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The Effect of TDS on the Hydrogen and Oxygen Production Using Photovoltaic Power Generation System

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Abstract

In this work, an experimental study was conducted to investigate the effect of TDS (Total Dissolved Solids) 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 TDS from zero to 2000 ppm, the higher TDS level gave better production, and when the level equals zero it gave no production at all.

Keywords: *Hydrogen and oxygen production, TDS, Photovoltaic.*

1. Introduction

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 in 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 for 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 electrolysis systems. Paul and Andrews [5] presented a theoretical analysis of the conditions required for connection of a photovoltaic array to an 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.

This work aims to investigate experimentally the effect of TDS on the hydrogen and oxygen production using photovoltaic power generation system

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

In purpose of investigation the effect of TDS which means total disolved solids on the performance of hydrogen and oxygen production using solar energy, a testing rig was built. A schematic diagram of photovoltaic powered water electrolyzer used in this work is presented in figure 1.

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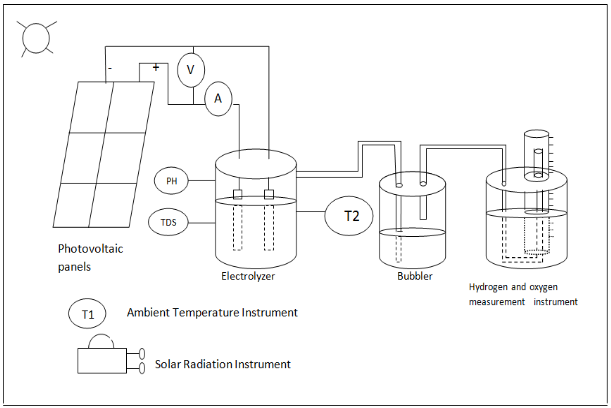

Fig. 1.Schematic Diagram of photovoltaic powered system.

Four identical photovoltaic powered water electrolyzers were constructed. One electrolyzer will work with TDS equals 298 ppm, the second electrolyzer will work with TDS equals 530 ppm, the third electrolyzer will work with TDS equals 1089 ppm and the fourth will work with TDS equals 2000 ppm values to estimate the effect of of variable TDS values on the performance of electrolyzer. Four identical systems with different values of TDS will be operated at the same time and and at the same weather conditions.

Each system is consisting of photovoltaic generator,waterelectrolyzer, 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 each 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 consists of cylindrical plastic container which has 30 cm hieght with 11 cm diameter and two cylindrical electrodes with18 cm hieght. 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.

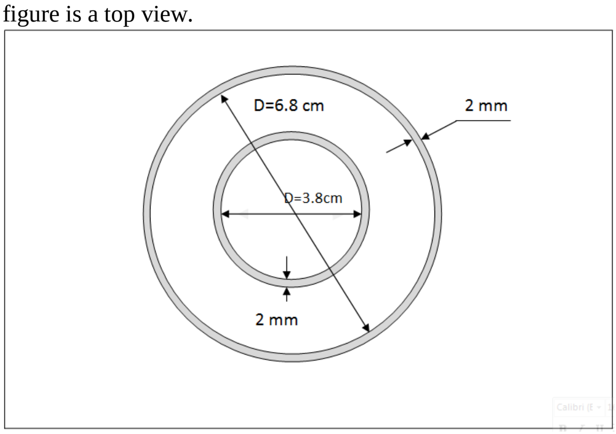

Fig. 2. Dimensions of electrodes (Top view)

At start of experiment each electrolyzer is filled with 1.5 liters of water with certain value of TDS. 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.

2.4. 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. Experemntationand 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 $\mu V/W/m^2$.

Calibrated thermocouples (type-K) coupled to a digital thermometer were used to measure the temperature. Where the 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 is + 0.2 PH.

A continuous test during 22 of November from 8 AM to 3:30 PM local time was performed at the Renewable Energy Laboratory of the Applied Science University, Amman, Jordan. The readings of instruments were taken every 30 minute, which means that 13 readings were taken for every physical variable. The measured physical variables are as following: hydrogen and oxygen production, electrical current, electrical voltage, TDS, PH, water temperature and ambient temperature.

The hydrogen and oxygen production function of time depending of different TDS values is shown in figure.3. The electrical current and the electrical voltage generated by photovoltaic system at the input of water electrolyzer are shown in figure.4 and figure.5. Figures 6 and 7 show the water PH and water temperature inside electrolyzer. Hourly variation of solar intensity and ambient air temperature respectively measured during the test period are presented in figures 8 and 9.

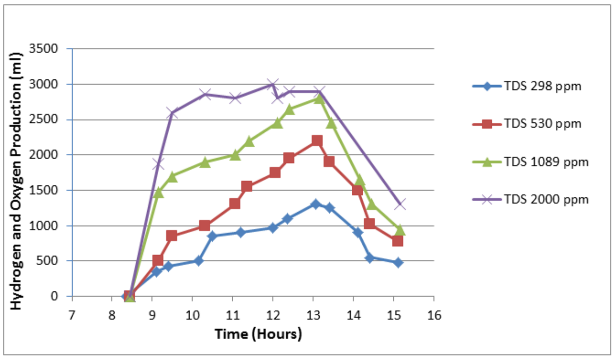

Fig. 3.The Variation of Hydrogen and Oxygen Production as Function of Time

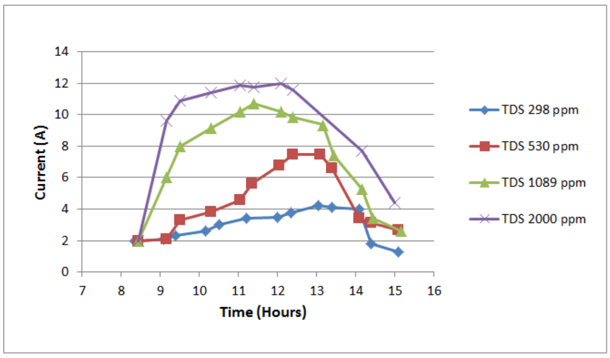

Fig. 4. the Variation of Current as Function of Time

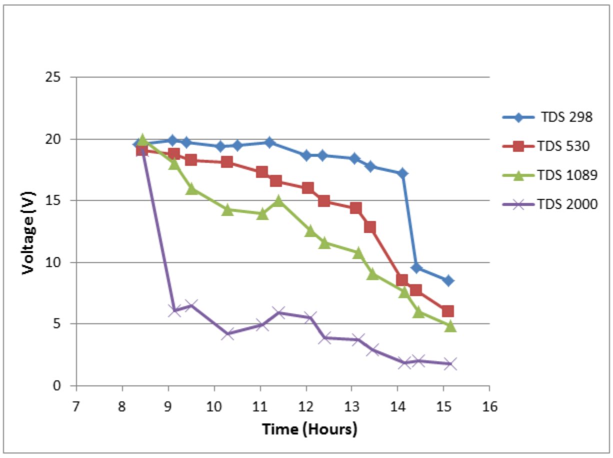

Fig. 5. the Variation of Voltage as Function of Time

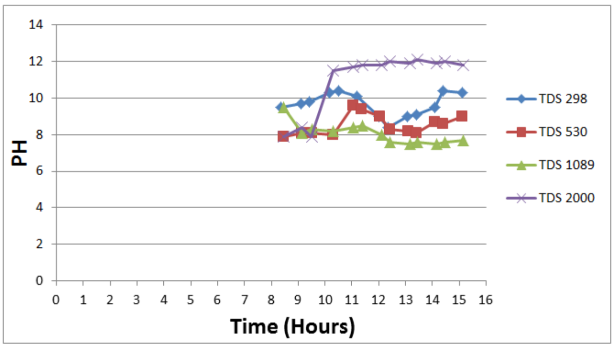

Fig. 6.The Variation of PH as Function of Time

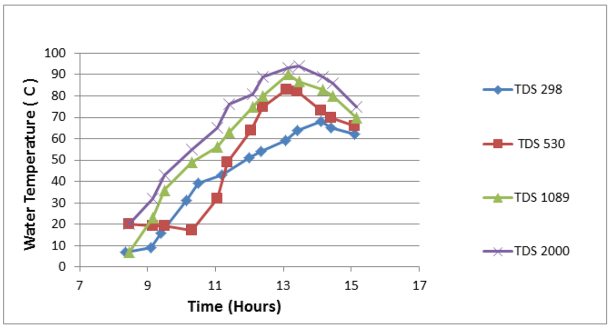

Fig. 7.The Variation of Water Temperature as Function of Time

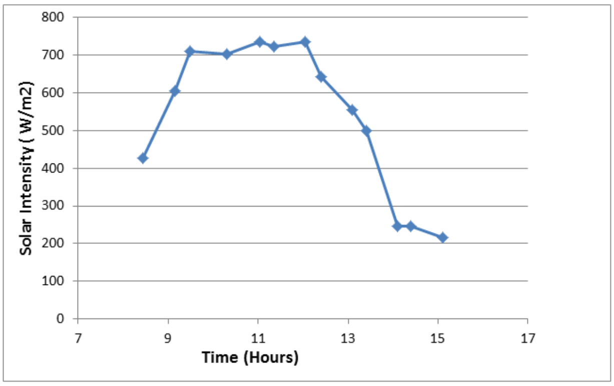

Fig. 8. TheVariation of Solar Intensity as Function of Time

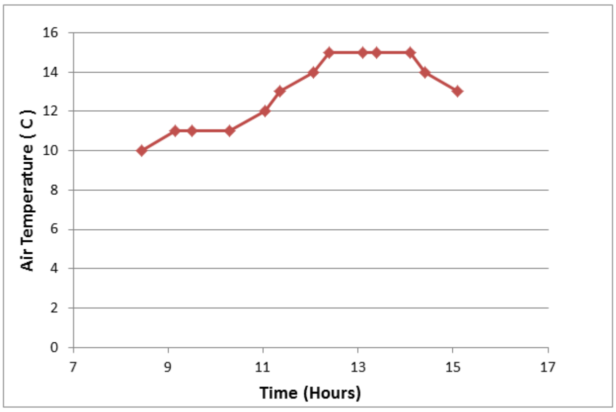

Fig. 9.the Variation of Air Temperature as Function of Time

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. Also, the results of experimentation indicate that within the range of TDS from zero to 2000 ppm, the higher TDS level gave better production. When the level of TDS equals zero it gave no production at all. 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.

In the limit of experimentation the higher TDS level gave better electrical current with decreased electrical voltage.

4. Conclusions

An experimental study was conducted to investigate the effect of TDS 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.

The results of experimentation indicate that within the range of TDS from zero to 2000 ppm, the higher TDS level gave better production, and when the level equals zero it gave no production at all.

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