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Experimental study of the effect of meteorological parameters on the performance of the solar chimney power plant

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Abstract – *The solar chimney power plant (SCPP) is an economical technology for the production of solar electricity. The increase in the production efficiency of this type of installation is depended of the several theoretical and experimental studies. This paper studied the effect of some key parameters such as (ambient temperature, solar radiation), on the performance of the solar chimney power plant. Using the dimensions of our SCPP prototype and also compared by the Manzanares prototype with Ouargla weather conditions.* Where the m*aximum solar radiation and ambient temperatures are 957 W/m^2 and 30 ° C at 15h00. Respectively. The measured average air speed is 1.04 m/s, and the electric power value of the prototype is 2.04W. The results show that the solar radiation and the ambient temperature have a direct effect in the SCPP efficiency, and also confirm that the technology of solar chimneys is the best solution to install in the hot and arid areas like Ouargla city.*

Keywords: Solar chimney, Meteorological parameters, electricity production, solar energy.
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I. Introduction

In Algeria, the global radiation received in different sites without altitudes or with altitudes of Mediterranean or Saharan climates, is one of the highest in the world. In addition, the southern regions benefit from exceptional qualities to harness solar energy in the most varied forms [1]. Solar energy is harnessed by a device called a solar fireplace. A solar chimney is the new technology for produce the electrical energy using the solar energy where the main components are consists of:

1- The solar greenhouse or collector ground;
2- The chimney or tower;
3- The turbine with electrical generator;

The technology of the solar chimney power plant was proposed in the first time by the engineer Jorg Schlaich and German in 1976. In 1979, where they developed the first prototype that is reached the power output of 50 kW in Manzanares city situated in the south of Madrid, Spain. Consisted of collector of 120 m radius and high from ground of 2 m, and with chimney height of 195 m its radius of 5 m, the solar chimney power was operated from 1982 until 1989. The tests that are carried out in the power plant shown that the installation is reliably and therefore the concept is technically viable. The energy cost analysis and evaluation were studied in the work of Haaf et al. the analysis showed that the power generation cost of the plant was (0.098 USD / kWh based on the 1983 average exchange rate). Since then, no chimney solar power plant has been built but many theoretical and numerical studies have been carried out by many researchers. [2-4-5].

In the work of Balijepalli et al an Investigation has carried out in a small prototype solar chimney power plant, where the maximum air velocity was achieved at chimney is 1.9 m/s. and the efficiency of the SCPP estimated is 0.0019% [6]. Kiwan et al performed a modification in the SCPP in aim to improve the

performance of the SCPP viability. where they added two modifications the first is the photovoltaic (PV) and the second is installation of water pool for cooling the PV panels, the goal from these two modifications is to increase the power output of the installation, where the results found that the proposed system produces 45.35% more electricity annually than a standalone PV system installed in the same location [7]. Setareh carried out a comprehensive study of the effects of geometric parameters on the performance of solar chimney power plant (SCPP), the proposition reveal that the ratio of pressure drop to total pressure potential of turbine must be chosen between 0.7–0.85 in the aim to achieve the optimum performance of SCPP. also the results shown that the increasing in air speed in side the chimney has a positive effect on the power output as well the performance of the SCPP [8].

In this paper, we would like to show our study that is carried out at Ouargla University on the solar chimney power plant (SCPP) and analysis the Effective of metrological parameters on the Performance of Solar Chimney Power Plant such as (ambient temperature solar radiation, air velocity Inside collector and chimney).

II. Material and Methods

II.1. Working principle

Solar Chimney Power Plant (SCPP) is a simple solar thermal power plant capable of converting solar energy into electricity. A solar tower is a renewable energy plant built in such a way that air from a greenhouse heated by the sun is channeled into a chimney, in order to drive turbines to produce electricity. as shown in Figure 1.

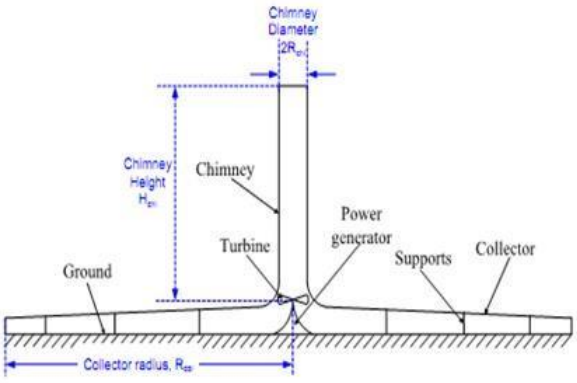

Figure 1. Working principle of the Solar Chimney Power Plant SCPP

II.2. Prototype description

In order to carrier out evaluate the measurement of the temperature field and air velocity in side the solar chimney, a prototype of SCPP was built University of Ouargla as shown in Figure 2 composed from collector wood ground of (5 m x 5 m) and (PVC) pipe with 0.16 m diameter 6 m high used as chimney, where The PVC pipe was isolated using glass wool. The material used in the collector is a transparent glass and the height of collector from the ground is 0.2 m.

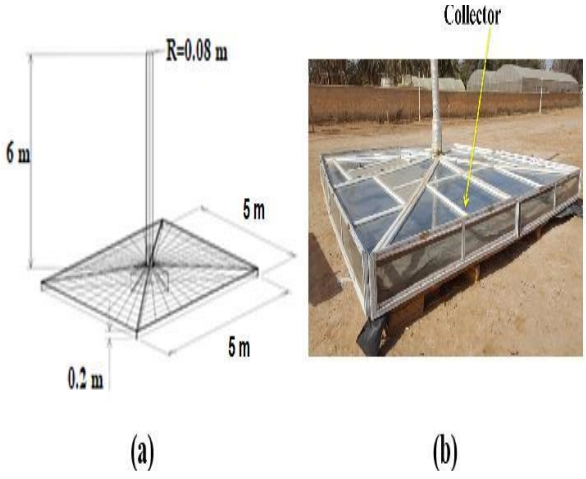

Figure 2. (a): The solar chimney prototype. (b) The SCCP prototype with glass collector used in our experimental study

The dimensional parameters of the SCPP prototype are presented in the Table 1.

Table 1. The dimensional parameters of the Solar Chimney prototype

Description	Value
area of Collector	5 x 5 m^2
High of Chimney	6 m
High of collector from the ground	0.2 m
diameter of the Chimney	0.16 m
Tilt angle of the Collector	≈ 6°

III. Discussion of the measured results

III.1. Variations of solar radiation and ambient temperature

Figure 2 presented the fluctuation of the solar radiation (G) and ambient temperature (Ta) measured with the time. These two parameters were registered in the day of 15 Marche 2020. During the recorded of the results it was shown that the ambient temperature changes between 17 °C at 08h00. to 30 ° C at 15h00. And the average value of the ambient temperature was 26.18 °C. Also the solar radiation increases wit the time after and the maximum value recorded is 957 W/m^2 at 13h00. And decreases until sunset; where the average value was 728.9 W/m^2. It was observed following the results recorded that the potential of the village of Ouargla it is the suitable to install the solar power plants as the solar chimney power plant.

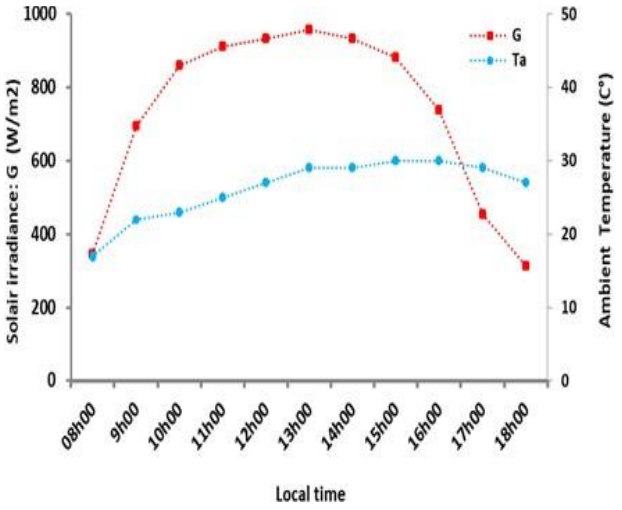

Figure 2. Typical measured solar irradiance and ambient temperature vs Time (15/03/2020)

III.2. Variations of ambient temperature and air speed

Figure 3 shows the variations in measured ambient temperature (Ta) and air speed as a function of time. These two parameters were registered during the day of 15 March 2020 in Ouargla. Where observed that when the ambient temperature increases the air speed increases until reaching the maximum value of 1.6 m/s with ambient temperature value of 30 °C at 13h00, and begins to decrease to 0.8 m/s for an ambient temperature value of 27 °C at 18h00. So we can also say that the air speed and the ambient temperature have a proportional relationship.

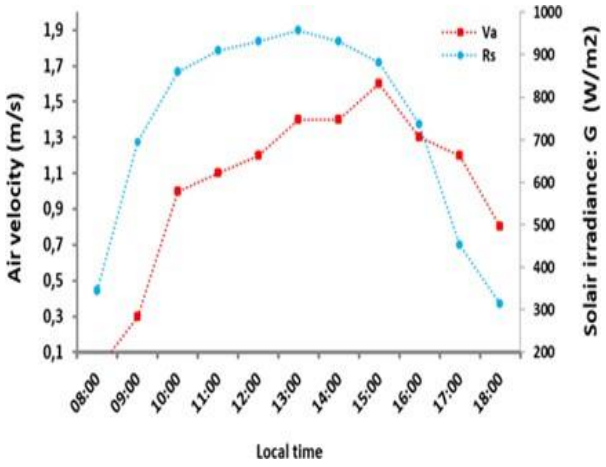

Figure 3. Variation of air velocity at the chimney entrance vs. solar irradiance (15/03/2020)

III.3. Variation of the power calculated by the mathematical model

Figure 4 illustrates the expected energy variance using the SCPP dimensional mathematical model as a function of solar radiation, using meteorological parameters for a typical day on 03/15/2020 in Ouargla. It is observed can that the power output generated by the prototype reached more than (1) watts in the presence of more than 860 W/m² of solar radiation between 10h00 and 13h00. It is important to note that the electrical energy that can be produced at Ouargla will be (1.13). The form of the power output curve confirms the precisions of the mathematical model.

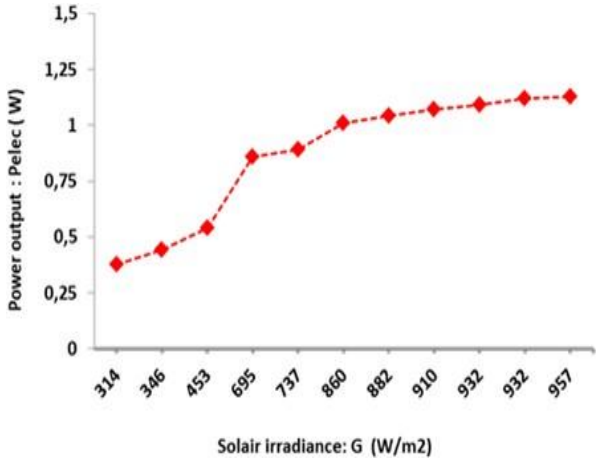

Figure 4. Variation of the power calculated by the mathematical model using the dimensions of the SCPP vs. solar radiation (15/03/2020)

IV. Conclusion

This paper presents the results as well as their discussions for an experimental study of the small-scale SCPP and also the results of the theoretical study by using the mathematical model for the calculation of the power. We can summarize the results found in our study as follows:

The meteorological values recorded for the typical day of 03/15/2020 where the maximum solar radiation and ambient temperatures are 957W/m^2 and 30°C at 13h00 respectively, The measured average air speed is 1.04 m/s, and the electric power value calculated by the mathematical model for the prototype is 2.04 W, we found that the efficiency of the chimney has a proportional relationship with solar radiation as well as the height of the chimney. And the value of the maximum air speed reached 1.4 m/s with solar radiation of 957 W/m² at 13h00, for the typical day of 03/03/2017.

The air velocity inside chimney increasing remarkably with the increasing of the solar radiance and the ambient temperature, it is clearly observed that the efficiency of the chimney has a proportional relationship with solar radiation as well as the ambient temperature.

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