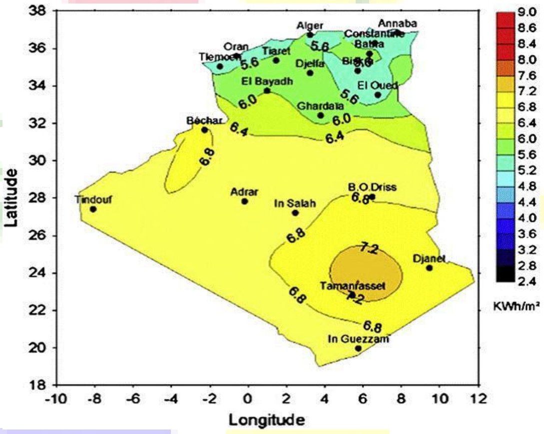
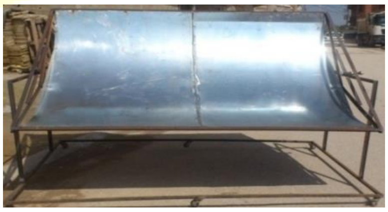


Fig. 1. The solar irradiation in various areas in Algeria.

III. EXPERIMENTAL STUDY

A. The Realization

1) The different steps of contribution of parabolic trough solar



(A)

(B)

(C)

(D)

Fig.2. The cylindrical parabolic concentrator.

These four photos show the different steps of the designing of this cylindrical parabolic concentrator. In the beginning, the structure of the galvanized support is designed to form the semi- cylindrical solar parabolic concentrator as it is shown in the photo (A), the photo (B) shows the location and the pasting of mirrors on cylindrical iron. However, for the photos (C. D), they present the final form of our cylindrical parabolic body.

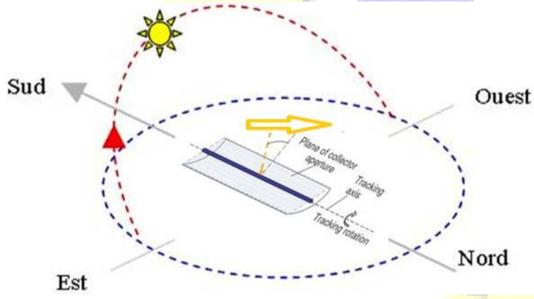


Fig .3. Guidance Mode

B. Experimental Results

It is true that the tests will be conducted in two different days. But we chose the days which have almost the same radiation **[11].**

1) Performance test with vertical orientation

The figure (4) shows the results of the test which is done on July **25th2014**. There was an ambient temperature **41°C** with an occasional wind.

In the beginning, the temperatures were very close. Then, they were increased especially in the absorber and the outgoing temperature.

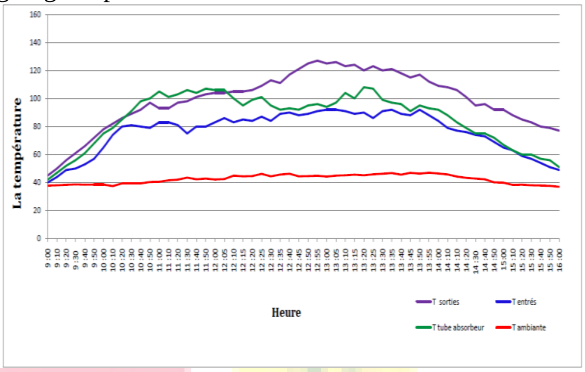


Fig .4. Experimental results of cylindrical parabolic concentrator with vertical orientation done on July 25th2014.

After **80minutes**, we observe that the temperature of the absorber has exceeded the temperature of heat-transfer fluid in the outgoing but it does not stay a long time till the fluid's temperature exceeds the temperature of the absorber in the outgoing, it attended its maximum **127° C** at **12H 55mn**. Then, it is decreased to **77° C** at **16h** in the end of the experimental session.

We notice quite changes of heat in the absorber pipe under the influence of the variety and the speed of the wind. The following table indicates the maximum temperature in the different parts of the cylindrical parabolic concentrator:

TABLE -04-

	T°C	HOUR	DATE
Ts max	127	12 :55	July 25th 2014
Te max	93	13 :00	July 25th 2014
Tabs max	108	13 :20	July 25th 2014
Tamb max	47.1	13 :55	July 25th 2014

2) Performance test and a bi-axial orientation (slanting)

The tests are done on July **29th 2014** from **9h00** till **16h**, it was a clear day but there was some wind at the beginning with an ambient temperature **41° C.**

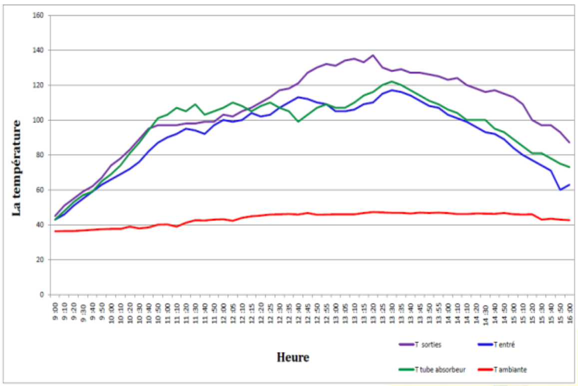


Fig .5. Experimental results of cylindrical parabolic concentrator with a bi-axial orientation done on July 29th2014.

After the method's change of the bi- axial orientation of cylindrical parabolic concentrator, we have noticed an increase in the fluid's temperature at its outgoing, in this case, the capitation of solar rays is very important where the huge use of solar energy is insured.

We noted a temperature **137°C** which have attended only **127°C** during the last experience that proves the performance of this case.

The next table proves the experimental results:

TABLE -05-

	T°C	HOUR	DATE
Ts max	137	13 :20	July 29th2014
Te max	117	13 :30	July 29th2014
Tabs max	122	13 :30	July 29th2014
Tamb max	47.3	13 :20	July 29th2014

3) The performance test with bi- axial orientation 5 cm

The Figure (6) indicates the results of the test which is done on **August 13th 2014** with an ambient temperature **41°C.**

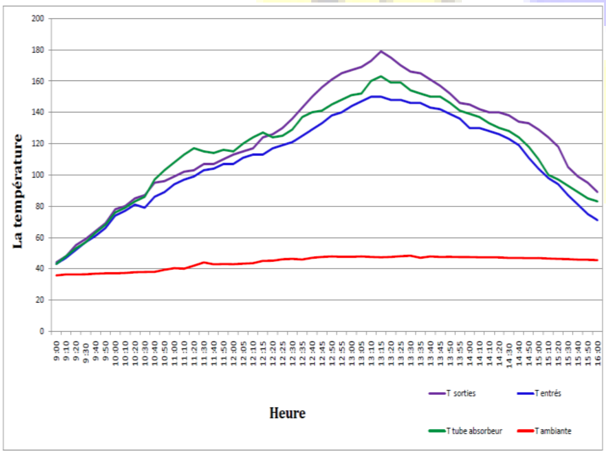


Fig .6. Experimental results of cylindrical parabolic concentrator with bi-axial orientation and the absorber pipe covered by a glass envelope which is done on July 25th 2014.

In the third experiment, we have covered the absorber pipe by **05 cm** diameter of glass. In this case, the obtained results are more effective than they were in the second one.

In the temperature increase process, this one became fast and attended **100°C** at **11h** o'clock, where it does not increase in the last experiments till **11 h 40 mn**. The glass cover of the absorber pipe has clearly contributed in the increase of the outgoing temperature which has attended the maximum **(179°C)** at **13 h 15 mn.**

TABLE-06-

	T°C	HOUR	DATE
Ts max	179	13 :15	August 13th2014
Te max	151	13 :15	August 13th2014
Tamb max	163	13 :15	August 13th2014
Tamb max	48.3	13 :30	August 13th2014

C. Comparative Study

The comparative analysis on the projections of the essential thermal performance indicators shows the advantages and disadvantages of these three test models according to both the practical operation and weather conditions, which proves that the method of orientation be the potential core of a quick, reliable on-site thermal performance test method at some future time.

1) between the vertical and the bi-axial orientation

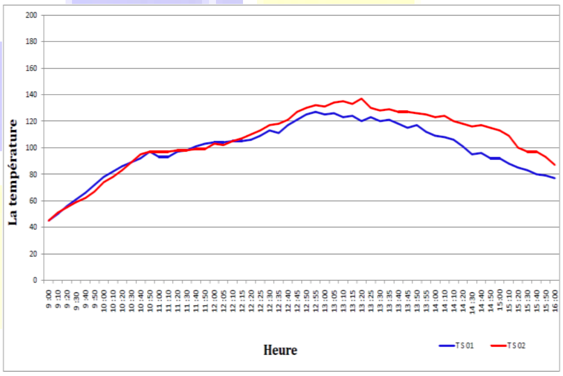


Fig .7. The difference between the experimental results and vertical and bi-axial orientation

According to the figure **7**, we can notice that the temperature of heat-transfer fluid in the outgoing is almost the same until **12 h 15 mn**. After that; we observe an increase in temperature in the bi-axial orientation experiment. This last one will remain at this level until the end of this experiment.

The next table shows the difference between the two experiments especially the levels

TABLE -07-

	Ts	Te	Tabs	Tamb
Tmax 01°C	127	93	108	47,1
Tmax 02°C	137	117	122	47,3

2) between the vertical and bi-axial orientation (5cm)

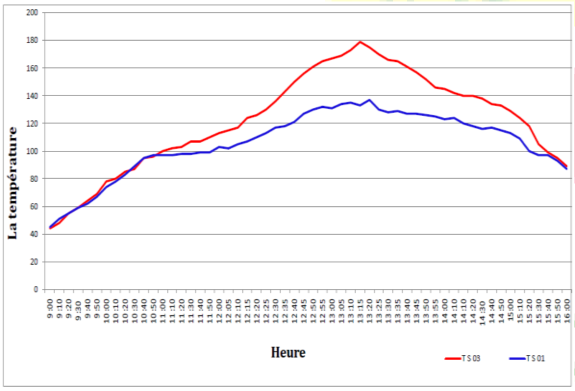


Fig .8. The difference between the experimental results with vertical and bi-axial orientation and the absorber pipe covered by a glass envelop.

According to the comparison between the two methods, it seems that the efficiency is based on:

- Bi-axiale orientation.
- Absorber pipe covered by a glass envelop.

In the **figure 8** the proximity of temperature does not remain for long time because we notice a clear difference of temperature between the two experiments from **10h 40 mn** till **15h 20 mn** where the temperatures attended the same level.

The following table shows the difference between the two experiments, especially the levels.

TABLE -08-

	Ts	Te	Tabs	Tamb
Tmax 01°C	127	93	108	47,1
Tmax 03°C	179	151	163	48,3

3) The difference between the bi-axial orientation with and without glass envelope

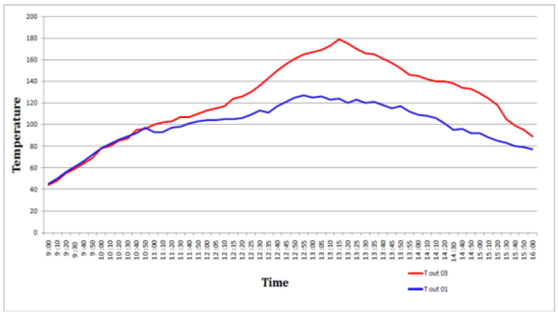


Fig .9. The difference between the experimental results with vertical and bi-axial orientation and the absorber pipe covered by a glass envelop.

With a slight change by modifying the orientation, a substantial difference will be noticed between the experiment's results with a glass cover in comparison with other experiments. It demonstrates the efficiency of the glass cover performance in the CPTSC.
The next table demonstrates the difference between the two tests:

TABLE -09

	Ts	Te	Tabs	Tamb
Tmax 02°C	137	117	122	47,3
Tmax 03°C	179	151	163	48,3

IV. CONCLESION

This work suggests an analytical study for evaluating future projects of solar energy in Algeria. While being interested by the average temperatures [200°C, 500°C], the bibliographical analysis shows that the solar concentrators meet this aim rather well. And experimental study of cylindrical parabolic concentrator. The theoretical study is based on the solar rays, the thermal balance and the equation system, and then we have realized a cylindrical parabolic concentrator with a system, which allows the absorption using the best method of solar energy.

After that, we have applied tests on this concentrator in several cases that are related either to the meaning or to the absorber pipe.

We have remarked that the temperature of the outgoing heat-transfer fluid has exceeded **100°C** with a difference in time according to the applied method. Considering these experiments, we deduce that the bi-axial orientation of solar concentrator, which uses an absorber pipe covered by glass envelop, is the most efficient method. Out of the other experiments.

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