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Experiments for Hydrogen Production Using Photovoltaic System and Hoffman Voltameter Electrolyser in Ouargla (South East of Algeria)

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ABSTRACT

This study sets forth an experiment of producing hydrogen via utilizing the solar energy through the electrical analysis of the solution of hydroxide sodium whose concentration (2 g/l). Thus, there should be a direct linking between the electrolyser (Voltametre Hofman) and two photovoltaic panels. This experiment took place in Ouargla (Southeast of Algeria) and it lasted seven consecutive months (from August 2012 to February 2013). This study made clear that the highest amount of the produced quantity of hydrogen was in August and the lowest was in December, and during the whole day, hydrogen production was at its best in the evening time. In addition, the relationship between the hydrogen flow and the solar system is exponential.

Keywords: Hoffman voltameter, Hydrogen production, Photovoltaic panels, Solar energy

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INTRODUCTION

Sources of renewable energy have become on**e** of the most significant issues in the world today, and because hydrogen is an effective mean for storing this energy (can be used as a non-toxic energy storage and transport medium) and thus its production became of great interest for scientists and researchers. The hydrogen can be generated by a wide range of technologies and but to respect the environment, most promising options for obtaining hydrogen from a clean renewable energy source is hydrogen production by water electrolysis, which uses solar electrical energy directly and it is the more rapidly available process, moreover, the electrolysis has numerous advantages, such as low environmental impact and easy maintenance.

There are many experimental and theoretical studies dealing with the field of hydrogen production using solar energy and such studies were reported by Estive et al. [1] and with time, the intensity of research increased and became widely varied, some examples are described [2-8].

About Algeria, some studies were carried out as it is mentioned [9-12]. Algeria is considered as one of the best insolated regions in the world especially its south. One of the promising place in the south of Algeria for hydrogen production is the region of Ouargla, were these experiments were carried out.

Some studies were recently conducted in the region of Ouargla, showing the potential possibilities in this field, but the research on the production of hydrogen is very modest and this does not negate the existence of some serious attempts. Recently, some studies were conducted as it is mentioned [12-14].

In this paper, we present the experimental results for hydrogen production using photovoltaic system and Hoffman voltameter electrolyser in the region of Ouargla, They were obtained during seven successive months from August 2012 to February 2013.

MATERIALS AND METHODS

The main components of the hydrogen production system are the Hoffman voltameter electrolyser and the photovoltaic panel. The Hofmann voltameter is used as electrolytic cell. It is made of glass and it consists of three joined upright cylinders. The inner cylinder is open at the top to allow the addition of water and the salt. A platinum electrode is placed at the bottom of each of the two side cylinders.

The volume of every cylinder is 25 ml; the electrodes are connected to the positive and negative terminals of a source of electricity. When current is run through the Hofmann voltameter, gaseous oxygen forms at the anode (negative) and gaseous hydrogen at the cathode (positive). Each gas displaces water and is collected at the top of the two outer tubes, where the volume of produced hydrogen can be measured. The solution used is sodium hydroxide with a concentration of 2 (g/l), the Hofmann voltameter is shown in Figure 1. The experimental V-I curve of electrolyser is illustrated in Figure 2. The photovoltaic panel is has an overall surface of 0.45 m^2. The panel is mounted on an inclined steel frame. The tilt angle is maintained at 30° with the horizontal and the frame is placed such that the panel is facing south direction.

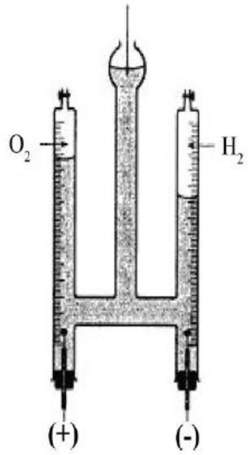

Figure 1: Schematic representation of Hofmann voltameter

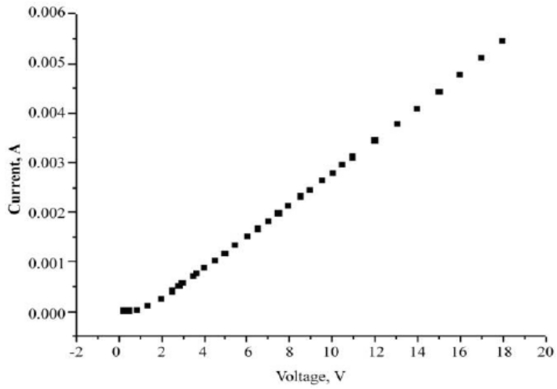

Figure 2: Experimental V-I curve of electrolyser

In these experiments, two photovoltaic panels are connected in series and the variations of the voltage with the current for various isolations illustrated in Figure 3. The hydrogen produced volume, the voltage V, the current I and the solar radiation H are measured every 30 min. The voltage V and the current I are measured using a digital voltmeter and an ammeter, while the solar radiation is measured using a digital solarimeter. A schematic diagram and a photograph of the experimental setup are shown in Figures 4 and 5 respectively.

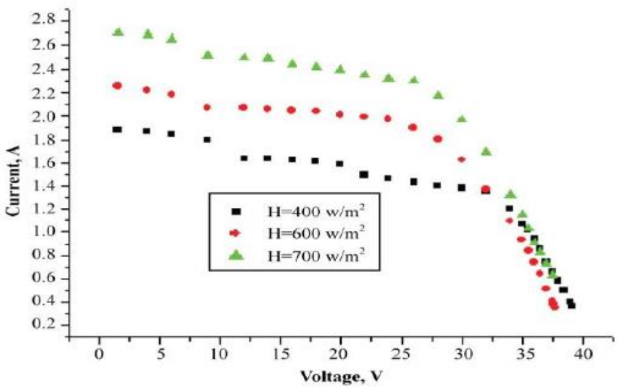

Figure 3: Experimental V-I curve of PV model

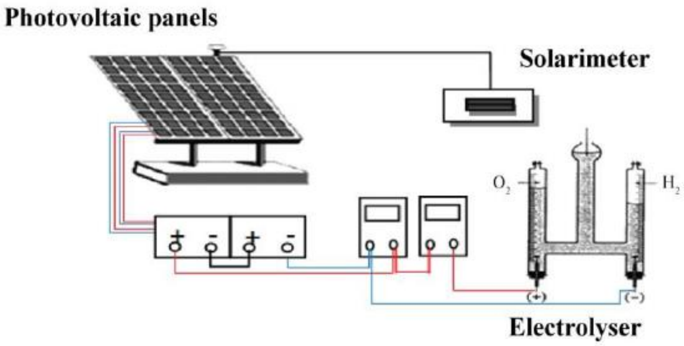

Figure 4: Schematic diagram of the experimental set up

Figure 5: Photograph of the system

RESULTS AND DISCUSSION

The Experiments of hydrogen production using photovoltaic system and Hoffman voltameter electrolyser were conducted during seven successive months, from August 2012 to February 2013. The days chosen are the sunny ones of every month and the experiments started every day from 08:00 am to the sunset.

Figure 6 shows the solar radiation recorded for the 24, 25, 26, 27, 28 and 29 of August 2012. The voltage V and the current I of the electrolyser during the electrolytic production of hydrogen by directly connecting the solar PV panel to the terminal of the electrolyser during six successive days from August 2012 are shown in Figures 7 and 8 respectively. Figure 9 illustrates the hydrogen flow rate produced for the same period.

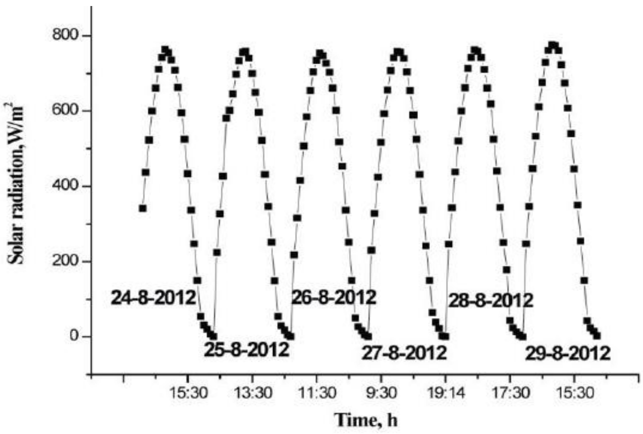

Figure 6: Solar radiation as a function of the time

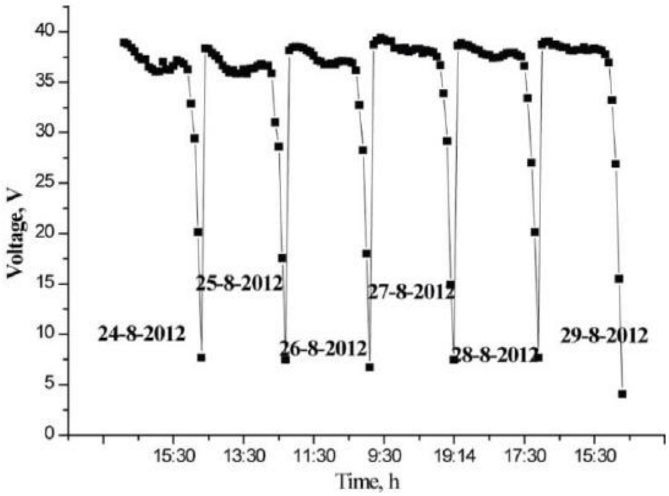

Figure 7: Voltage as a function of the time e

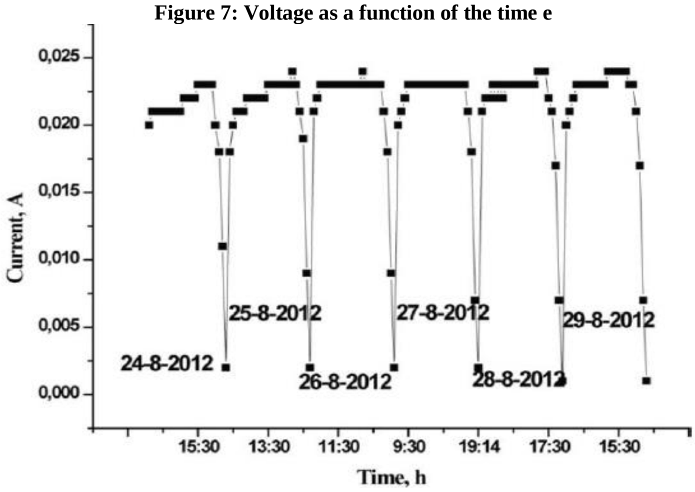

Figure 8: Current as a function of the time e

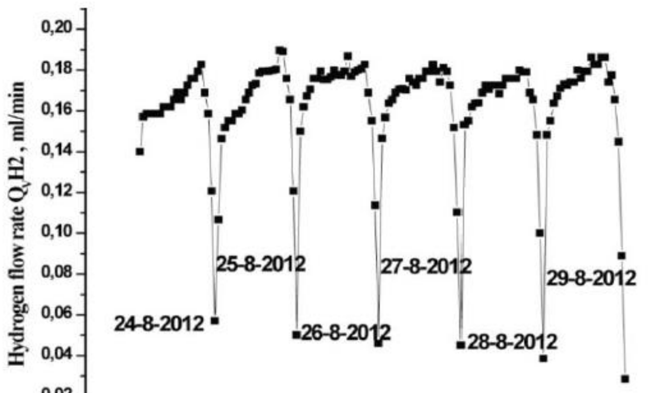

Figure 9: Hydrogen flow rate as a function of the time e

As it can be noticed from the Figures 6-9, during the period, from 8 a.m. to 12 a.m, the solar radiation, the electric current, and the hydrogen flow rate tend to augment, whereas the voltage tends to decrease. That is due to the effect of temperature, from the onset of the experiment, the solution temperature is low, and hence the solution resistivity is high, as the temperature increases during the electrolysis process, the resistivity decreases and this yields to the decrease of the voltage. After noontime, the solar radiation starts to decrease after reaching its maximum value. However, the electric current and the hydrogen flow rate would continue to augment. Furthermore, the voltage would fairly increase thanks to the high temperature of the solution, and consequently, an augment would happen in the current, the voltage and the hydrogen flow rate. Therefore, we can come to the conclusion that the best period for hydrogen production would be the evening-time. Figure 10 represents the changes of the solar radiation during the months during which the study took place (from August to February). According to this Figure, we can notice that the solar radiation increases faintly from August to November, and then it starts to decrease till it reaches its lowest in December. After that, it begins to augment in an apparent way till it reaches its highest. We, as well, notice that the variance between the lowest degree and the highest one does not exceed 22%.

Figure 11 represents the change of the voltage underwent during the months of August to February. According to this Figure, we can see that the voltage is approximately constant, with faint augment during November, December and January because of the apparent decrease in temperature during these months. That eventually resulted in the heightening of the resistivity, and henceforth the increase in voltage between the two ends of the electrolyser.

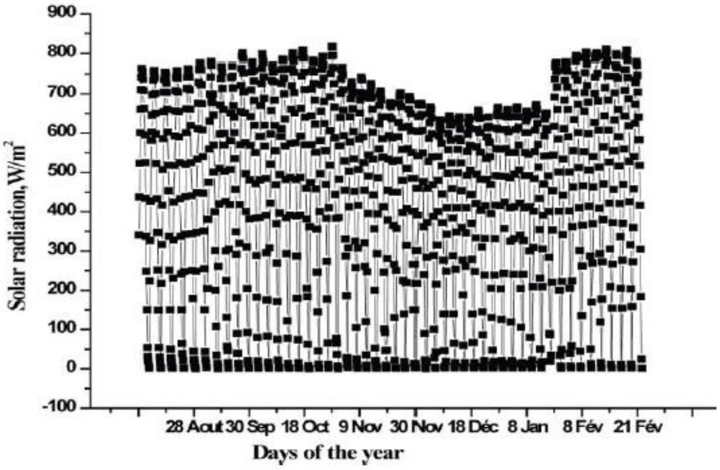

Figure 10: Solar radiation as a function of days of the year

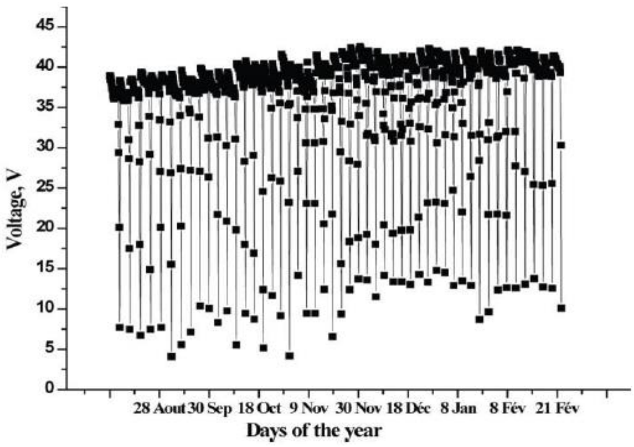

Figure 11: Voltage as a function of days of the year

The changes in the electric current and the hydrogen flow rate during the months of the year are illustrated in Figures 12 and 13 respectively. We can notice that the highest value of the current intensity and the hydrogen flow rate were during August and then they began to attenuate till they reach their lowest values in December. After that, they started to augment during the two months of January and February.

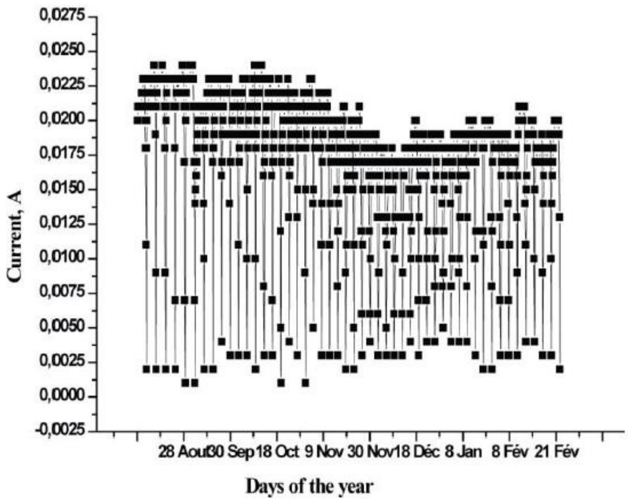

Figure 12: Current as a function of days of the year

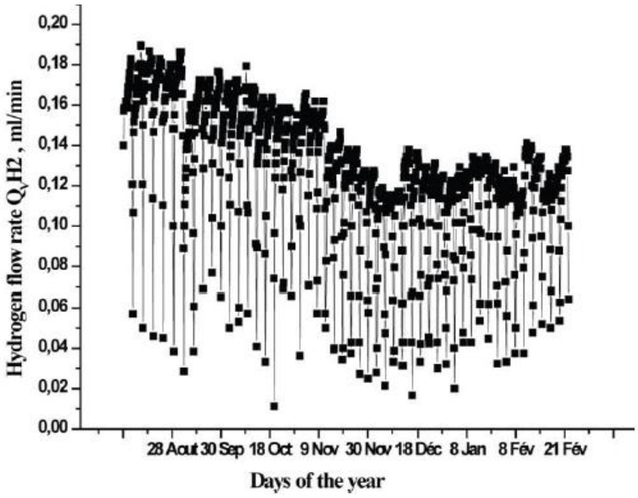

Figure 13: Hydrogen flow rate as a function of days of the year

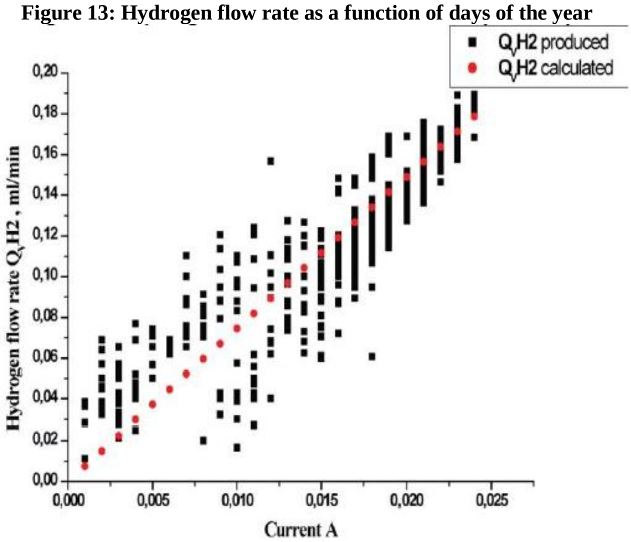

Figure 14: Hydrogen flow rate as a function of the current

Figure 14 shows the correlation between the hydrogen flow rate Q_{VH2} produced and Q_{VH2} calculated the current I. The amount of hydrogen estimated by the electrolyser can be calculated according to Faraday's law [12]:

$$v_{H2} calculated = \frac{R I_{el} T_a t}{FPZ} \quad (1)$$

Where I_{el} is the input current of the electrolyser, t is the time during which the current is supplied to electrolyser in minutes, F is the Faraday's constant (96485 C/mol), Ta is the ambient temperature (298 K), P is the atmospheric pressure (1.01325 10^5 Pa), R is the ideal gas constant (8.314 J/mol K) and z is the excess number of electron which is 2 for hydrogen. By substitution, we obtain:

$$Q_{VH2} calculated = \frac{v_{H2} calculated}{t} = 7.445 I_{el}\left(\frac{ml}{min}\right) \quad (2)$$

From the Figure 14, it is clear that there is a linear relationship between the hydrogen flow rate and the electrolyser current and that is demonstrated by relationship (2), and also the theoretical and experimental results seem to be compatible to a large extent. The voltage V, the current I of the electrolyser and the hydrogen flow rate as functions of the solar radiation are illustrated in Figures 15-17 respectively. It can be seen from the Figures 15-17 that the overall shape of the relationship for The voltage V, the current I of the electrolyser and the hydrogen flow rate with the solar radiation is the same overall shape and that because there is a linear relationship between the voltage V, the current I of the electrolyser and the hydrogen flow rate.

CONCLUSION

After conducting the experiment of producing hydrogen using the solar radiation, though, the electrolysis of sodium hydroxide solution sodium in Ouargla during seven consecutive months, from August 2012 to February 2013, we came to the following results: It was in August that hydrogen production was at its best, and it was at its weakest in December. The afternoon period was the best period for hydrogen production. The relationship between the hydrogen flow and the solar radiation is exponential, and that the very same relationship is noticed for both the voltage and the electric current with the solar energy.

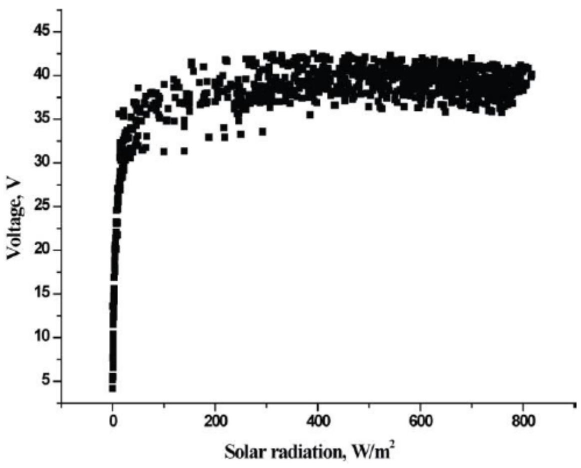

Figure 15: Voltage as a function of the solar radiation

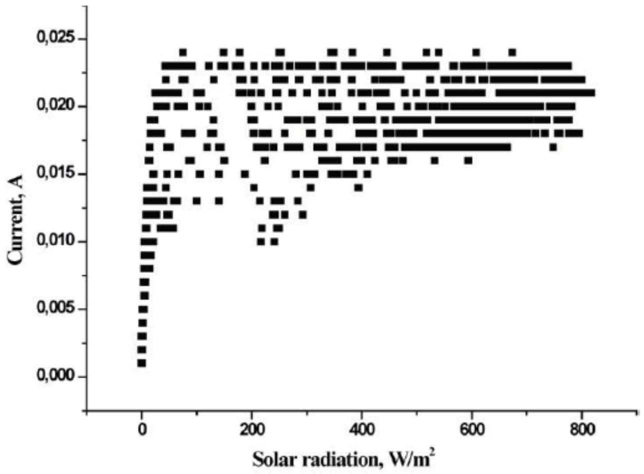

Figure 16: Current as a function of the solar radiation

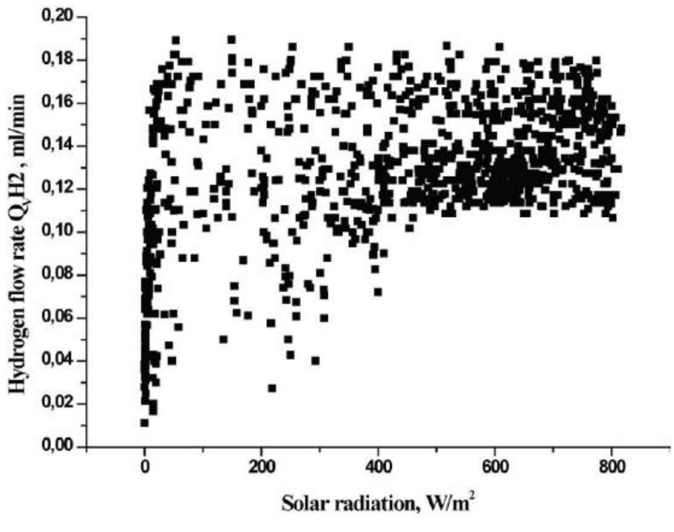

Figure 17: Hydrogen flow rate as a function of the solar radiation

REFERENCES

[1] D. Estive, C. Ganibal, D. Steinmetzt, A. Vialaront, *Int. J. Hydr. Energ.*, **1982**, 7, 711-716.
[2] L.G. Thomas, N.A. Kelly, *Int. J. Hydr. Energ.,* **2008**, 33, 5931-5940.
[3] S. Eker, F. Kargi, *Int. J. Hydr. Energ.,* **2010**, 35, 12761-12766.

[4] A. Đuki, M. Firak, *Int. J. Hydr. Energ*., **2011**, 36, 7799-7806.
[5] R. Valde, L.R. Rodrı guez, J.H. Lucio, *Int. J. Hydr. Energ*., **2012**, 37, 4018-4025.
[6] A. Fernando, H. De Battista, J. Ricardo, *Int. J. Hydr. Energ*., **2012**, 37, 14951-14958.
[7] K. Fujii, S. Nakamura, M. Sugiyama, K. Watanabe, B. Bagheri, Y. Nakano, *Int. J. Hydr. Energ.,* **2013**, 38, 14424-14432.
[8] G. Zini G, A. Dalla Rosa A, *Int. J. Hydr. Energ*., **2014**, 39, 107-118.
[9] H. Derbal-Mokrane, A. Benzaoui, M.A. Raoui, M. Belhamel, *Int. J. Hydr. Energ*., **2011**, 36, 4198-4207.
[10] R. Boudries, R. Dizene, *Renew. Energ*., **2011**, 36, 2872-2877.
[11] R. Boudries, *Int. J. Hydr. Energ.,* **2013**, 38, 11507-11518.
[12] D. Ghribi, A. Khelifa, S. Diaf, M. Belhamel, *Int. J. Hydr. Energ.,* **2013**, 38, 8480-8490.
[13] A. Djafour, M. Matoug, H. Bouras, B. Bouchekima, M.S. Aida, B. Azoui, *Int. J. Hydr. Energ.,* **2011**, 36, 4117-4124.
[14] B. Negrou, N. Settou, N. Chennouf, B. Dokka, *Int. J. Hydr. Energ.,* **2011**, 36, 4110-4116.