Materials & Biomaterials Science
Researche and Engineering

Mater. Biomater. Sci. 03 (2020) 030–033

View Journal | View Issue

ORIGINAL PAPER

Production of solar hydrogen at desert site of Algeria

K. Bouziane [a,*], N. Chaouch [a]

[a] GEEMS laboratory, Faculty of Applied Sciences, Kasdi Merbah University, Ouargla, Algeria.

ARTICLE INFO

Article history:
Received: 17 October 2019
Revised: 25 November 2019
Accepted: 29 December 2019
Published: 08 January 2020

Keywords:
Solar
Hydrogen
Electrolyzer
Photovoltaic
Alkaline
Algeria

ABSTRACT

Hydrogen is a sustainable fuel option and one of the potential solutions for the current energy and environmental problems. Renewable energy–hydrogen systems for remote applications constitute an early niche for sustainable hydrogen energy. Optimal matching between the photovoltaic (PV) system and the electrolyzer is essential for maximum electrical energy transfer and hydrogen production.

This paper concerns the study of an autonomous hydrogen production system basically consisting in a solar panel array supplying an alkaline electrolyzer. The system used photovoltaic (PV) modules, an alkaline electrolyzer, and an optimized direct connection between the PV and electrolyzer systems.The data supplied by the experimental system clearly showed the importance of considering the efficiency of photovoltaic module to hydrogen generator efficiency when designing an optimum solar hydrogen system.

Nomenclature

I_l : light generated current, is proportional to instantaneous solar irradiance.
q : electron charge (1.602 x 10^{-19} C).
K: Boltzmann's constant (1.38 x 10^{-23} j/K).
T: temperature (K).
A: surface area part of the cell exposed to solar radiation (m^2).
I_o: saturation current density (A).
I: current flowing in the circuit (A).
V: voltage of the circuit (v).
V_{OC}: open circuit voltage (v).
I_{SC} : short circuit current (A).
FF : fill factor.
V: volume (m^3).
t : time (s).
ρ : volumes'masse (0.09 kg/m^3).
PCI: inferior calorific power (199 x 910^6 J/kg)

Introduction

The energy sector plays a key role in achieving sustainable development and in the future the energy production system must take the lead in meeting environmental goals [1]. In response to problems involved in the current crisis of energy, with the rise in the price of the oil barrel and with the gas emissions for purpose of greenhouse, hydrogen seems today as a clean fuel and strategic substitution for the next decades. In parallel, the increase in the contribution of renewable energies, such as solar energy, with the energy balance requires the development of methods of storage and means of transportation of this energy [2].

Hydrogen production is the industrial method for generating hydrogen. Currently the dominant technology for direct production is steam reforming from hydrocarbons. Hydrogen is also produced as a byproduct of other processes and managed with hydrogen pinch [3]. Many other methods are known including electrolysis and thermolysis.

Hydrogen produced from renewable energy (e.g. solar) sources is a very efficient and clean fuel, hydrogen is the best fuel and solar hydrogen system has the lowest effective cost, when environmental damage and higher utilization efficiency of hydrogen are taken into account [4].

Various experimental and theoretical references studied the production of the hydrogen by an electrolyzer using the PV energy. The electrolysis of a synthetic alkaline was carried out at different temperatures varying between 10 and 80 °C [4–5].

The present paper studies the integration between the solar photovoltaic array and water electrolysis unit for hydrogen production. A photovoltaic module is coupled with the electrolyzer unit by direct coupling.

* **Corresponding author:** Khadidja Bouziane
Khadidja.c@gmail.com

Materials and methods

Presentation of site

A small community at Ouargla - Algeria is chosen as a case study for this research, some climate and energy data necessary for design and simulation concern is presented. The latitude of the town of Ouargla is 31° 57" North, and the Latitude is 5° 19'' East. Its area is about 270030 Km^2. All of its area is desert or semi desert land. The average solar insolation is estimated as 2900 kWh/m^2 annually, and the average sunshine duration is more than 3300 hrs. The measured global radiation in Ouargla varies from 2.280 kWh/m^2 in December, to 7.620 kWh/m^2 in July, on a horizontal surface, Diffused radiation is 1.324 kWh/m^2 in January, and 1.984 kWh/m^2 in May [6].

Fig. 1. Map of Ouargla.

Water electrolyzer

Electrolysis is defined as splitting apart with an electric current. Decomposition of the water occurs when a direct current (DC) is passed between two electrodes immersed in water separated by a non-electrical conducting aqueous or solid electrolyte to transport ions and completing the circuit. The voltage applied to the cell must be greater than the free energy of formation of water plus the corresponding activation and ohmic losses before decomposition will proceed. Ion transport through the electrolyte is critical as the purest of water would only contain small amounts of ions making it a poor conductor.

The alkaline electrolyzer is a well-established technology that typically employs an aqueous solution of water and 25–30 wt % potassium hydroxide (KOH). However, sodium hydroxide (NaOH), sodium chloride (NaCl) and other electrolytes have also been used.

The liquid electrolyte enables the conduction of ions between the electrodes and is not consumed in the reaction but does need to be replenished periodically due other system losses. Typically commercial alkaline electrolyzers are run with current densities in the range of 100–400 $mA.cm^{-2}$. The reactions for the alkaline anode and cathode are shown in Eqs. (1) and (2) respectively, showing the hydroxyl (OH^-) ion transport.

$$2OH^- \longrightarrow 1/2\ O_2 + H_2O + 2e^- \quad (1)$$

$$2H_2O + 2^- \longrightarrow H_2 + 2OH^- \quad (2)$$

The first water electrolyzers used the tank design and an alkaline electrolyte. These electrolyzers can be configured as unipolar (tank) or bipolar (filter press) designs. In the unipolar design, electrodes, anodes, and cathodes are alternatively suspended in a tank. In this design, each cell is connected in parallel and the entire system operated at 1.9 – 2.5 Vdc [7].

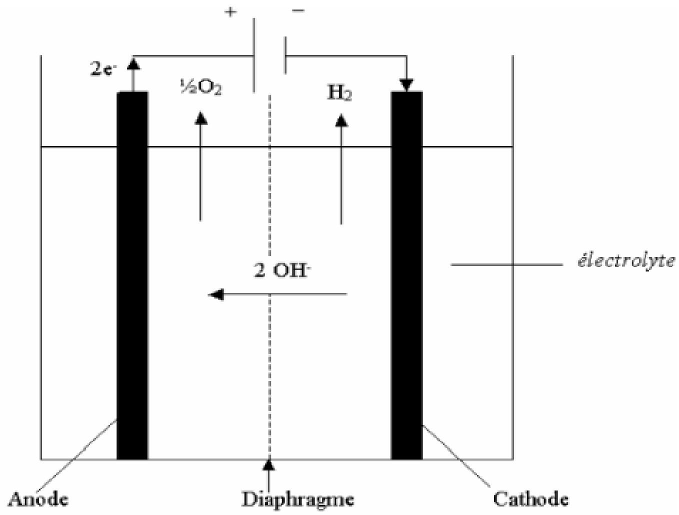

Fig. 2. Alkaline electrolyzer design.

Principle of energy conversion

The current-voltage characteristics of the electric circuit of solar cell can be described by the following simplified equation:

$$I = I_l - I_O \exp [\, q\,(V - I.R_s) / (A.K.T)\,] \quad (3)$$

The electric power output of PV is:

$$P_{el} = I.V \quad (4)$$

Moreover, the maximum output power is given by:

$$P_{max} = (I.V)_{max} = V_{OC} . I_{SC} .FF \quad (5)$$

$P_{max} = V_{mp} . I_{mp}$, corresponding to the maximum power point (MPP).

The energy conversion efficiency, η , is given by:

$$\eta = V_{mp} . I_{mp} / P_{in} = V_{oc} . I_{sc} .FF / P_{in} \quad (6)$$

The output power of the PV system, however, fluctuates depending on solar insolation and surface temperature. Then a storage system must be used to deliver the required power at lower insolation levels and during the night. In order to make solar hydrogen widely available, cheap solar electricity would be needed. It is presently not available but it is rapidly growing and improving its production techniques and costs. Today more than 90 % of photovoltaic activities are concentrated on classical crystallized silicon solar cell, only 7.8 % are related to thin layer solar cells, also other cells that include rear and toxic elements [8 - 9].

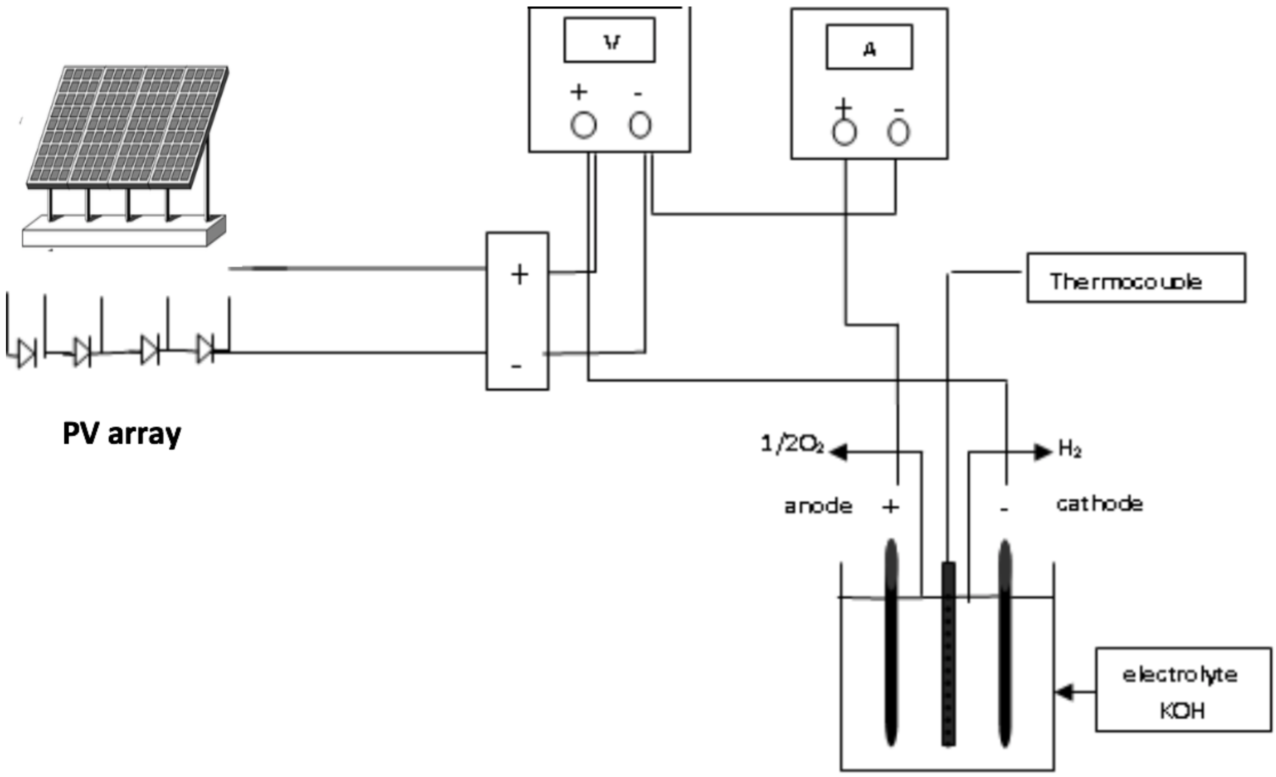

Fig. 3. A schematic diagram for the photovoltaic–hydrogen power system.

The experimental system of hydrogen production

The present travel studies the integration between the solar photovoltaic array and water electrolysis unit for hydrogen production. A photovoltaic module is coupled with the electrolyzer unit by direct coupling. Fig. 3 shows the photovoltaic–hydrogen power system. The system consists of:

(a) The photovoltaic module: is a polycrystalline silicon type with maximum output of 50 W with an open circuit voltage of 17.39 V and short circuit current of 2.87 A at STC. The PV module is supported up on a tilted structure from steel frames. The tilt angle is fixed at 30° with horizontal and the structure is mounted such that the module is facing south direction.

(b) The water electrolyzer: consists of an acrylic box with the dimensions of 20 x 15 x15 cm. The electrodes are made of carbon and immersed in the electrolyte. The electrolyte used is potassium hydroxide with a concentration of 2 g/l, (25% according to the highest conductivity with concentration).

The overall system parameters are measured accurately and recorded continuously for data storing as follows:

- The PV module and the electrolyzer voltages and currents are measured using digital voltmeters and ammeters.
- A thermopile pyranometer of type Kipp & Zonen is used to measure the solar radiation intensity. The pyranometer is mounted at the PV module structure and parallel to the module surface.
- A type K thermocouple is used to measure the electrolyte and ambient temperatures.

Results and discussions

Characterizations I-V

Figure 4 shows the PV and Electrolyzer I–V curves on the same plot. A second-order polynomial (quadratic) was fit to the electrolyzer I–V data and used to extrapolate the data to the higher voltage needed to find the intersection of the Electrolyzer I–V curve with the PV I–V curve. The intersection of the two I–V curves occurred at 16 V and 0.45 A. Notice that the intersection for the PV and Electrolyzer I–V curves at 16 V in Figure 4 is very near the PV MPP (maximum power point) voltage of 17.39 V.

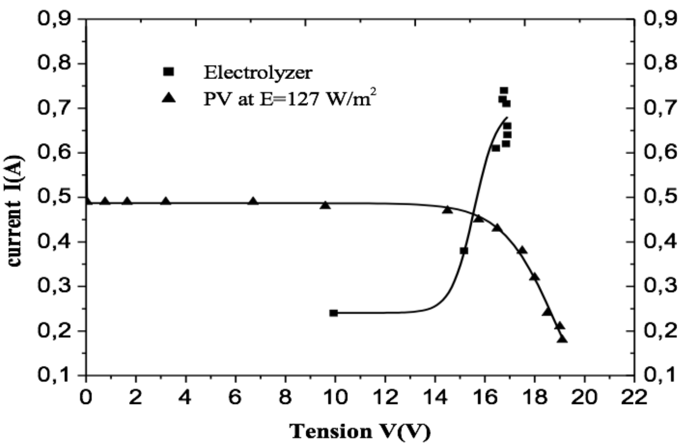

Fig. 4. Plots of the current–voltage curves of the solar PV and electrolyzer system.

Study of day type

From the Fig. 5 it is clear that the photovoltaic module current is directly affected by the solar radiation intensity. As well as, increasing the electrolyzer current increases the hydrogen production flow rate, as shown in Fig. 5 shows the relation between the hydrogen flow rate and the electrolyzer current.

Figure 6 shows the electrolyzer and overall system efficiencies. It is clear that the smaller photovoltaic module efficiency decreases the overall system efficiency. Also the module is not operating at its maximum power point.

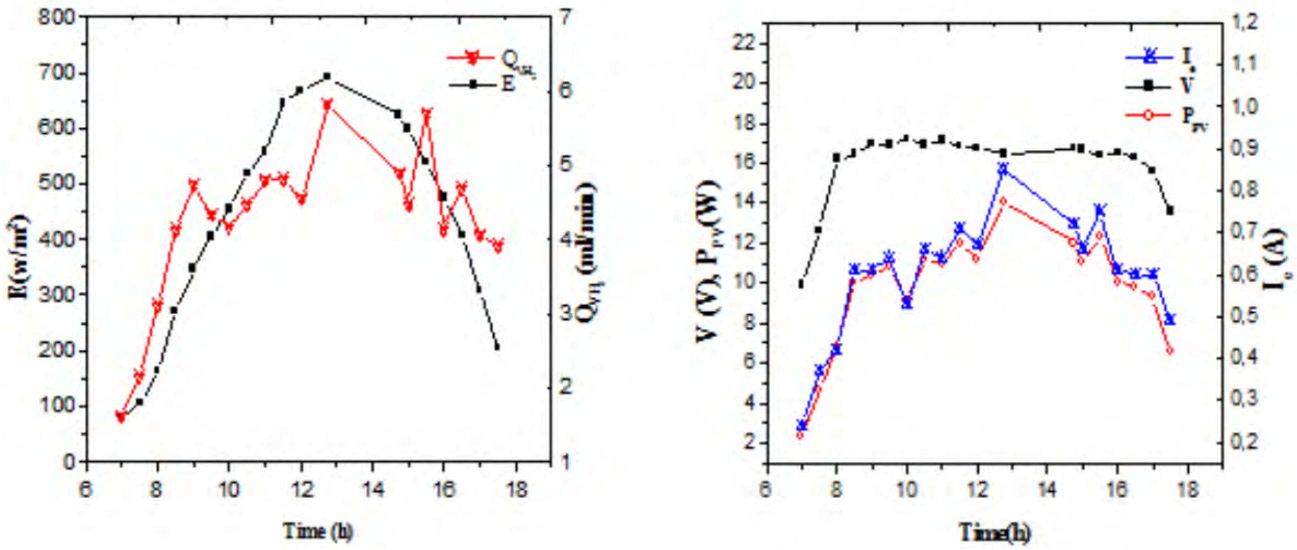

Fig. 5. Solar radiation, hydrogen flowrate, voltage, load current and PV power measured for a certain day in July as a sample of measurements.

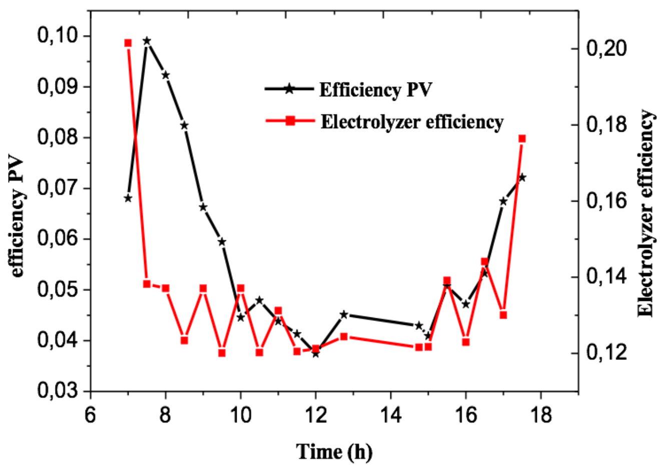

Fig. 6. Overall system and electrolyzer efficiencies measured for a certain day in July as a sample of measurements.

Conclusion

An experimental system was built for hydrogen production using photovoltaic energy. The system was designed and assembled for testing. It is shown from the experimental results that the hydrogen production can be more useful by using the photovoltaic energy from the side of view the environmental considerations. It is found that the average electrolyzer efficiencies are 12 and 15%. while the overall system efficiencies are found to be 1.5 and 2.3% for both cases, respectively. The small efficiencies are due to the losses in the electrolyte, the losses in the controller and that due to the surface temperature. Also, it is found that the environmental conditions such as solar intensity, ambient temperature and the module surface temperature have a large effect on the system performance and the rate of hydrogen production.

References

1. Fausto Cavallaro. Italy Multi-criteria decision aid to assess concentrated solar thermal technologies.Renewable Energy 34, (2009), pp 1678–1685.
2. Bouziane Mahmah et al. Future federator project of massive production of solar hydrogen.International journal of hydrogen energy 34, (2009) pp 4922 – 4933
3. Prospects for Hydrogen and Fuel Cells. International Energy Agency (IEA), Paris 2005
4. T. Najat Veziroglu, Sumer Sahin. Hydrogen energy system. Energy conversation and management 49, (2008), pp 1820-1831.
5. Bilgen E. Solar hydrogen from photovoltaic electrolyzer systems. Energy conversation and management 42, (2001), pp 1047–1057.
6. Office National de Météo ONM, 2008.
7. Krishnan Rajeshwar, Robert McConnell, Stuart Licht, Solar Hydrogen Generation Toward a Renewable Energy Future, Springer, USA, 2008.
8. Hemat Tributsch, Photovoltic hydrogen generation. International Journal of Hydrogen Energy 33, (2008), pp 5911-5930.
9. Tn. F. El-shatter, M.N. Eskander, M.T.El-Hagry, Hybrid PV fuel cell system design and simulation. Renewable Energy 27, (2002), pp 479 - 485.

Conflicts of interest

Authors declare no conflict of interests.

Notes

The authors declare no competing financial interest.

How to cite this article

K. Bouziane, N. Chaouch. Production of solar hydrogen at desert site of Algeria. Materials and Biomaterials Science 03 (2020) 030-033.