Solar Concentrator from a Parabolic Grid Antenna for Industrial Applications

Selva S. Rivera, Pedro A. Baziuk, Jorge E. Núñez Mc Leod, Romina D. Calvo Olivares, *Member IAENG* and Marcos Vásquez

Abstract— **This paper proposes and evaluates mathematical simulation of a solar collector built from a grid-type communications antenna.**

As a result, a parabolic solar collector of sufficient size was obtained for the generation of high temperatures for industrial applications.

Index Terms—**High temperatures, industrial-applications, parabolic-solar-collector.**

I. Introduction

SOLAR thermal energy is a form of energy and a technology for harnessing solar energy to generate thermal energy or electrical energy for use in industry, and in the residential and commercial sectors.

It is increasingly used domestically to obtain domestic hot water and as a support for heating. However, this technology also has another enormous potential of use that has been very little used to date.

The intensive use of solar energy requires the use of a series of conversion technologies that have been developed in the last 30 years and are still in a State of evolution, mainly to reduce their costs.

Before the world energy scene with oil resources decreasing, it looks to the Sun as the alternative, renewable, inexhaustible, not geographically located and cheap. Major efforts are focused in relation to the generation of electric power. Recently it has started to make progress in the application of solar energy in environmental solutions and hydrogen generation.

The few antecedents in our region in terms of the application of energy solar thermal for industrial applications, and considering that it is highly likely to take because in our region solar radiation levels are high, are the framework to develop this technology.

Manuscript received March 6, 2015; revised March 30, 2017. This work was supported by the National Council of Scientific and Technical Research CONICET Argentina and the National University of Cuyo (Mendoza, Argentina).

S. S. Rivera is with National University of Cuyo, Mendoza (e-mail: srivera@cediac.uncu.edu.ar).

P. A. Baziuk is with CONICET and National University of Cuyo, Mendoza, Mendoza 5500 Argentina (+542614135000; fax: +542614380120; e-mail: pbaziuk@cediac.uncu.edu.ar).

J. NuñezMcLeod is with CONICET and National University of Cuyo (e-mail: jnmcleod@cediac.uncu.edu.ar).

R. Calvo is with CONICET and National University of Cuyo (e-mail: rcalvo@cediac.uncu.edu.ar)

M. Vásquez is with National University of Cuyo

With the aim of developing a parabolic solar concentrator that can be manufactured in Mendoza - Argentina, studies were initiated to put an antenna of communications without Grill manufactured by a local company.

Solar thermal collectors are classified as low, medium or high-temperature collectors.

According to the author [8] low-temperature collectors provides a useful heat at temperatures below 65-80 ºC. There are different types and they are useful in applications requiring hot water but not at higher temperature of 80 ºC.

Solar thermal energy of medium-high temperature is used in applications requiring temperatures between 100 – 250 ºC. They are generally intended for industrial processes, thermal fluid generation, seawater desalination and solar energy cooling.

Some industrial processes may require very high temperatures that are difficult when not impossible to reach by solar thermal collectors of flat plate or vacuum tube. In these cases it is possible to use concentration systems with which temperatures up to 1000 ° C or more can be reached. These systems, although efficient and cost-effective, will require more complex developments and more specific adaptations.

Solar radiation is converted into thermal energy in the focus of solar thermal concentrating solar systems. These systems are classified by their focus geometry as either point-focus concentrators or lines-focus concentrators [9].

There are two types of concentrators [10]:

a) Cylindrical parabolic (single curvature) called "2D" for being "two Dimensions" that allow mean densities and temperatures in the focal environment (200-300 ° C) and

b) The paraboloids of revolution (double curvature) called "3D", for being in "three Dimensions" that allow temperatures even higher than 3000 ° C.

In this work we present the simulation and construction of a solar concentrator of type b previously described and the results of a simulation based on its geometric characteristics are promising.

II. Practical Design Considerations

A. General considerations

With the intention of determining the pre-feasibility of possible applications in the industrial area, a solar concentrator was built and a simulation was carried out based on its dissensions. The communications antenna used was built in Mendoza-Argentina. The set will allow to investigate the possibilities of its development through the local industry in Argentina.

B. Dimensions

As shown in Fig. 1, a parabolic antenna of grid type was adapted to achieve a parabolic solar concentrator with the possibility of rotation in two axes to follow the direct radiation and the elevation of temperature in the focal point to the maximum possible. Being its dimensions:

External diameter: 3,04m ± 0,03m
Internal diameter: 2.95m ± 0.02m
Diameter circular pipe antenna rim: 0.05m
Diameter rod rods grid: 0.02m
Diameter pipe crosses main grid: 0,05m
Depth of the parabola (edge to inner center): 0.7m
Focal length: 0.85m

Fig. 1 - antenna of grid type built by a local company

C. Specular coating

As shown in Fig. 2 y 3, it has been made a petal-shaped specular coating.

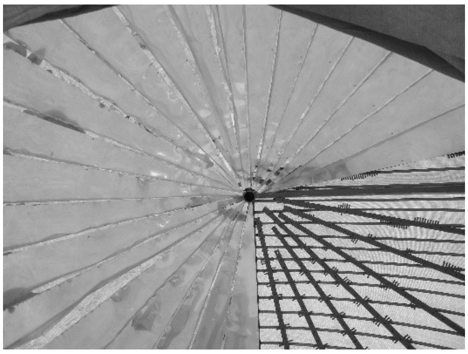

Fig. 2 – Parcial specular coating

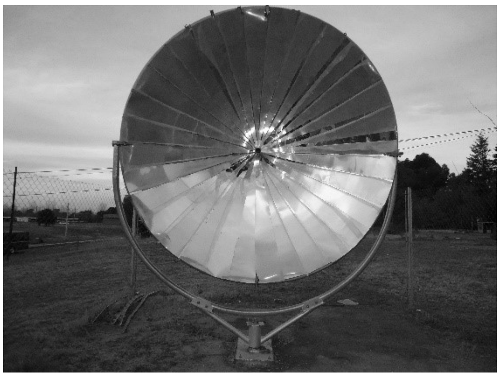

Fig. 3 –Specular coating finished

The reflected solar figure is ideally a point located in the focus of the paraboloid of revolution, which would be adapted to the objectives of the work. However there is a constructive difficulty in achieving a double curvature in each petal from a flat plate of reflective material. This constructive limitation implies a reduction of the width of the petal such that it avoids the lateral undulations of the plate when the double curvature provokes.

In relation to the difficulty of replicability, it is low, since it is enough to make a model petal and replicate it as many times as necessary to cover the specular area. The adaptation to the existing parabolic antenna is of medium complexity, since it requires adaptations that allow to support each petal serving as guide to them to produce the double curvature. Such an adaptation must in turn compensate for irregularities between rods and others by maintaining the parabolic shape, providing sufficient support to the rods and reflective material to withstand wind stresses and to allow adjustments in case the obtained geometry does not be exactly parabolic.

D. Reflective material

An aluminum foil was used, which has 95% overall reflectivity, presents a reflection practically independent of the angle of incidence of the beam and absolutely free of color interference.

Support guides of the petals were used as shown in Fig. 4. This allowed to maintain the parabolic format, to average the irregularities between the rods and to serve as support for the petals.

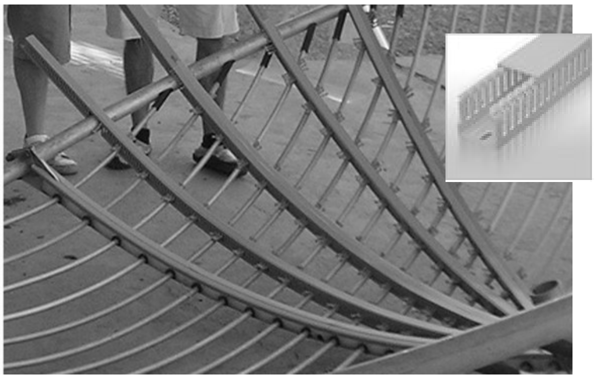

Fig. 4 – Support guides of the petals

III. SIMULATION

A model was developed to estimate the temperatures in the focus of the parabolic concentrators and fluctuations that this presents to allow analysis of pre-feasibility of the various applications of solar energy as heat source (photocatalysis, steam generation, heated or cooling systems, solar cooling through ammonia-water cycle and others generation of hydrogen, water treatment and desalination, power generation [11,12,13,14,15], etc.).

The methodology used was a simulation based on the system dynamics paradigm. The parameters and relevant variables of the system were identified.

The objectives of this first stage of the project were to mathematically model the temperature achieved in the focus and to obtain a simulation according to the constructive characteristics of the aforementioned concentrators and the environmental characteristics of Mendoza [16,17].

A. Model selection

According to the characteristics of the physical phenomenon, the dynamics modeling paradigm of the systems (continuous models and high degree of abstraction)

ISBN: 978-988-14048-3-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

is selected. The criteria used for the selection of this paradigm were:

- Simplicity
- Consistency with experimental data
- Consistency with a priori knowledge
- Admissibility of data
- Structural stability
- Globality

B. Elements of the model

The elements identified and included in the model are shown in the following table:

TABLE I
MODEL PARAMETERS

wind speed (The annual average was chosen for Mendoza [4])	2 m/s
average area of the receiver	0.12 m²
emissivity of the receiver	0.75
specific heat of the receiver (steel)	0.444 J / g ° K
mass of the receiver	1000 g
radius of the parabola	1.2 m
radius of the focal zone	0.14 m
Effective absorbance of the receiver (black steel)	0.85
maximum solar radiation (summer Mendoza)	700 W / m²
solar hourly amplitude (Mendoza summer)	36000 seconds
reflectance of the parabola (polished aluminum)	0.7
follow-up coefficient (depends on the tracking system)	0.8
intercept factor [5] (is the ratio of absorbed energy to reflected energy)	0.55

C. States variables

The state variable used (level) is the effective accumulated energy in the receiver measured in Joules.

D. Intermediate variables

Below are the intermediate variables:

Solar radiation

It is simulated as a parabola with a maximum at noon (at half the solar hourly amplitude).

Heat flux in the focus of the parabola

It is the gross energy concentration that is obtained in the focus as a result of the concentration.

Receiver temperature

By placing the parabola in a vacuum, a steel receiver with a temperature gauge is placed, the absorbed energy is transformed into losses by convection, radiation and a temperature increase of the mass of the receiver.

Lost by convection in the receiver

Are the losses that depend on the wind speed and the temperature in the receiver.

Lost by radiation in the receiver

Are losses that depend exclusively on the temperature of the receiver.

The values obtained of temperature and effective accumulated energy in the receptors are those shown in Fig. 5.

The model had several versions and as they were carrying out tests the parameters were adjusted and included some not considered initially.

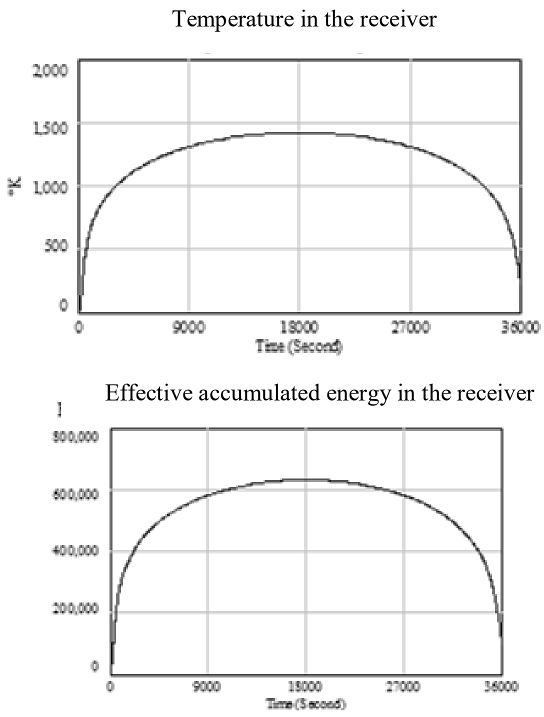

Fig. 5– Temperature and effective accumulated energy

IV. RESULTS

Different simulation runs were performed to verify the incidence of certain parameters by selecting four of them, as is shown in Fig. 6.

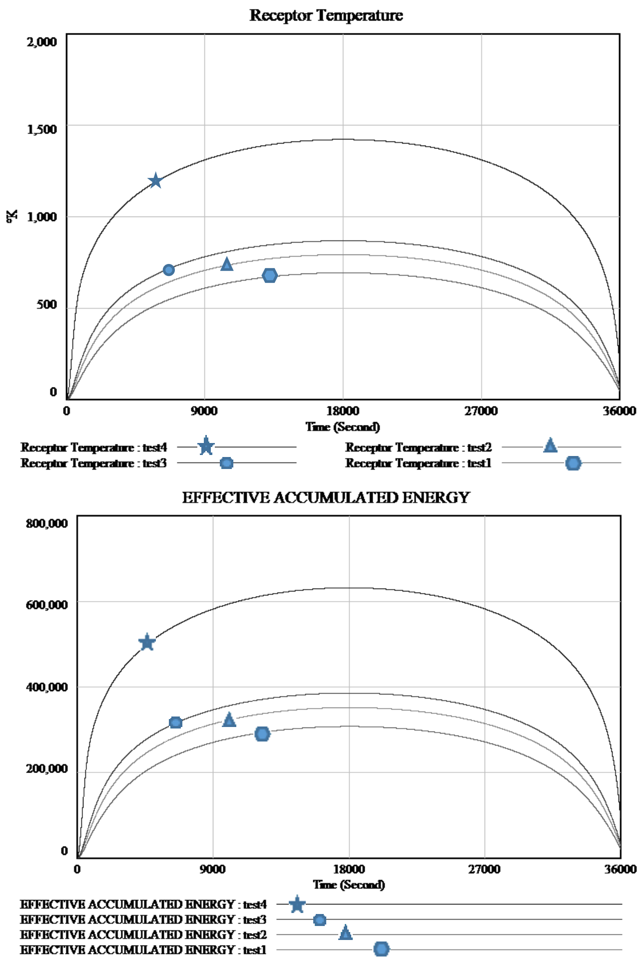

Fig.6– Simulations

The incidence of the parameters was analyzed: Maximum solar radiation, intercept factor and reflectance of the parabola with the values in Table II:

TABLE II
PARAMETERS EVALUATED

Intercept factor	Max solar radiation	Reflectance
0.55	700	0.7
0.55	500	0.7
0.55	700	0.9
0.65	700	0.7

V. CONCLUSION

The first results show the feasibility of manufacturing of solar parabolic concentrators for easy construction. The prototype evaluated and as a result of the early trials showed temperatures of 950 ° C in the focal area. The availability of the simulation will allow to anticipate results and consider possibilities of optimization in the prototype.

REFERENCES

[1] J. C. Durá and E. M. Godfrin, Boletín Enegético No 16, Grupo Energía Solar – Departamento de Física – Centro Atómico Constituyentes – Comisión Nacional de Energía Atómica, 2004, Available: http://www.cnea.gov.ar/sites/default/files/duran.pdf
[2] L. Scollo, "Energía Solar: aprovechamiento mediante concentrador y ciclo Stirling para producir electricidad-Estudio de disponibilidad del recurso solar en la Provincia de Mendoza; Grupo de Energía Solar; Instituto CEDIAC-Facultad de Ingeniería- Universidad Nacional de Cuyo", unpublished.
[3] R. Righini and H. Grossi Gallegos, "Aproximación a un trazado de nuevas cartas de irradiación solar para Argentina", Avances en Energías Renovables y Medio Ambiente; Vol.7, No 2, 2003, pp. 11.07-11.11
[4] R. Righini, "Empleo de imágenes satelitales GOES 8 en el cálculo de la irradiación solar global en distintas zonas de Argentina-Avances en Energías Renovables y Medio Ambiente, Vol. 8, No 2, 2004, ps. 11.01 – 11.06, CD versión.
[5] H. Grossi Gallegos, "Acerca de la distribución de la heliofanía en Argentina", Avances en Energías Renovables y Medio Ambiente, Vol. 6, No 2, 2002.
[6] H. Grossi Gallegos, "Distribución de la radiación solar global en la República Argentina- I Análisis de la Información", Energías Renovables y Medio Ambiente; vol. 4; pp. 119-123; 1998.
[7] H. Grossi Gallegos, "Distribución de la radiación solar global en la República Argentina- II Análisis de la Información", Energías Renovables y Medio Ambiente; vol. 5; pp. 33-42, 1998.
[8] S. A. Kalogiroug, "Solar thermal collectors and applications", *Progress in Energy and Combustion Science*, vol. 30, 2004, pp. 231-295.
[9] A. Fernández García, E. Zarza, L. Valenzuela and M. Pérez, "Parabolic-trough solar collectors and their applications", *Renewable and Sustainable Energy Reviews*, vol. 14, 2010, pp. 1695-1721.
[10] *Concentración de la radiación solar*. Available: http://www.unida.org.ar/Virtuales/Energias/Clase%204/CONCENTRADORES%20SOLARES.pdf
[11] S. Kalogirou, "Solar thermal collectors and applications", Department of Mechanical Engineering, Higher Technical Institute, Nicosia 2152, Cyprus, 2004.
[12] O. Esquivel, A. Busso, N. Sogari and J. Franco, Comunicaciones Cientificas y Grupo de Energias Renovables – FaCENA – Universidad Nacional del Nordeste –Tecnologicas, 2006
[13] Proyecto: "Solter-H: Generación de hidrógeno a partir de energía solar térmica a alta temperatura". Ref. FIT-120000-2004-66. Convocatoria: PROFIT CTE/3185/2003. Entidades: Hynergreen y CIEMAT, unpublished.
[14] Pearce J. M., Clarion University of Pennsylvania; Denkenberger D., University of Colorado at Boulder, Available: http://atlas.colorado.edu/people/faculty/
[15] Estudio de Vigilancia tecnológica: Electricidad termosolar (Competitive Intelligence Study: Solar thermal energy). Available: https://www.academia.edu/23551246/Estudio_de_Vigilancia_tecnol%C3%B3gica_Electricidad_termosolar_Competitive_Intelligence_Study_Solar_thermal_energy_
[16] N. D. Kaushika and K. S. Reddy, "Performance of low cost solar paraboloidal dish steam generating system", Centre for Energy Studies, Indian Institute of Technology Delhi, Hauz Khas, New Deli, 110 016, India, 1999, pp. 713 – 726.
[17] Clima Mendoza Aerodrome, Datos climáticos:1757 – 2017, Available:http://www.tutiempo.net/clima/Mendoza_Aerodrome/874180.htm

ISBN: 978-988-14048-3-1
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)