Determination of the Maximum Efficiency of the Photovoltaic Cells (Crystalline and Amorphous Silicon) using A Genetic Algorithm

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Abstract—the installation of photovoltaic systems is one of future sources to generate electricity without emitting pollutants .The photovoltaic cells used in these systems have demonstrated enormous efficiencies and advantages. 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. In this paper, two types of cells were selected: crystalline and amorphous silicon .Using the method of genetic algorithm, the results show that for an ambient temperature of 25 • C and direct irradiation of 625 W/m^2, the efficiency of crystalline silicon is 12% and 5% for amorphous silicon.

Keywords— PV, maximum efficiency, solar cell, genetic algorithm.

I. INTRODUCTION

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 PV (Photovoltaic) system that uses solar energy using solar cells without emitting pollutants and requiring no fuel as shown in Figure 1[1].
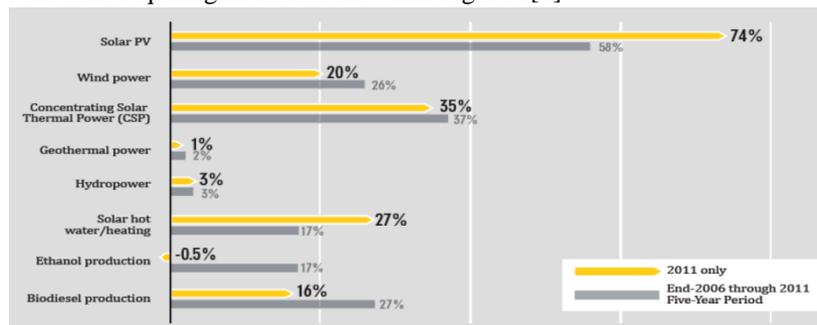

Fig.1: Average annual growth rates of renewable energy capacity 2006-2011[1].
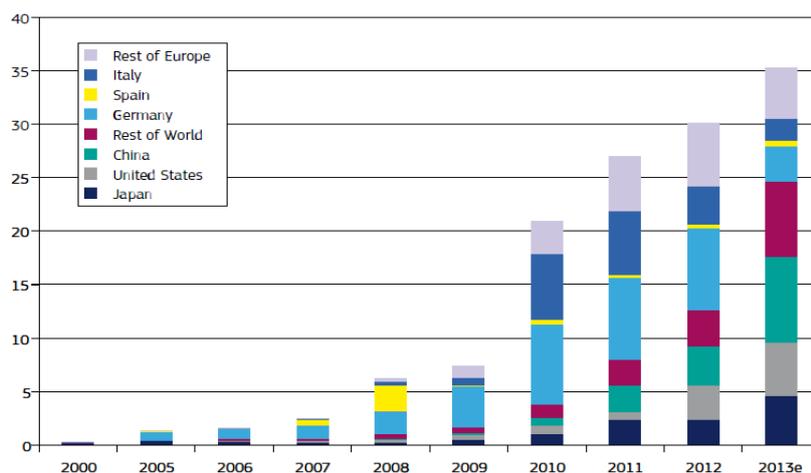

Fig.2: Annual PV installations from 2000 to 2013 in the world [2].

The main leader countries in PV market are Japan, United States, China, and Germany as shown in Figure 2[2].

Morocco, like other countries, has considerable solar resources as seen in Figure 3[3]. Based on this fact, Morocco launched in November 2009 the "Moroccan Solar Plan", an integrated program of producing electricity from solar energy so as to have 42% of electricity from renewable energy 14% solar, 14% wind and 14% hydraulic as shown in Figure 4[4]. This program aims to provide a minimum capacity of 2,000 MW in five potential sites as seen in Figure 5[5] from 2009 to 2020 and is assigned to MASEN, the Moroccan Agency for Solar Energy.
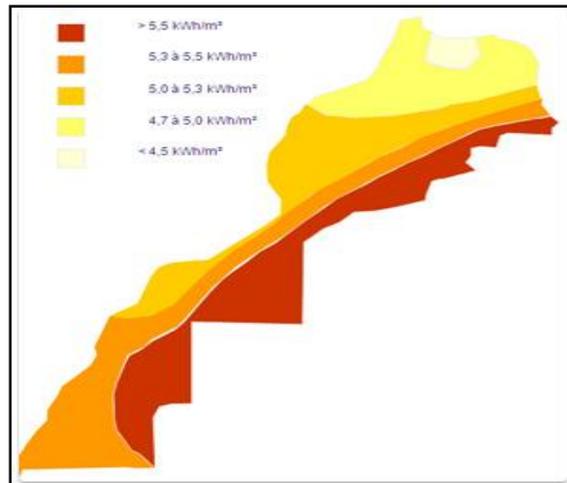
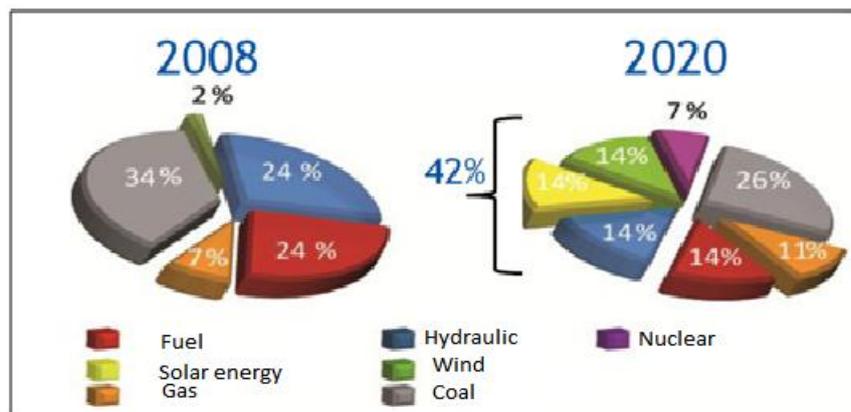Fig.3 The solar radiation map of Morocco [3].

Fig. 4: The objective of the "Moroccan Solar Plan" program [4].
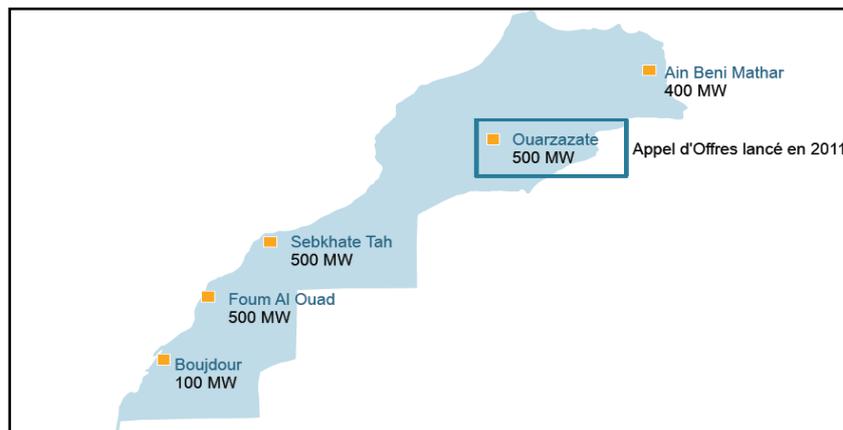

Fig. 5: The program of solar energy (2014 – 2020) [5].

There are models that give the cell temperature of PV module from ambient conditions such as this equation [6]:

$$Tc = Tamb + (NOCT - 20)\frac{G}{800} \qquad (1)$$

Where Tamb is the ambient temperature (°C), G is the direct irradiation (W/m^2) and V is the wind speed (m/s).
Another model to calculate this temperature is the following equation [7]:

$$Tc = Tamb + h \times G \qquad (2)$$

h is the Ross coefficient. Since meteorological databases give G and Tamb, the temperature of the cells in the module can be obtained with the aid of the Ross coefficient.
The PV module efficiency can be formulated [8]:

$$\eta = \eta_{T_{ref}} \left[1 - \beta_{T_{ref}} \left(Tc - T_{ref} \right) \right] \qquad (3)$$

In which $\text{П}_{T_{ref}}$ is the module's electrical efficiency at the reference temperature, $\beta_{T_{ref}}$ is the temperature coefficient (%/°C) and T_{ref} is the reference temperature (°C).

The $\beta_{T_{ref}}$ and T_{ref} depends on PV material and are usually specified by the cell manufacturer [9].
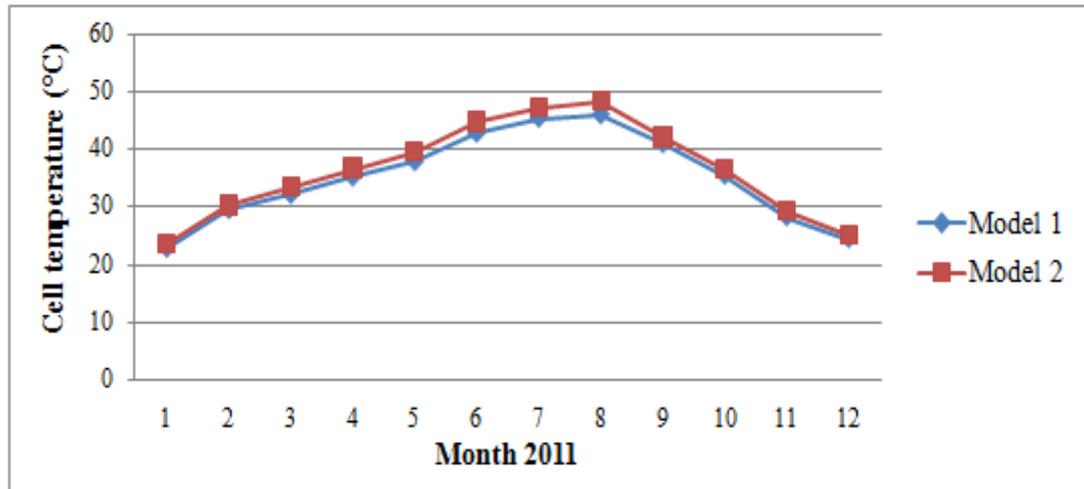
FFig. 6: Cell temperature calculated from the two models.

The comparison obtained between the two models as shown in the Figure is the following: The two models are in excellent agreement.

There are many studies that show the maximum efficiency of the PV cells, but there are few studies that determine the ambient conditions to reach this maximum efficiency.

In this article, two types of technology of PV cells are used such as: crystalline and amorphous silicon.

The efficiency of crystalline silicon is 14-20% and as for the amorphous silicon, its efficiency estimated to be 6-9% [10].

II. 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 [11].

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 [12].

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 value for any individual in the population.

To obtain the maximum efficiency of the PV module for both crystalline and amorphous silicon, the method of algorithm genetic is used. Lower bounds of the ambient temperature and direct irradiation are chosen in the margin [25 0] and upper bounds are chosen in the margin [45 800].

For the metrological data, the values of the site of Ouarzazate in Morocco were used on 30/07/2011 as shown in the Figures 7 and 8.
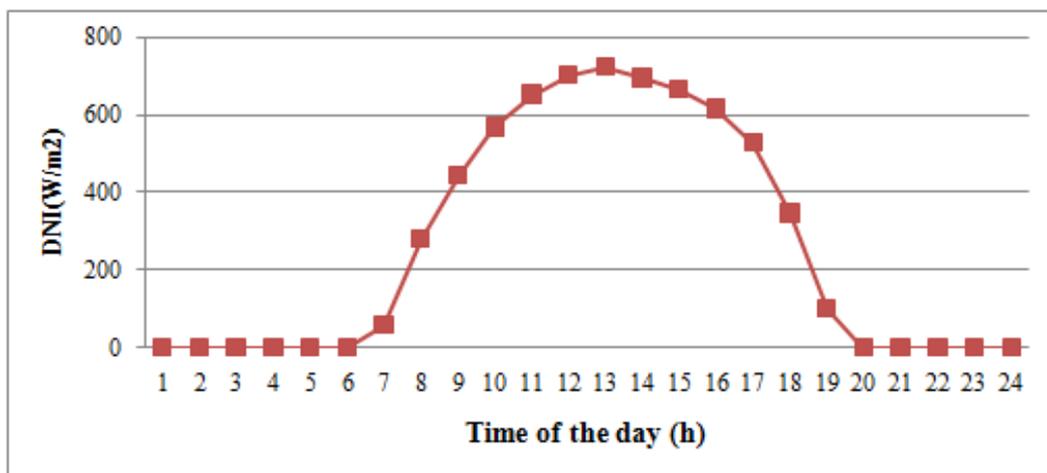

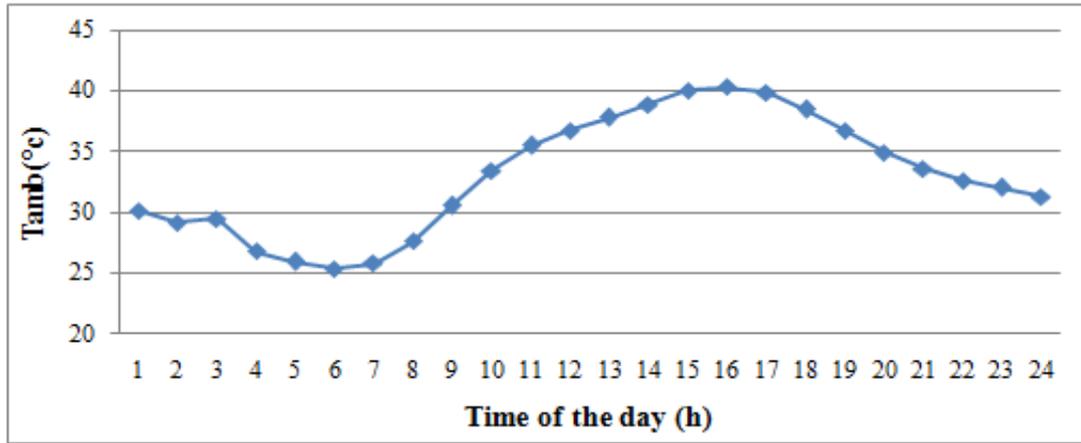Fig. 7: The direct irradiation in Ouarzazate on 30/07/2011.

Fig. 8: The ambient temperature in Ouarzazate on 30/07/2011.

For both technologies used in this article, the maximum efficiency is obtained in ambient conditions which are ambient temperature of 25 °C and direct irradiation of 625 W/m^2 so as to have 5% of efficiency for amorphous silicon and 12% for crystalline silicon as seen in Figure 9.

Figure 10 shows us the best, average and worst scores for crystalline silicon; Figure 11 shows us the best, average and worst scores for amorphous silicon.
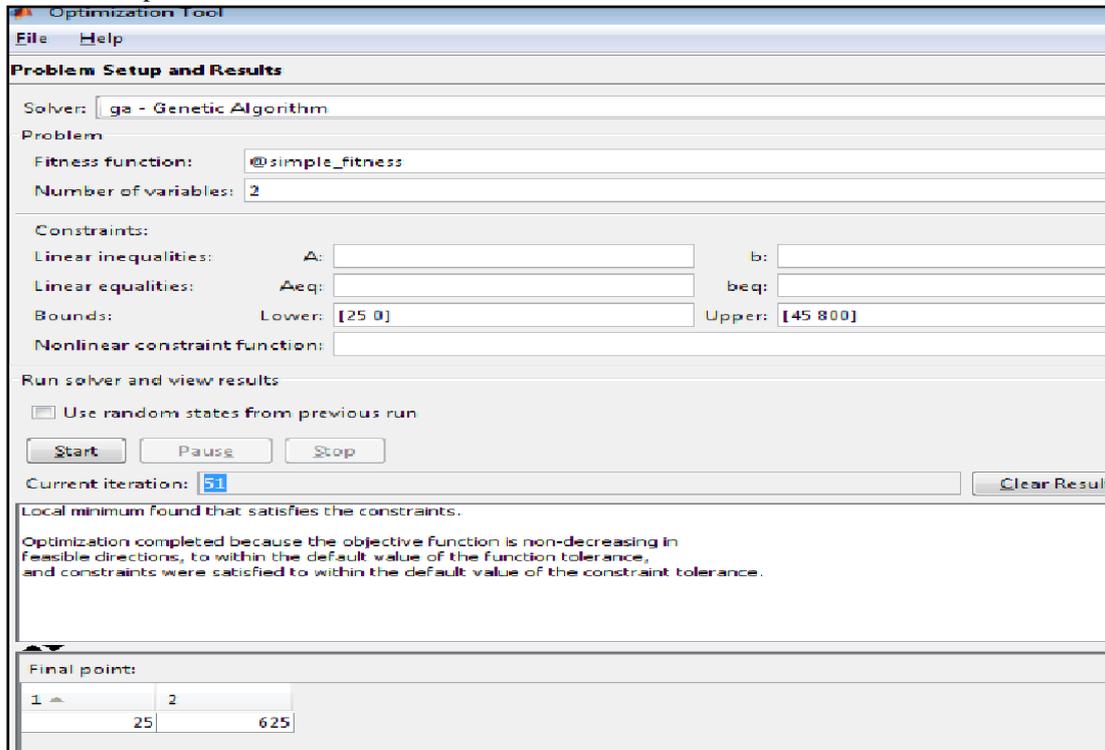

Fig. 9: The obtained results using the genetic algorithm in MATLAB.
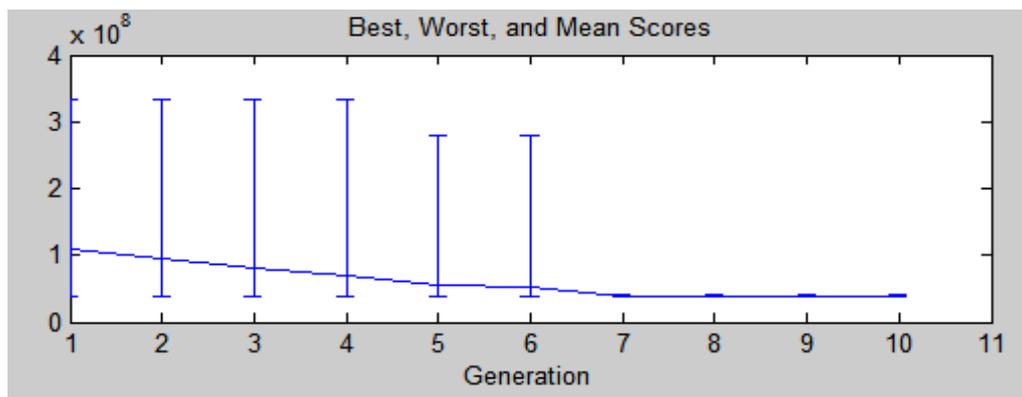

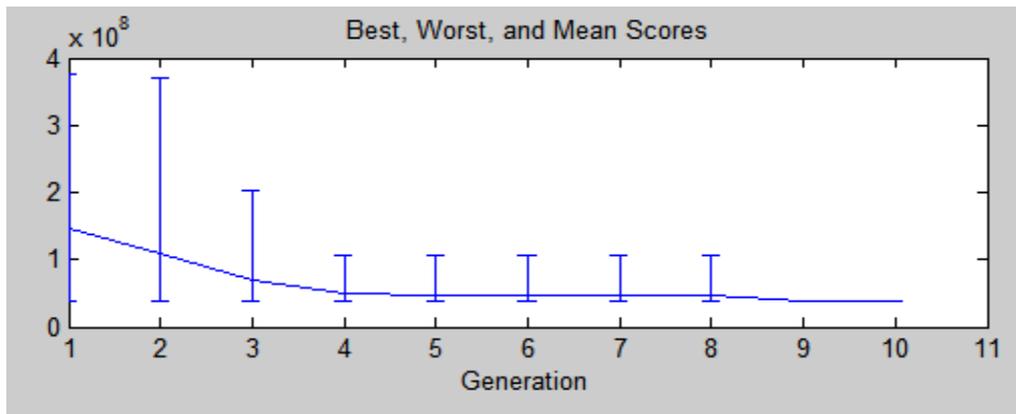Fig. 10: The best, worst and average scores for crystalline silicon.

Fig.11: The best, worst and average scores for amorphous silicon.

III. CONCLUSIONS

Among the most popular applications of renewable energy technology is the installation of PV 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 PV: Crystalline and amorphous silicon, 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 12% of C-Si and 5% of a-Si are obtained at 25 °C of ambient temperature and 625 W/m^2 of direct irradiation.

REFERENCES
[1]   Dan E. Arvizu, "Solar Photovoltaic Technology Status, Challenges and Promise," NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, December 6, 2012, pp 1-45.
[2]   Arnulf Jäger-Waldau, "PV Status Report 2013,"European Commission, DG Joint Research Centre, Institute for Energy and Transport, Renewable Energy Unit Via. Italy, Tech Rep. 1-52, September 2013.
[3]   (2010) masen homepage.Carte d'irradiation solaire. [Online]. Available: http://www.masen.org.ma/index.php?Id=15&lang=fr#/_.
[4]   Plan Solaire Marocain: Un projet intégré et structurant. Plan Solaire Marocain, pp.1-16.
[5]   Les Energies Renouvelables au Maroc: Stratégie et plan d'action. ROYAUME DU MAROC MINISTERE DE L'ENERGIE, DES MINES, DE L'EAU ET DE L'ENVIRONNEMENT. Casablanca Maroc, 20 novembre 2012, pp.1-36.
[6]   C. Schwingshackl, M. Petitta, J.E. Wagner, G. Belluardo, D. Moser,M. Castelli, M. Zebisch and A. Tetzlaff, "Wind effect on PV module temperature: Analysis of different techniques for an accurate estimation," *Energy Procedia*, vol.40, 2013, pp. 77 – 86,2013.
[7]   Wilhelm Durisch, Bernd Bitnar, Jean-C. Mayor, Helmut Kiess, King-hang Lam, Josie Close, "Efficiency model for photovoltaic modules and demonstration of its application to energy yield estimation," *Solar Energy Materials and Solar Cells*, vol. 91, 2007, pp. 79–84, 2007.
[8]   E. Skoplaki, J.A. Palyvos, "On the temperature dependence of photovoltaic module electrical performance: A review of efficiency/power correlations", *Solar Energy*, vol.83, pp. 614-624, 2009.
[9]   S. DE UNAMUNO and E. FOGARASSY, "A THERMAL DESCRIPTION OF THE MELTING OF c- AND a-SIILICON UNDER PULSED EXCIMER LASERS", *Applied Surface Science*, vol.36, pp.1-11, 1989.
[10]   M.M. Aman, K.H.Solangi, M.S.Hossain, A.Badarudin, G.B.Jasmon, H.Mokhlis, A.H.A.Bakar, S.NKazi, "A review of Safety, Health and Environmental (SHE) issues of solar energy system", *Renewable and Sustainable Energy Reviews*, vol. 41,pp. 1190–1204, 2015.
[11]   Xin-She Yang. *Genetic Algorithms. Nature-Inspired Optimization Algorithms*. Chapter 5, 2014.
[12]   Mitchell Melanie. An Introduction to Genetic Algorithms. A Bradford Book, The MIT Press Cambridge, Massachusetts: London, England, Fifth printing, 1999.