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Efficiency analysis of solar chimney power plant in Tissemsilt city

Analyse de l'efficacité d'une centrale à cheminée solaire dans la ville de Tissemsilt

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ABSTRACT

The present work shows a study of energetic efficiency of a solar chimney power plant (SCPP) destinated for electrical power production in Tissemsilt region. A mathematical modeling of the installation based on PERRIN Brichambaut irradiation solar model has been carried out. First, a validation of the solar irradiation model with Algerian Atlas Solar has been performed. The results show a good agreement. The effect of some geometrical and physical parameters, such as the collector diameter, the height of the chimney and solar radiation on the electrical power output is analyzed. The results show that electricity production increases with increasing chimney height and collector surface. It is also observed that solar irradiation has a great influence to increase the tower productivity.

RÉSUMÉ

Le présent travail porte sur une étude de l'efficacité énergétique d'une centrale à cheminée solaire (SCPP) destinée à la production d'énergie électrique dans la ville de Tissemsilt. Une modélisation mathématique de l'installation basée sur le modèle de l'irradiation solaire de Perrin Brichambau a été élaborée. Tout d'abord, une validation du modèle d'irradiation solaire avec Atlas solaire algérien a été effectuée. Les résultats montrent une bonne concordance. L'effet de certains paramètres géométriques et physiques, tels que le diamètre du collecteur, la hauteur de la cheminée et le rayonnement solaire sur la puissance électrique produite a été analysé. Les résultats montrent que la production d'électricité augmente avec l'augmentation de la hauteur de la cheminée et de la surface du collecteur, il est également observé que l'irradiation solaire a une grande influence sur la productivité de la tour.

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1 Introduction

For more than a century, it has clear that the world market has seen significant growth in energy demand where this demand has been covered by the use of fossil energy sources that are themselves on the verge of Disappearance, Most of the electricity consumed comes from the use of fossil fuels (oil, natural gas, coal...), which can lead to depletion of these reserves and threaten the environment. This threat has been manifested by global climate change related to carbon dioxide emissions from the combustion of fossil fuels which is the main gas responsible for strengthening the greenhouse effect. This has led to a race to new energy sources or new processes to achieve more energy. As a result, the issue of environmental preservation has emerged in the forefront for many developed countries. Indeed, in 1992 at the Rio conference and later, in 1997, during the Kyoto protocol, most States committed themselves to combating greenhouse gas emissions in order to contribute to the preservation of the environment and climate. In this context, the development of renewable energies has emerged as an answer to treat and support in particular solar energy. Speaking of renewable energy, Algeria is a Mediterranean country known for having a very high potential for solar energy. According to the solar data, Algeria is among the sunniest countries in the world; its potential in solar resources is optimal for the execution of solar projects. The solar tower with a chimney effect is one of the means of production of electric energy; It's a renewable power plant. It is built so as to channel the air heated by the sun and then to train power-generating turbines. The concept was proposed by the German engineer Jörg Schlaich in 1968 [1 and 4].

From 1980 to 1989, a prototype at Manzanres was developed, built and tested. The chimney height is 195 m and 10 m in diameter. The Collector's surface (greenhouse effect) is 46 m^2. The maximum power generated is 50 KW. According to Schlaich [5] and Padki and Sheriff [6], the desert and subtropical zones are of paramount interest to the medium and large SCPP. Solar power plants can also be used under exceptional conditions [7, 8 and 9].

B. Mebarki et al. [10] had conducted an analytical study of a solar chimney to the Southwest of Algeria. The results obtained show that the solar tower can produce from 100 to 200 kilowatts of electricity and that it can reach up to 1.8 MW for 3000 m in diameter and 200 m in height.

S. Larbi et al. [11] had presented an analysis of the energy performance of a SCPP to provide electricity to isolated villages in the Southwest of Algeria. Solar energy and the psychometric condition of the air Southern Algeria are important to fully promote the development of solar chimneys both for the production of thermal or electrical energy for various uses.

The authors are interested in the town of Adrar where solar radiation is important. The results obtained show that the SCPP can produce from 140 to 200 KW of electricity on a site such as Adrar throughout the year, according to an assessment made on the monthly average of sunshine.

The objective of this present work is devoted to the study of energetic efficiency of a SCPP destined for electrical power production in Tissemsilt city. The effect of some geometrical and physical parameters, namely the diameter of the collector, the height of the chimney and solar radiation on the electrical power output are presented.

2 Mathematical modeling

The SCPP is composed of three essential elements: a solar collector (collector), the chimney located in the center of the collector and the power conversion unit that includes one or more turbines [1]. The turbines are driven by the air produced by the greenhouse effect inside the collector (figure 1).

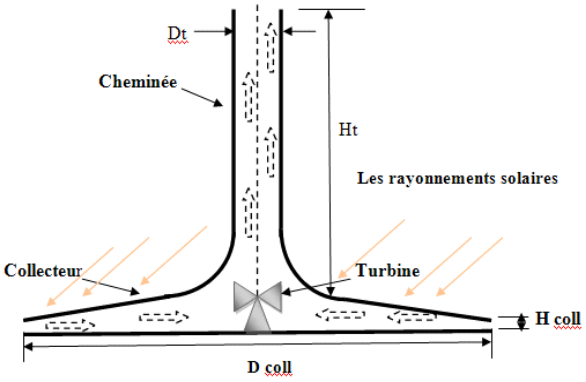

Fig.1- schematic presentation of a SCPP [1]

2.1 Chimney

The efficiency of the chimney is defined by:

$$\eta_c = \frac{P_{utile}}{P_{solaire}} \quad (1)$$

$$P_{solaire} = m.Cp.(T_3 - T_2) = m.Cp.\Delta T_{23} \quad (2)$$

The output power is given by the following equation:

$$P_{utile} = \frac{g.H_c}{Cp\ T_2} . \rho_{coll} . A_c . V_c . \Delta T_{23} \quad (3)$$

And the total pressure difference that occurred between the entrance and the exit of the chimney is:

$$\Delta P_{tot} = \rho_{coll} . g . H_c . \frac{\Delta T_{23}}{T_2} \quad (4)$$

2.2 Collector

The efficiency of the collector is expressed by the report:

$$\eta_{coll} = \alpha^* - k\ \frac{\Delta T_a}{E} \quad (5)$$

2.3 The turbine

The maximum mechanical power given by the turbine is:

$$\Delta P_{tur,max} = \frac{2}{3} \frac{\eta_{coll} . A_{coll} . E . H_c}{Cp . T_a} \quad (6)$$

The electrical power produced by the chimney is:

$$P_{elc} = \frac{2}{3} \frac{g . \eta_{coll} . A_{coll} . \eta_{tur} . E . H_c}{Cp . T_a} \quad (7)$$

3 Results and discussion

To see the influence of the solar irradiance, the diameter of the collector and the height of the chimney on the power produced by the solar Tower during the days December 15th, (winter period) and July 15th (summer period), curves were plotted translating the following variations:

-The daily power output based on time,
-The daily power output depending on the diameter of the collector,
-The daily power output depending on the height of the tower.

3.1 Comparison of the results of the solar irradiation

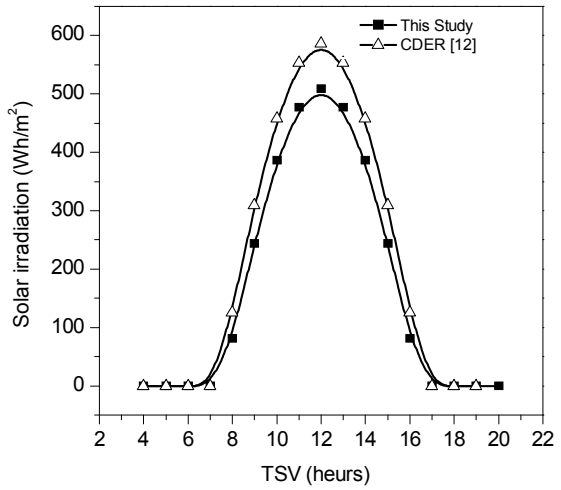

Fig.2- the comparison of the results of solar irradiation for December 15 - Tissemsilt

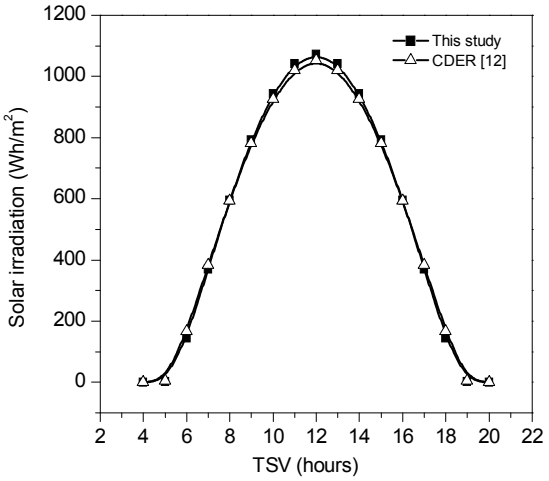

Fig.3- the comparison of the results of solar irradiation for July 15 - Tissemsilt

A comparison of the results of solar irradiation obtained by this study and those obtained by Center of Renewable Energy Development (CDER) was carried out figures 2 and 3. This comparison shows a good agreement with an average error less than 4 %.

3.2 The change in power produced during the year

Figures 4 and 5 illustrate the power output according to the solar time for the two localities Adrar and Tissemsilt. We note that the power output is much higher during the month of July compared to the month of December, as the solar irradiance received at the level of the collector is very high in this month. In July, Tissemsilt city receives a considerable amount of solar radiation, radiation appears at noon peak, approximately it is of the order of 1074 W/m2, corresponding to a power of 94365.88W while in December the peak of illumination is about 508W/m2, representing half of the output in July which is of the order of 44634.88W for the locality of Tissemsilt. It can be concluded that the effectiveness of the system is important during the summer. It is to emphasize that the power produced at the level of the locality of Adrar is superior to that produced at Tissemsilt due to solar irradiation of each locality.

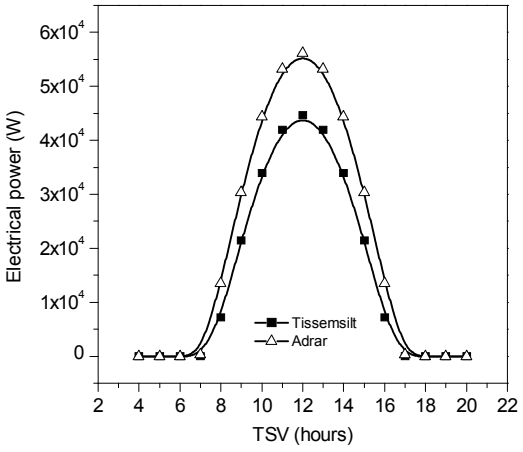

Fig.4-the variation of the P_{elec} = f (TSV) for the month of December

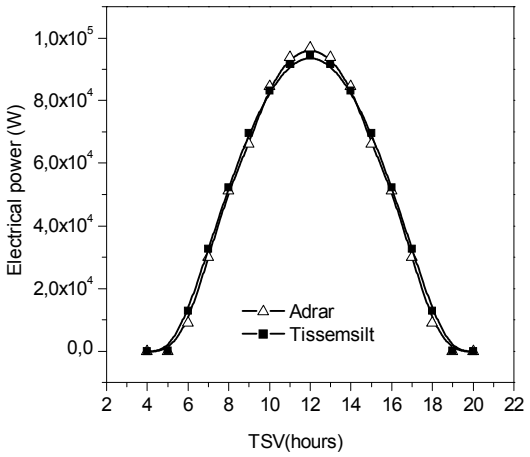

Fig.5- the variation of the P_{elec} = f (TSV) for the month of July

3.3 The change of daily produced power depending on the diameter of the collector

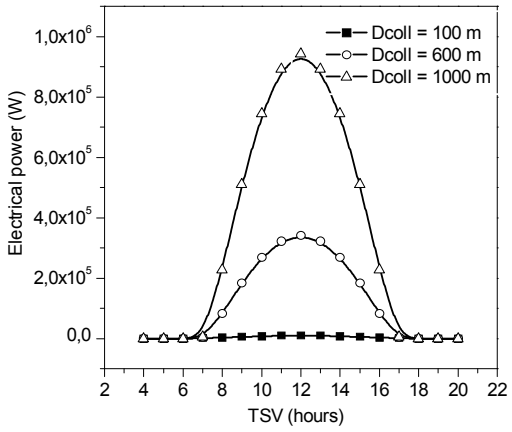

Fig.6- daily power output for different diameters of the collector for the month of december for the locality of Tissemsilt

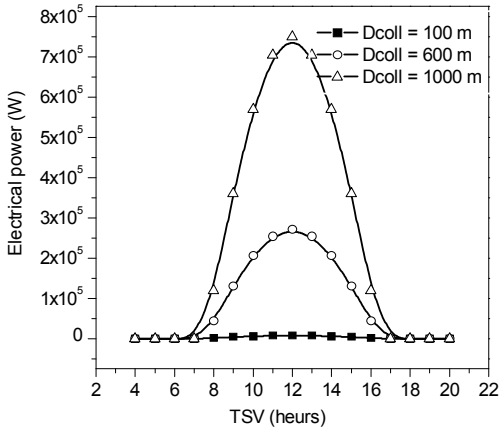

Fig.7- daily power output for different diameters of the collector for the month of July for the locality of Tissemsilt

Fig.6 and 7 show the evolution of the daily power produced by the SCPP for different diameters of the collector. The reading of these figures show that the power generated increases with the increase in the diameter of the collector.

3.4 The change of daily produced power depending on the height of the tower

The Fig.8 and 9 show the variation of the daily power output for different heights for the months of July and December. Examination of these figures shows that the increase of the height of the solar Tower led to an increase of the produced electrical power.

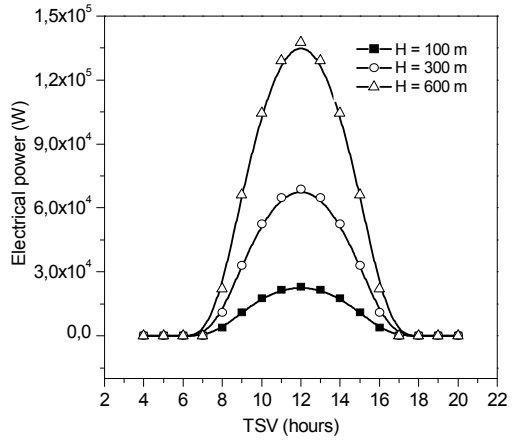

Fig.8- daily power output for different heights of the chimney for the month of December for the locality of Tissemsilt

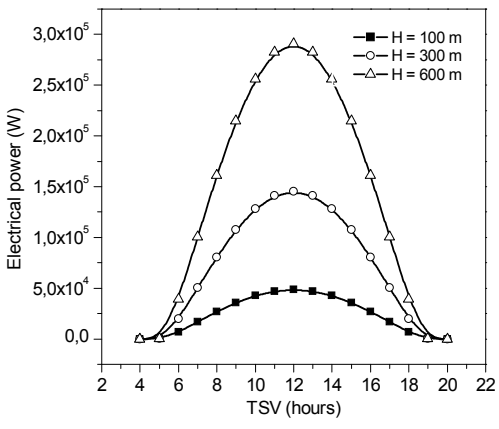

Fig.9- daily power output for different heights of the chimney for the month of July for the locality of Tissemsilt

4 Conclusions

At the end of the work, some conclusions can be summarized as follows:

- A program in FORTRAN environment based on the determination of the solar radiation according to the model of PERRIN Brichambaut has been developed,
- Solar radiation varies during day in a way Gaussian. It is weak in the vicinity of the sunrise and the sunset which is at a

height of Sun zero and it reached the maximum in the middle of the day i.e. at noon when the height of the Sun is at its maximum.

- The power output is much higher in July than the month in December, as the solar irradiance received at the level of the collector is very high in this month.
- The increase of the height of the solar Tower as well as the diameter of the collector led to an increase in the produced electric power.
- Comparison of the solar irradiation results obtained by this study and those of Algerian Atlas Solar shows good agreement.

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