DEVELOPMENT OF A COST EFFECTIVE LINEAL FRESNEL SOLAR THERMAL COLLECTOR FOR HIGH TEMPERATURE PROCESSES, THERMAL DRIVEN CHILLERS AND HYBRID ELECTRICITY GENERATION

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1. Introduction

According to studies of potential published recently[1], the potential of solar thermal energy for process heat and cold in industries at medium and high temperature (T >250 ° C) accounts for more than 20 million square meters of solar thermal collectors. It would represent primary energy savings of about 2 000 000 MW per year. Not only process cold has a big potential but also solar air conditioning is increasing due to the rising of demand, solar air conditioning's installations realized last recent years have shown that could not yet be considered as cost competitive to conventional technologies.

In this framework, a cost effective Lineal Fresnel solar thermal Collector is being developed inside a cofounded research project in Catalonia , focusing on the production of solar heat and cold and considering as mid-term goal renewable electricity generation,.

2. Background

A first small Prototype (300 square meter) was designed and constructed by AIRA TERMOSOLAR in 2009 for process heat; it has been producing meat industry cleaning water in Catalonia.

Fig. 1: First 300 m^2 Prototype.

These two years of operation have allowed us not only to be able to assess the actual performance of the prototype (η = 55% for a global beam horizontal G_{bh} = 700 W/m^2 and an average temperature above ambient ΔT = 50ºC), but also to identify improvements in collector's design (from the standpoint of energy and cost). Furthermore this operation experience has led to take into account relevant aspects related to the maintenance of the plant, such as mirror cleaning. The estimated cost of the first Prototype was over 450 €/m^2 of mirror.

With the purpose of improving the solar thermal collector efficiency and reducing costs in 2010 AIRA

TERMOSOLAR, AIGUASOL and MAFRICA began the development of new prototypes which had also the goal of reaching a wider field of possibilities, such as solar air conditioning and electricity generation.

3. Second Prototype

From autumn 2011, a pilot plant of approximately 3000 square meter, with an optimized new design suitable for high temperatures, will provide energy for the meat industrial process cleaning water.

For reaching the optimal design, the following steps have been undertaken:

- Determination of optimum solar cone for each target temperature range.

Definition of the geometry through the optimization of the distribution of primary reflector and focal length, taking in account shadowing and blocking effects between reflectors, the cosine and atmospheric attenuation, and the spillage and end-focus effect, for which has been necessary the development of a tool.

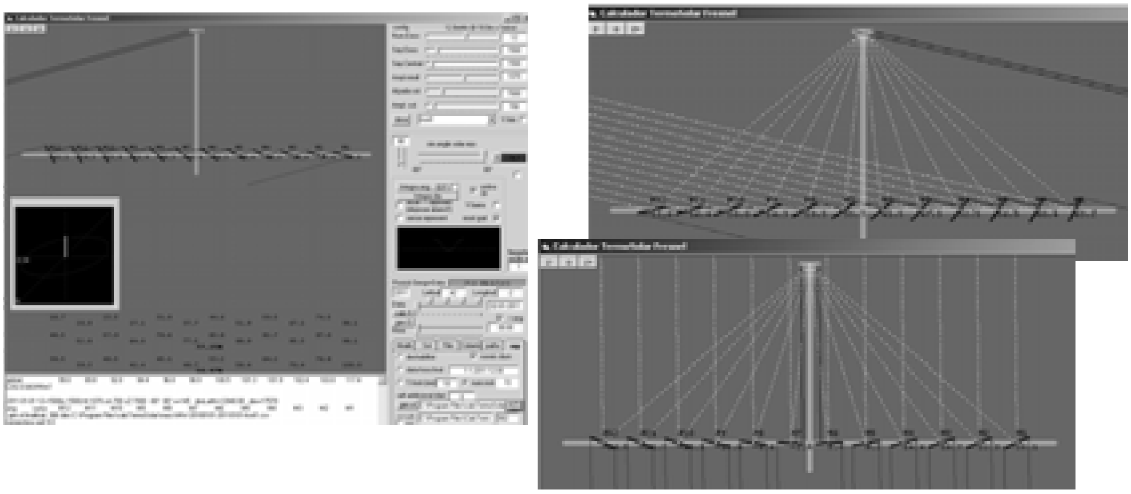

Fig. 2: Developed software for determining the optimal solar cone.

- Design of the secondary absorber according to the range of temperatures.

Determination of several geometry models developed during the study phase according to a cost effective criteria. Modeling in EES[2] and characterization of the different geometries of secondary energy absorber. Selection of promising designs for different temperature ranges. Optimizing the design of the secondary - absorber. Analysis of energy distribution and homogeneity of the incident radiation on the absorber and its effects on himself and the absorber heat carrier fluid. Development of hydraulic solutions.

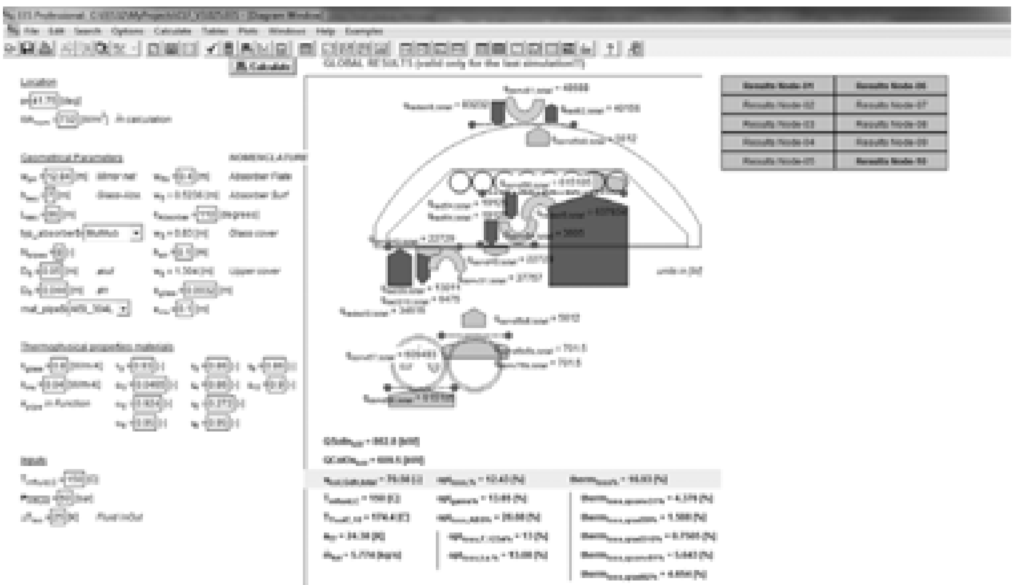

Fig. 3: EES Diagram Window with data and results .

- Structural design

Analysis of structural requirements of the structure weight, snow loads and wind. Selection of materials and surface treatments.

- Thermo hydraulic design of the plant and annual production.

For the evaluation of the annual production TRNSYS simulations of the whole system will be developed.

- Monitoring and control design of the plant.

4. Design conditions and targets for second Prototype

The design targets for this second Prototype are:

- A global solar collector efficiency of η = 70%, for a global beam horizontal Gbh = 732 W/m2 and an average temperature above ambient ΔT = 50ºC. A global solar collector efficiency of η = 50%, for a global beam horizontal Gbh = 732 W/m2 and an average temperature above ambient ΔT = 150ºC.
- An investment cost below 300 €/m^2 of mirror (despite it is foreseen to achieve investment costs below 200 €/m^2 in next prototypes).

5. Lineal Fresnel solar thermal collector Modeling in EES

In order to evaluate the performance of the Lineal Fresnel solar thermal collector, a detailed model in EES has been developed. The hypotheses used are listed below:

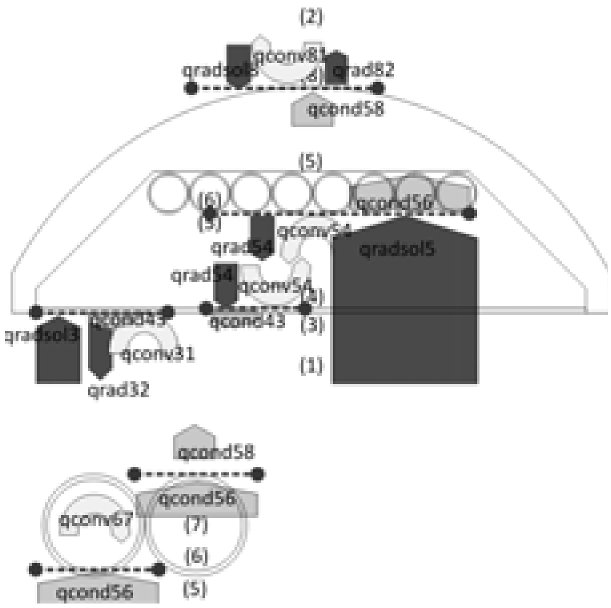

Fig. 3: EES Model characterization

Hypothesis

- steady state model, no transient issues,
- dimensional discretization on the x-axis (longitudinal); therefore, end-effect will be considered,
- dimensional discretization in the y-axis (transverse heat transfer) not considered,
- air non-participating of radiation,
- glass completely opaque to long-wave radiation,
- convection heat transfer between inner glass cover and absorber considered as a steady-state correlation obtained from CFD's simulations,
- thermal conduction from back absorber isolating as conduction through an infinite planar surface,
- water as HTF (Heat Transfer Fluid),

- conductive resistance through the selective coating of the absorber has been neglected,
- thermal conduction through glass cover as conduction through an infinite planar surface,
- convection heat transfer in the outer face of the cover: top of a plate. As it is turbulent flow, the approach is anywhere close plausible. Wind perpendicular to the cover,
- optical looses for primary reflector obtained from the Developed software for determining the optimal solar cone.

6. Future developments

This new Prototype, which is expected to provide energy for the cleaning water meat industrial process, will be used for testing future developments for of reaching the suitable conditions of efficiency and cost for solar air conditioning or electric generation systems.

7. Conclusions

As a result of design tasks which have brought to the optimal design, we can conclude:

- Lineal Fresnel solar thermal collector modeling, both from the optical and thermal point of view, leads to a more efficient and economically reliable design, than constructing real prototypes,
- Lineal Fresnel solar thermal collector modeling allows the selection of the most suitable materials and treatments. Not always the best and most efficient results in a higher benefit,
- Lineal Fresnel solar thermal collector modeling can "test" the operation of the collector in different operating conditions, obtaining a deeper knowledge about its operation.

8. Acknowledgments

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9. References

1. AIGUASOL et al., POSHIP (http://www.aiguasol.coop/poship.htm) a project funded by the EU, or Task33 conducted within the International Energy Agency (http://www.iea-shc.org/task33)
2. S.A.Klein, EES (http://www.fchart.com/ees/)