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The Effect of PH on the Hydrogen and Oxygen Production Using Photovoltaic Power Generator

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Abstract

In this work, an experimental study was conducted to investigate the effect of PH on the hydrogen and oxygen production using photovoltaic power generation system. A testing rig was built, where the process of splitting water into hydrogen and oxygen occurs when a DC current generated by a photovoltaic system is passed between two electrodes, immersed in water and separated by a non-electrical conducting material which is resistive Teflon. The results of experimentation indicate that within the range of PH from 3 to 13, the further PH levels gets from PH=7 gives better hydrogen and oxygen production. Alkaline region gave better production.

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Keywords: *Hydrogen and oxygen production, PH, photovoltaic*

1. Introduction

Electricity production using solar energy is one of the main research areas at present time in many institutes and research centers. Electrical energy production using photovoltaic systems is very important issue for sustainable energy sources. The most important drawback of using photovoltaic systems is the sunlight fluctuations in daytime and the absence of solar radiation at night time. So, to use the electrical energy produced by photovoltaic modules efficiently it is necessary to storage this energy to batteries or to convert it into high energy materials, such as hydrogen and oxygen gases.

Mahrous et al. [1] presented an experimental investigation of alkaline water electrolysis for the purpose of hydrogen production. The experimental results showed that the performance of water electrolysis unit is highly affected by input voltage and the gap between the electrodes. Higher rates of produced hydrogen can be obtained at smaller space between the electrodes and also at higher voltage input.

Prasad [2] designed a simple, cheap and efficient electrolyzer of hydrogen generation in the remote area using solar photovoltaic energy. The system fabricated and experimentally tested for small scale production of high purity fuel cell grade renewable hydrogen. Aoki et al. [3] fabricated a series circuit of six organic thin-film solar cells consisting of poly and PCBM in order to electrolyze water into hydrogen and oxygen gases. The series circuit was combined with the water electrolysis cell with two platinum electrodes. Hydrogen and oxygen gases were generated at each platinum electrodes of the electrolysis cell under illumination. The operating current and voltage was determined to be 1.3 mA/cm^{3}and 2.6 V, respectively. Bilgen[4] presented a mathematical model to determine and optimize the thermal and economic performance of large scale photovoltaic electrolyzer systems. Paul and Andrews [5] presented a theoretical analysis of the conditions required for connection of a photovoltaic array to an

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electrolyzer in solar hydrogen systems. Nagaia et al [6&7] studied the effect of electrical current, distance between electrodes, and the temperature on the efficiency of water electrolysis at a particular concentration on the solution. Also, they studied the effect of bubbles between electrodes on alkaline water electrolysis. Suffredini et al [8] discussed different types of electrode which can be used for water electrolysis and hydrogen production. They noticed that for alkaline water electrolysis Ni-based alloys either amorphous or crystalline have been successfully tested as efficient cathode materials, while the choice of anode is mainly focused on mixed Ni-Co oxides with a spinal structure.

The aims of the present experimental study were as follows: firstly to design and build a hydrogen and oxygen production system using photovoltaic generator, using the simple and cheap available resources. Secondly to conduct an experimental study to investigate the effect of PH on the hydrogen and oxygen production using photovoltaic power generation system.

2. The design of solar hydrogen and oxygen water electrolyzer.

In this work, a testing rig of hydrogen and oxygen production system using solar energy was built. A schematic diagram of photovoltaic powered water electrolyzer used in this work is presented in figure 1.

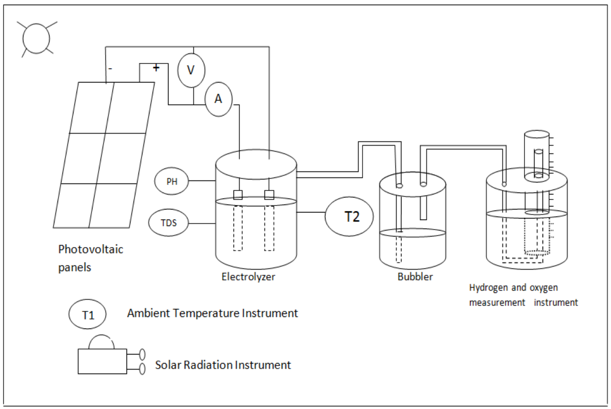

Fig. 1. Schematic Diagram of photovoltaic powered system.

Seven identical photovoltaic powered water electrolyzers were constructed. One electrolyzer will work with PH equals 7 which are neutral and reference point. As PH has two regions acidic where PH<7and alkaline where PH>7, three levels of PH will be tested in each region. In alkaline region, one electrolyzer will work with PH=9, the second electrolyzer will work with PH=11 and the third electrolyzer will work with PH=13.In acidic region, one electrolyzer will work with PH=3, the second electrolyzer will work with PH=4.5 and the third will work with PH=5.5. Seven identical electrolyzers with different values of PH will be operated at the same time and at the same weather conditions. The purpose of this experiment is the investigation the effect of PH of water inside electrolyzer on the hydrogen and oxygen production.

Each system is consisting of photovoltaic generator, water electrolyzer, bubbler, and hydrogen and oxygen measurement instrument. The detailed information about each element of this system can be described as following:

2.1. Photovoltaic generator

The electrical power supply in this system is a photovoltaic array consisting of six parallel connecting modules. The main technical specifications of photovoltaic module are: Nominal maximum output power =40 W, Nominal maximum output voltage = 16.9 V, Nominal maximum output current = 2.34 A, Nominal mass = 4.5 Kg. the array is replaced on the fixed mechanical base with 32 degrees inclination to the south.

2.2. Water electrolyzer

Water electrolyzer consist of cylindrical plastic container which has 30 cm height with 11 cm diameter and two cylindrical electrodes with 18 cm height. All electrodes are made of stainless steel 316. Dimensions of electrodes are shown in figure 2, where the view seen in the above mentioned figure is a top view.

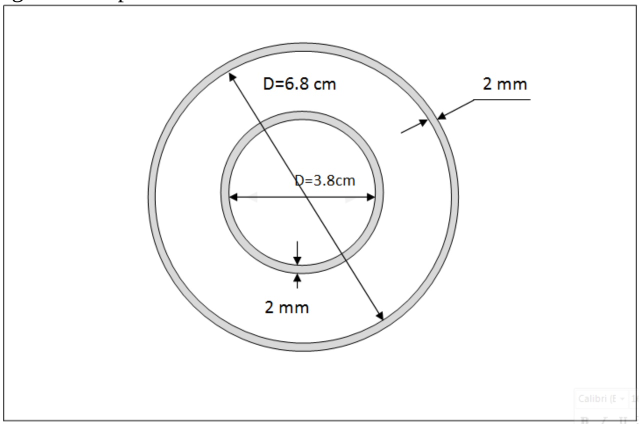

Fig. 2. Dimensions of electrodes (Top view)

At start of experiment each electrolyzer is filled with 1.5 liters of water with TDS=400 ppm. The terminals of flat plate photovoltaic array are connected to the electrodes in the electrolyzer. The electrodes will be immersed in water, where the hydrogen will appear at the cathode (the negatively charged electrode) and the oxygen will appear at the anode (the positively charged electrode).

2.3. Bubbler

The bubbler is a cylindrical shape device which prevents the reverse of hydrogen and oxygen flow for safety purposes.

D) The hydrogen and oxygen measurement instrument.

The hydrogen and oxygen measurement instrument is a homemade instrument. This instrument is a plastic container with a cylindrical shape, which has 650 ml capacity, 16 cm length and 7 cm diameter. During production the plastic container is placed under water surface, and it rises over a scale above water surface as it is being filled with gases.

3. Experimentation and results

The electronic measurement instruments and devices were tested and calibrated before being used. The global solar radiation on the horizontal surface was measured using Kipp and Zonenpyranometer. The sensitivity of an instrument was 18.99 μV/W/m^2.

Calibrated thermocouples (type-K) coupled to a digital thermometer were used to measure the temperature. Where its range of measurements from -120 C to 550 C. The accuracy of thermometer is ±1 □ .

Current measurement is accomplished with an ammeter. The range of measurements is from 0 to 20 A. The accuracy of ammeter is ± 3%. Voltage measurement is accomplished with voltmeter, where the range of measurements is from 0 to 40 VDC and the accuracy of the instrument is ± 4%.

TDS measurement is accomplished using TDS tester, where the range of measurement is from 0 t0 2000 ppm. The resolution of the instrument is 1ppm and the accuracy is ±1%. PH measurement is accomplished using PH tester, where the range of measurement is from 0 to 14 PH. The resolution is 0.1 PH and the accuracy are± 0.2 PH.

A continuous test during 6 August from 8 AM to 4:30 PM local time was performed at the Renewable Energy Laboratory of the Applied Science University, Amman, Jordan.

The readings of instruments were taken every hour, which means that 9 readings were taken for every physical variable. The measured physical variables are as following: hydrogen and oxygen production, electrical current, electrical voltage, PH, TDS, and ambient temperature. The value of TDS of water is selected to be 400 ppm at the start of experiment.

The hydrogen and oxygen production function of time depending on different PH values is shown in figure.3. The electrical current and the electrical voltage generated by photovoltaic system at the output of photovoltaic array are shown in figure.4 and figure.5. Hourly variation of solar intensity and ambient air temperature respectively measured during the test period are presented in figures 6 and 7.
Figure.3 shows an increase in the hydrogen and oxygen production during the early hours of day until it reaches the maximum yield around mid-noon corresponding to the highest solar radiation then decreases as the sunsets. The results of experimentation indicate that within the range of PH from 3 to 13, the further PH levels gets from PH=7 gives better hydrogen and oxygen production. Alkaline region gave better production.
As the electrolyzing process took place sediments started to appear as a result of losing water. A solution to this problem could be changing the water in the electrolyzing cell periodically.
As shown in figures 3 and 4 within the range of PH from 3 to 13, the higher electrical current with decreased electrical voltage gave better hydrogen and oxygen production.

4. **Conclusions**

In this work, hydrogen and oxygen production system using photovoltaic power generator was designed and constructed. An experimental study was conducted to investigate the effect of PH on the hydrogen and oxygen production.

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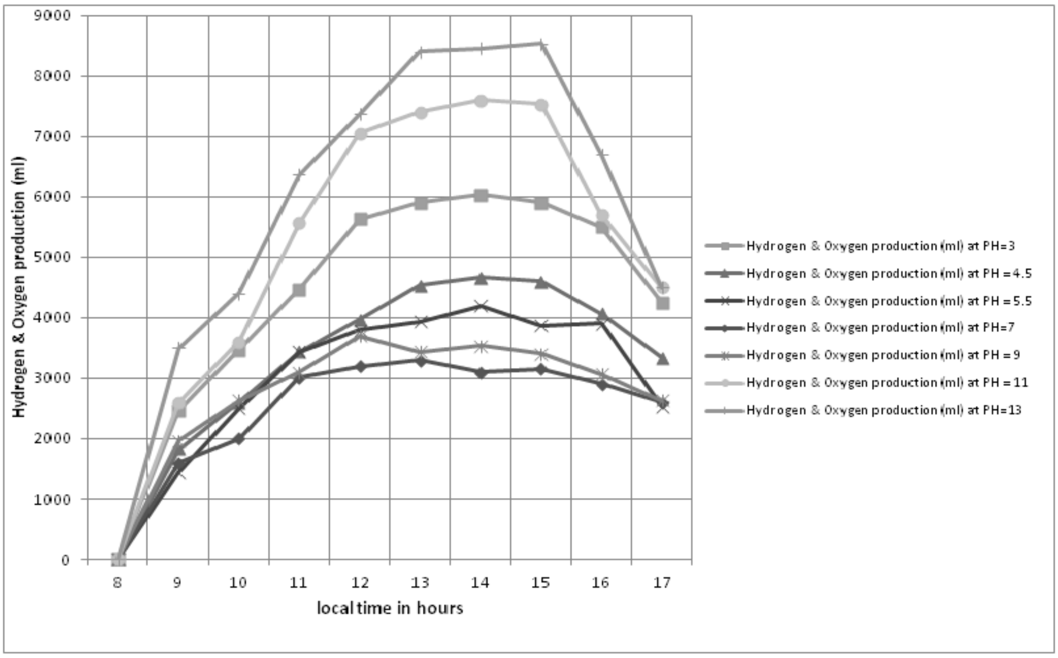

Fig. 3. Variation of Hydrogen and Oxygen Production as Function of Time

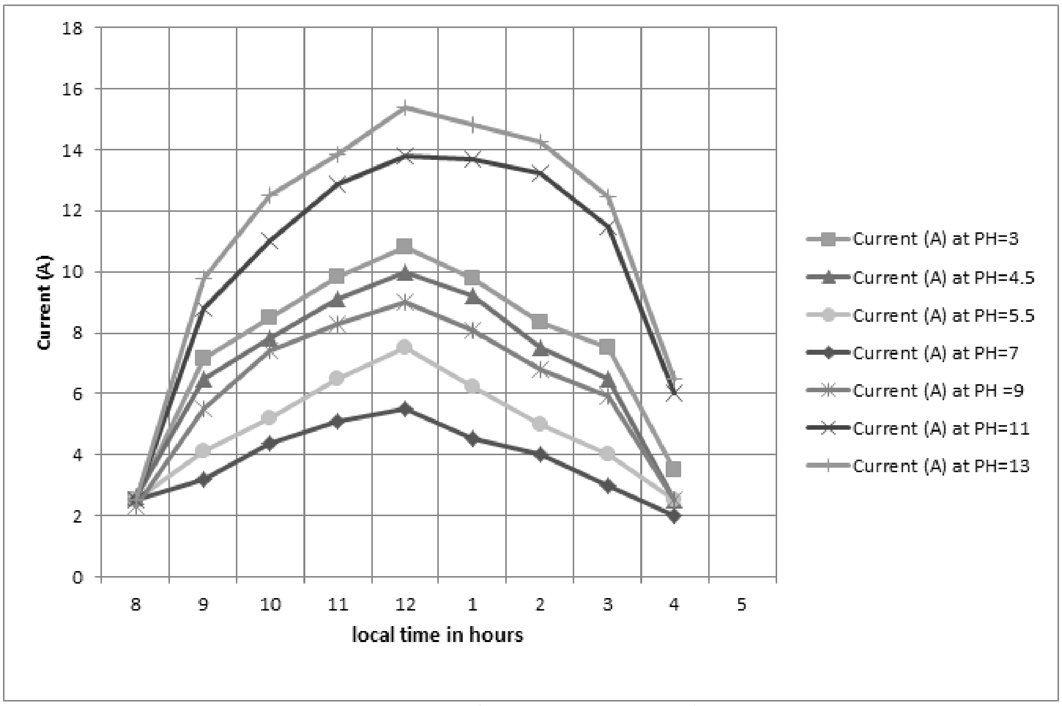

Fig. 4. Variation of Current as Function of Time

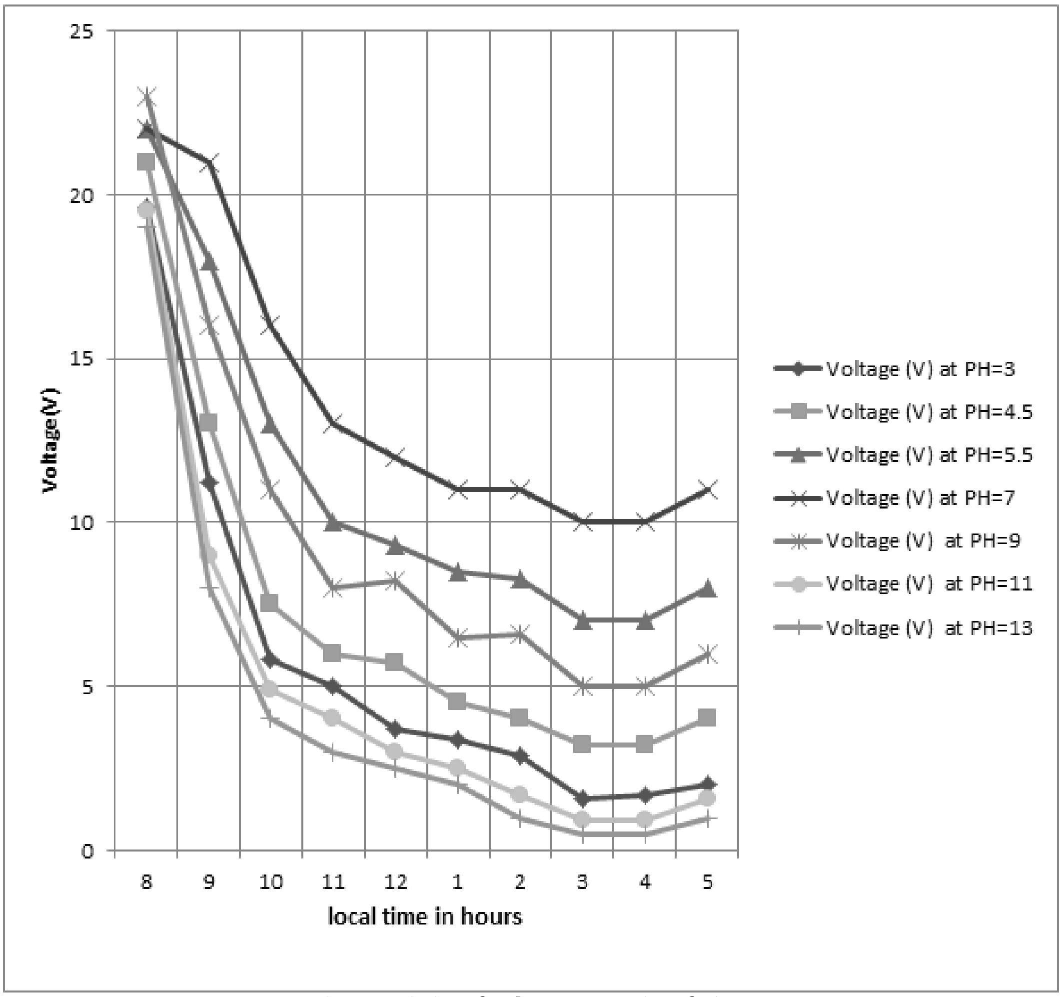

Fig. 5. Variation of Voltage as Function of Time

Fig. 6. Variation of Solar Intensity as Function of Time

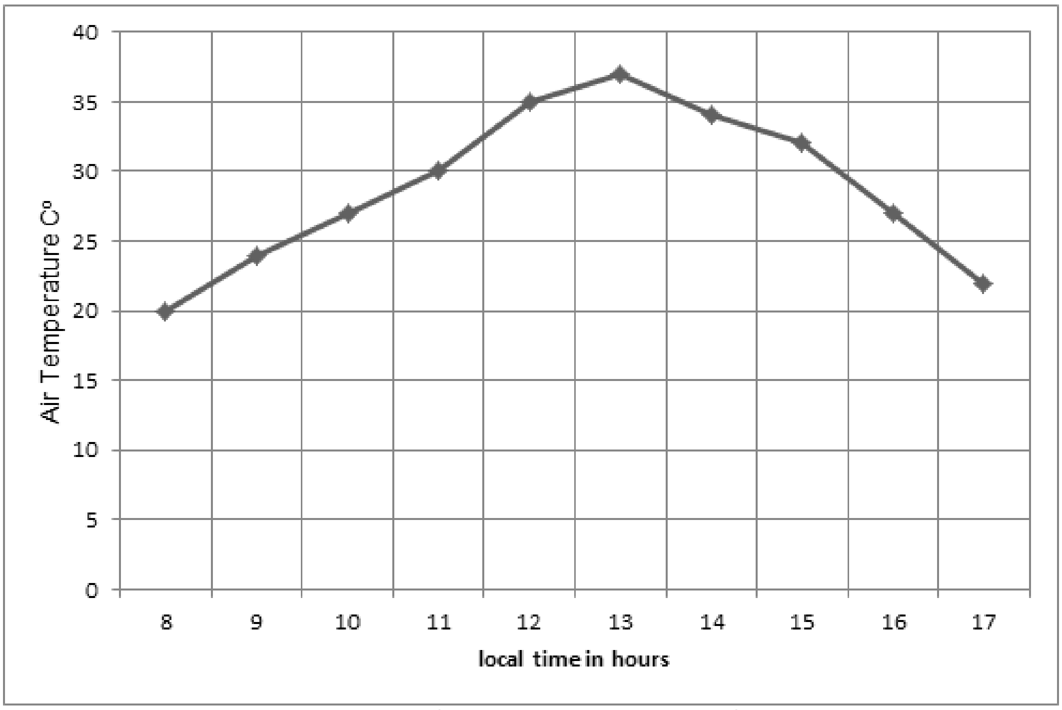

Fig. 7. Variation of Air Temperature as Function of Time

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