Determination of the Maximum Efficiency of Concentrated Solar Power (Parabolic Trough and Central Tower) using A Genetic Algorithm

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ABSTRACT— ***the ambient conditions are ones of the most important factors because it affects the energy load of Concentrated Solar Power (CSP). The installation of concentrated solar plants is one of future sources to generate electricity without emitting pollutants .The solar plants used in these systems have demonstrated enormous efficiencies and advantages. This paper evaluates the effects of ambient conditions on the system efficiency of CSP plants of two types of CSP systems: parabolic trough and central tower technologies. Several researches have discussed the maximum efficiency of these technologies, but only a few experiences have succeeded to right weather conditions to get these results. Using the method of genetic algorithm, the results show that for an ambient temperature of 25 ° C, wind speed of 5 m/s and direct irradiation of 868 W / m^2 for parabolic trough so as to have an efficiency of 23.06% and 24.25% for central tower in direct irradiation of 879 W/m^2.***

Keywords— CSP, system efficiency, genetic algorithm**.**

1. INTRODUCTION

Other than causing a severe environmental degradation, the use of fossil fuels also causes serious environment problems especially the greenhouse. Nowadays, research efforts are taking place to develop alternative sources of energy, more efficient conversion technologies and environmentally sustainable applications. The use of solar energy technology is a viable solution to some of the environmental problems that were generated by the use of fossil fuels.Nowadays, the world knows a great interest for developing a new technology to produce electricity without any emission of pollution .One of these technologies is a CSP (Concentrated Solar Power) system that uses solar energy using mirrors without emitting pollutants and requiring no fuel as shown in Figure 1[1].

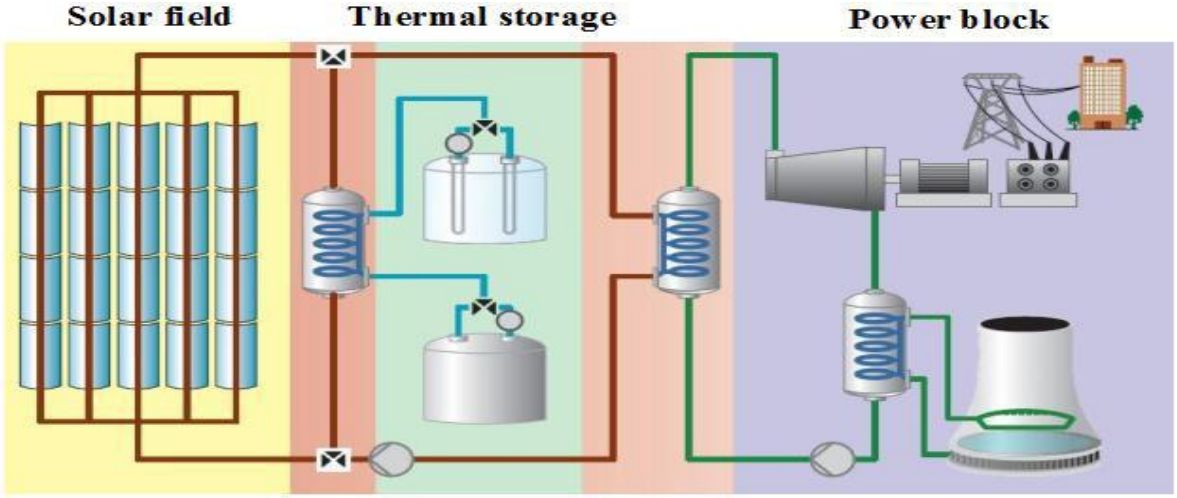

Figure 1:The compenents of CSP plants.

The incident solar radiation is collected in a specific system using a mirrors, heat a thermal fluid. This fluid is then us to drive a turbine and generate electricity. During the night, the energy can be saved in the thermal storage.
The main concentrated solar power systems are: The parabolic trough system, the parabolic dish system, the central tower system and linear Fresnel as seen in Figure 2[2].

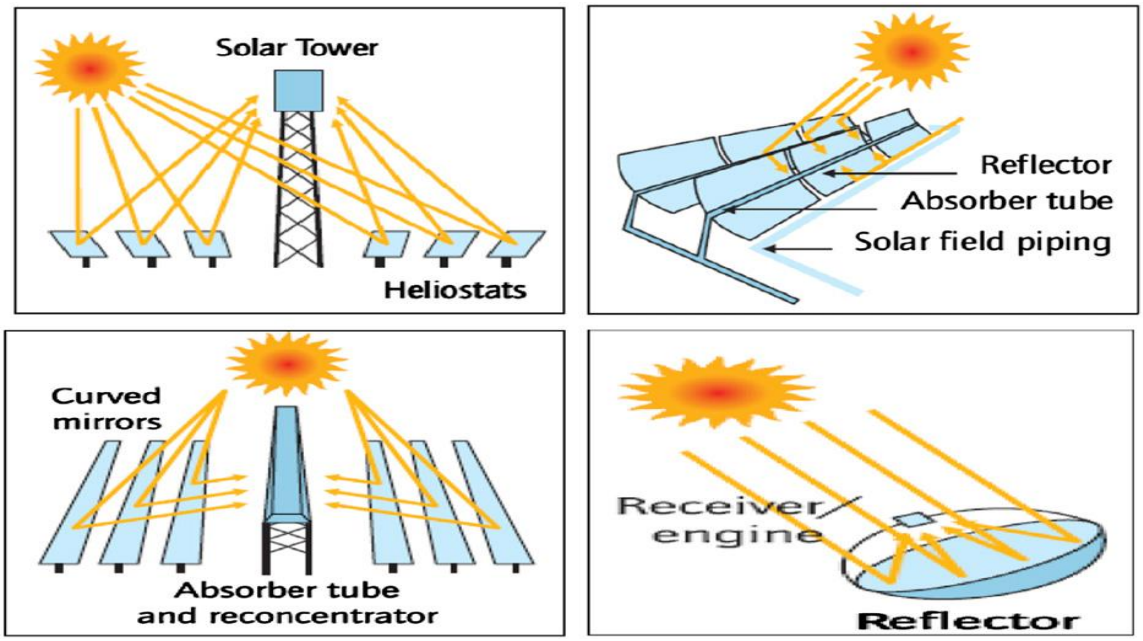

Figure 2:The different types of CSP systems.

Certainly, the performance of these power plants depends on ambient parameters including: ambient temperature, wind speed, direct radiation, etc. Many studies have been done like [3, 4, 5, 6], which determine the impact of the meteorological parameters on performances of CSP plants. There are models that give the system efficiency of CSP plants from ambient conditions such as this equation [7]:

$$\eta_{system} = \eta_{th} * (\alpha_{abs} - \frac{\varepsilon_{abs} * \sigma * T_{abs}^{\ 4} - h_{convection} * (T_{abs} - T_{amb})}{\eta_{field} * C * I_{DNI}} \qquad (1)$$

Where η_{th} is the thermal efficiency, η_{field} is the solar field efficiency, α_{abs} is the radiative absorptive of the absorber, ε_{abs} is the radiative emissivity of the absorber, σ is the Stefan–Boltzmann constant $5.67 * 10^{-8}$ (W/m^2K^4), T_{abs} is the absorber temperature, T_{amb} is the ambient temperature (°C), C is the concentration factor, I_{DNI} is the direct irradiation (W/m^2) and V is the wind speed (m/s).

The convective heat exchange $h_{convection}$ can be formulated [6]:

$$h_{convection} = 5.7 + 3.8 * V \qquad (2)$$

In which V is the wind speed (m/s).Baseline values given and outlined in Table 1 are used for the receiver efficiency calculation.

Table 1: Baseline parameter values used to calculate receiver efficiency in Eq. (1).

η_{th}	0.38
ε_{abs}	*0.88*
η_{field}	*0.6*
α_{abs}	*0.95*
C	*100 and 1000*

2. MATERIALS AND METHODS

To obtain the purpose of this paper, parabolic through and central tower type of CSP technologies considered. In order to get the results of this article, the meteorological data are taken from the site of Ouarzazate, Morocco the 7 August 2012 with the specific parameters mentioned in Table 2 and Figures 3, 4 and 5.

Table-2. Overview of the meteorological conditions at Ouarzazate.

Latitude	30.92 °N
Longitude	-6.89 °W
Elevation	1152 m
Time zone	GMT + 0

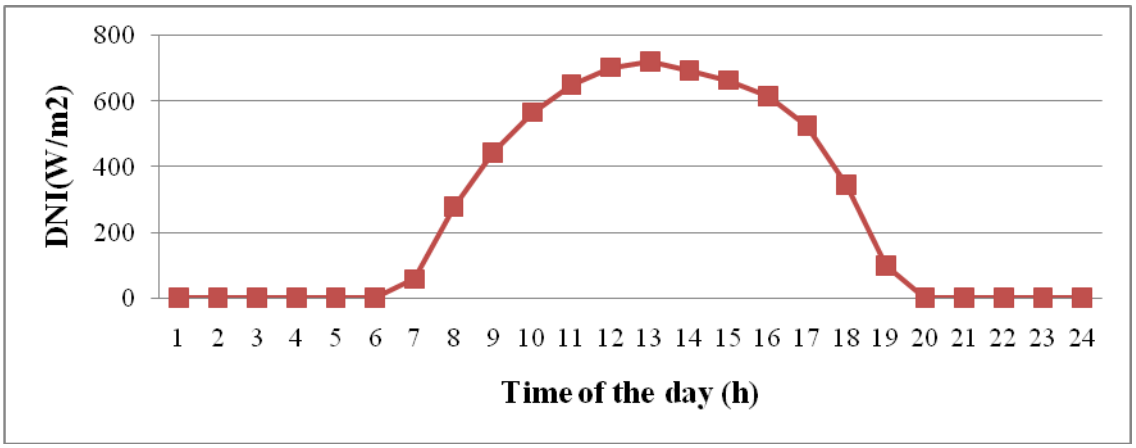

Figure 3: The direct irradiation in Ouarzazate on 30/07/2011.

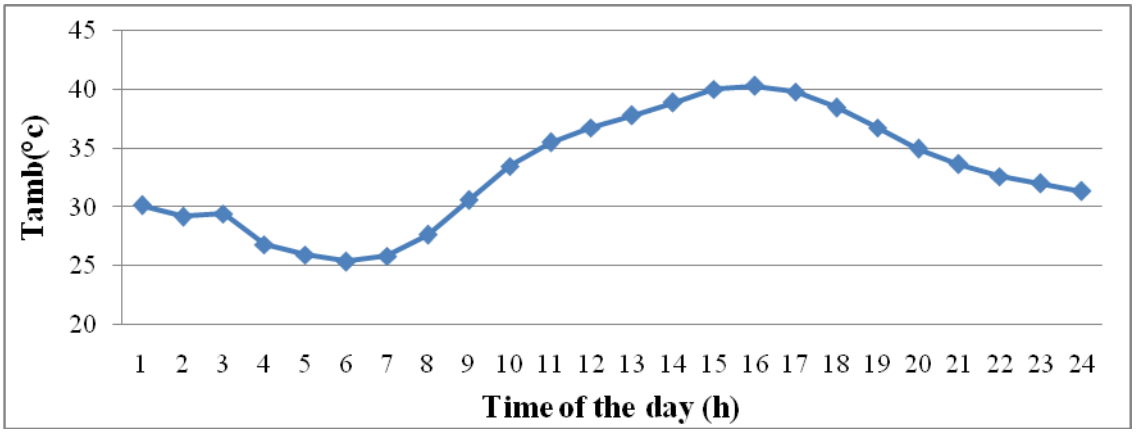

Figure 4: The ambient temperature in Ouarzazate on 30/07/2011.

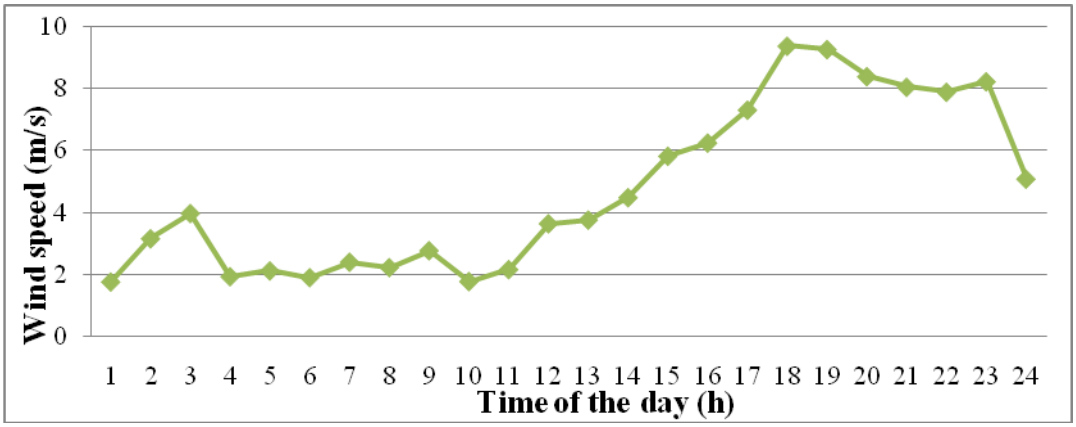

Figure 5: The wind speed in Ouarzazate on 30/07/2011.

3. DESCRIPTION OF METHOD

In terms of the diversity of its applications, genetic algorithm is known as the most popular algorithm. Enormous well-known optimization problems have been resolved by genetic algorithm. It was developed by John Holland and his collaborators in the 1960s and 1970s [8].One common application of GA (Genetic Algorithm) is function optimization, where the purpose is to find a set of values that maximize a complex multi-parameter function [9].An individual is any point to which you can apply the fitness function. The value of the fitness function for an individual is its score. The fitness value of an individual is the value of the fitness function for that individual. Because the toolbox software finds the maximum of the fitness function, the best fitness value for a population is the smallest fitness values for any individual in the population. To obtain the maximum efficiency of the CSP for both central solar and parabolic trough, the method of algorithm genetic is used. Lower bounds of the ambient temperature, wind speed and direct irradiation are chosen in the margin [1 25 100] and upper bounds are chosen in the margin [5 45 900].For both technologies used in this article, the maximum efficiency is obtained in ambient conditions which are ambient temperature of 25 °C, wind speed of 5 m/s and direct irradiation of 876.679 W/m^2 so as to have 24.25% of efficiency for solar receiver and 23.06% for parabolic trough for the same ambient temperature of 25 °C, wind speed of 5 m/s and direct irradiation of 867.676 as seen in Figure 6 and 7.Figure 6 shows us the results obtained for solar tower; and Figure 7 shows us the results obtained for parabolic trough.

4. RESULTS

There are many studies that show the maximum efficiency of the solar plants, but there are few studies that determine the ambient conditions to reach this maximum efficiency. In this article, two types of technology of concentrated solar power are used such as: central tower and parabolic trough. The efficiency of central receiver is 23-35% and as for the parabolic trough, its efficiency estimated to be 14-20% [10].

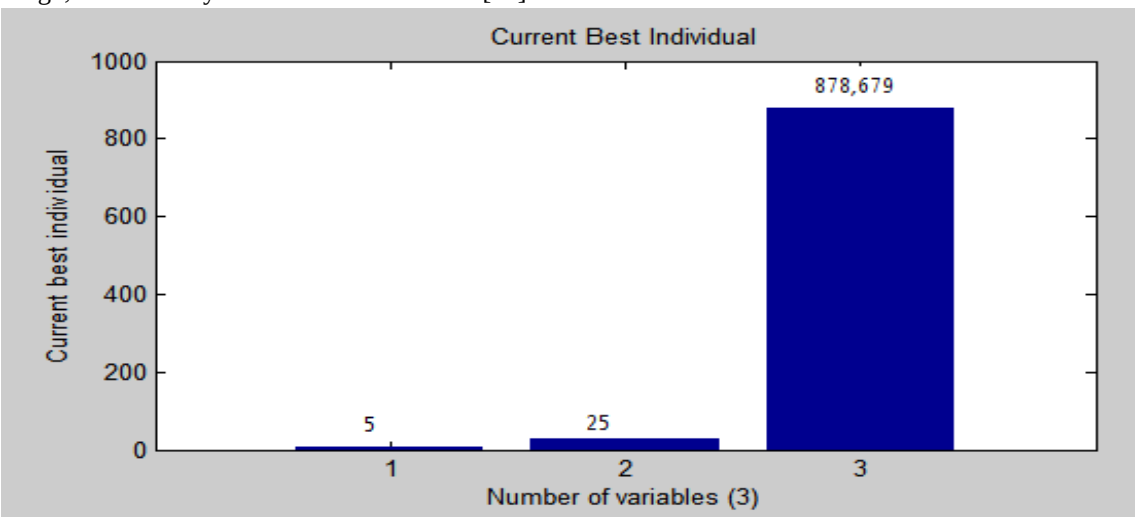

Figure 6: The values of the three variables for central tower.

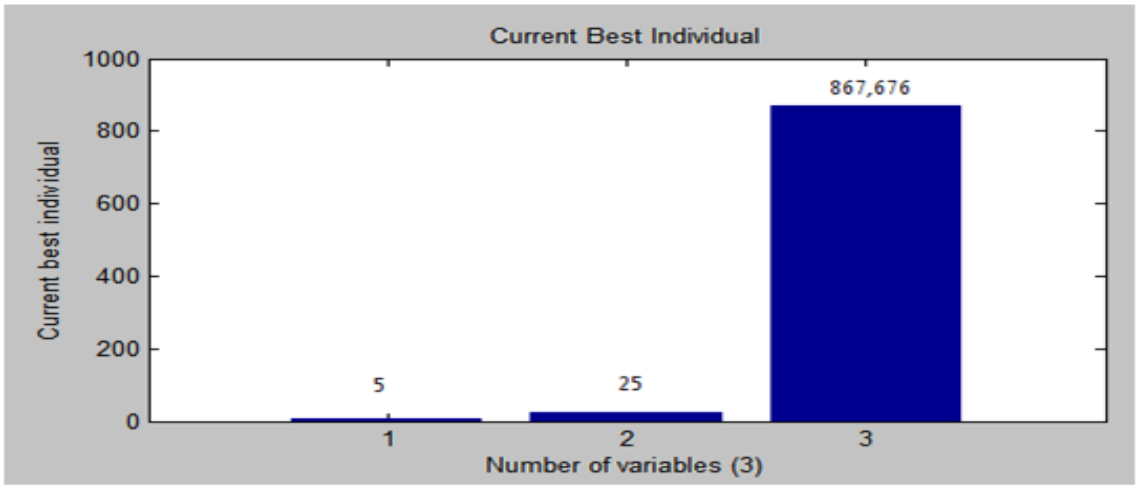

Figure 7: The values of the variables for parabolic trough.

To verify these results obtained by genetic algorithms, the equation (1) is used keeping the value of the wind speed constant 1 m/s, 3 m/s and 5m/s. The same is done in the case of the ambient temperature 25 °C, 35 °C and 45°C as shown in Figures 8,9,10 and 11 using MATLAB software.

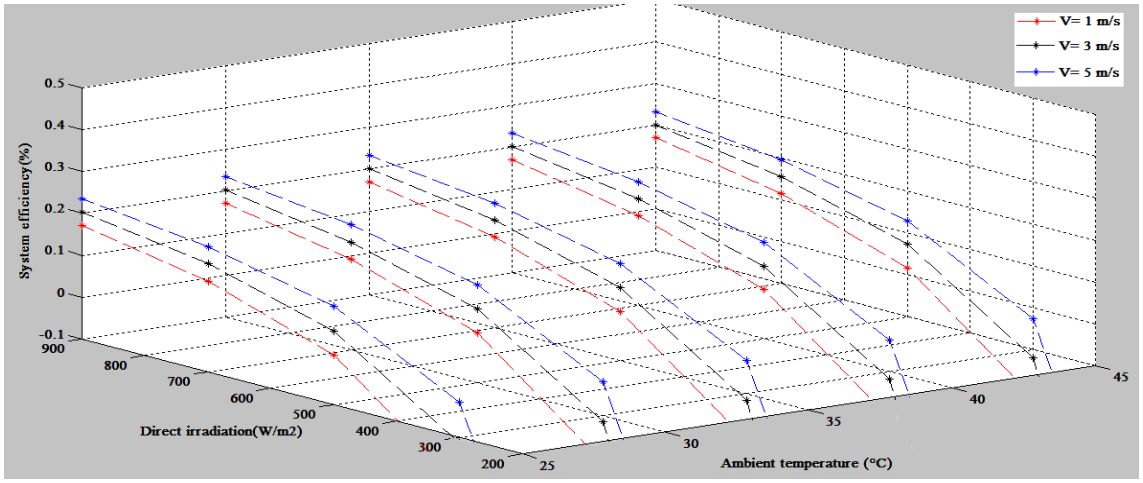

Figure 8: System efficiency according to ambient temperature and direct irradiation for parabolic trough.

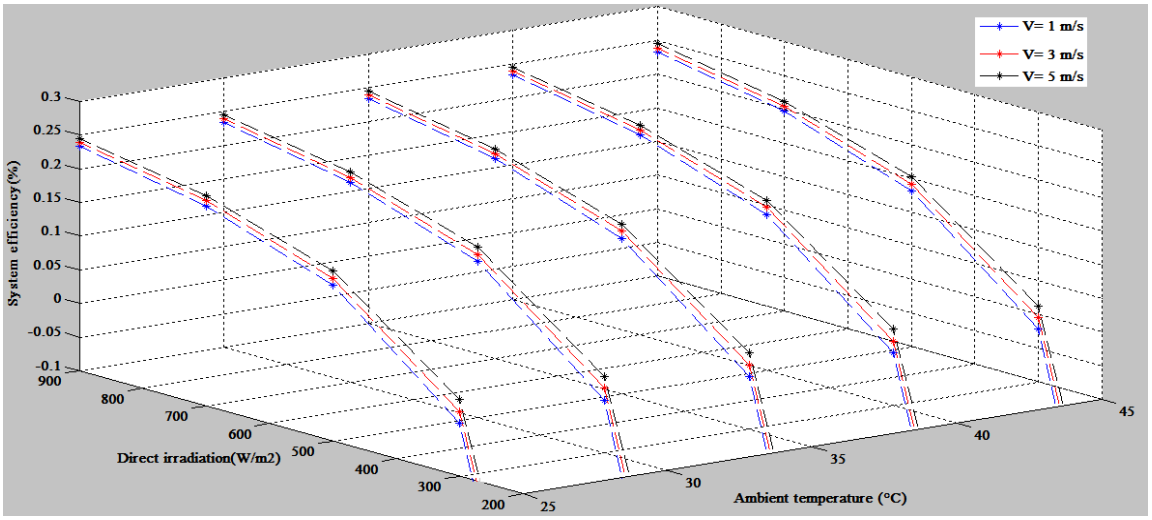

Figure 9: System efficiency according to ambient temperature and direct irradiation for the central tower.

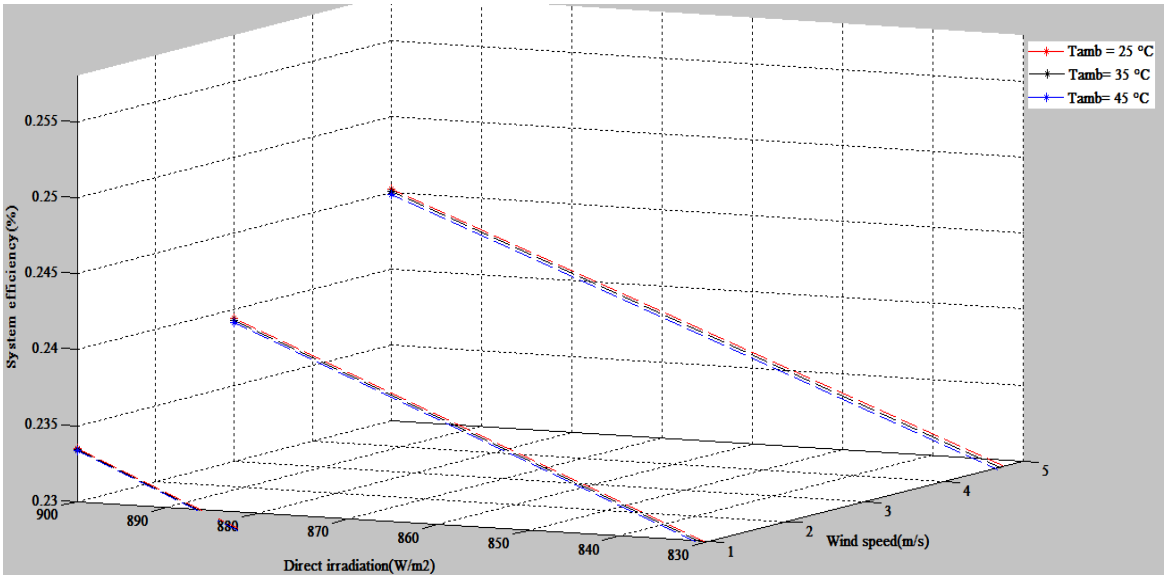

Figure 10: System efficiency according to wind speed and direct irradiation for parabolic trough.

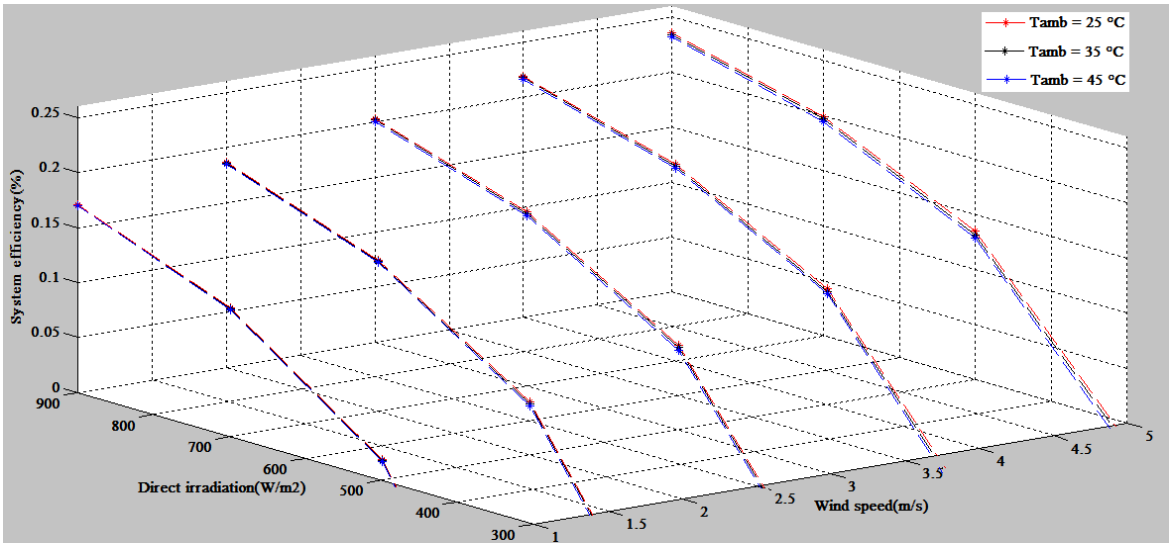

Figure 11: System efficiency according to wind speed and direct irradiation for central tower**.**

The following figures give the view in 3D of the system efficiency with the direct irradiation, ambient temperature and wind speed for both types considered in this paper. According to the first curves 8 and 9, it is found that for wind speed 5 m / s, there is higher efficiency than the other two other wind speeds .In the Figures 10 and 11 shows that the ambient temperature 25 ° C, which allows to have a better performance compared to the other two ambient temperatures 45 ° C and 35 ° C which explains the results obtained by the method of genetic algorithms and give that for maximum efficiency, it is necessary to have an ambient temperature of 25 ° C and a wind speed of 5 m / s in this case. Which is logical, since in other articles [3, 6] revealed that the increase of ambient temperature in solar power plants, the system efficiency drops.

5. CONCLUSIONS

Among the most popular applications of renewable energy technology is the installation of solar power systems using sunlight to produce electricity. This paper has presented a detail overview of the method of algorithm genetic.Based on meteorological data of the site of Ouarzazate in Morocco for the day of 30/07/2011 and the two technologies of solar plants: central receiver and parabolic trough, genetic algorithms were applied to find the ambient conditions that gives the maximum efficiency of these technologies .From this, it's concluded that a maximum efficiency of 23.06% of parabolic trough and 24.25% of solar tower are obtained at 25 °C of ambient temperature ,5 m/s of wind speed and 867.676 W/m2 of direct irradiation for parabolic trough and 878.679 W/m2 for central tower **.**

6. REFERENCES

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