Developing Prototype and Performance Evaluation of a Hydrogen Generator

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ABSTRACT

A prototype of hydrogen generator has been developed in which two electrolytic cells are connected in parallel. Experiment has been carried out to find the input power at which efficiency and hydrogen production of the generator are to be optimum. Experimental results show that optimum hydrogen production rate of 96.6 ml/min with an efficiency of 63% has been achieved when input voltage and current are 6.4 V and 4 A respectively.

Keywords— electrolysis; hydrogen; overpotential; renewable energy

INTRODUCTION

Hydrogen is providing the connecting point between renewable energy and transportation sector. Electricity from solar Photovoltaic (PV), wind, geothermal, ocean or hydro energy can be used to produce and store hydrogen which is used as fuel in fuel cell vehicles [1]. Hydrogen can also increase the reliability of electrical power from intermittent sources of renewable energy. The excess electricity generated from renewable energy sources during off-peak hours can be stored in the form of hydrogen which can provide constant electricity using fuel cells or engines when renewable sources aren't available [1]. The common source of hydrogen is water which can be split into hydrogen and oxygen by electrolysis. During electrolysis, water is separated into hydrogen and oxygen by charging with electric current. However hydrogen generation by electrolysis of water has a share of only 4% in global production as electricity cost is the largest fraction of the production cost [2]. A hydrogen generator has been developed for electrolytic production of hydrogen which can be powered from a solar panel. Design, construction and performance evaluation of the generator are going to be discussed in the following sections of this paper.

A. *Electrolysis of water*

An electrolysis unit which is also called electrolytic cell has two main components namely electrodes and electrolyte. In case of electrolytic production of hydrogen, water is used as electrolyte. For all practical purpose, water does not conduct electrical current. Therefore ionic compound such as NaCl is added to improve electrical conductivity of water [3]. When a certain voltage is applied to the electrodes, electrical current passes through the electrolyte and water splits into hydrogen and oxygen at cathode and anode electrode respectively. The minimum required voltage for decomposition of water is 1.23 V but in practice higher voltage which is known as over potential is required to overcome inefficiencies of the system [2, 4].

B. *Efficiency and Production of hydrogen*

The amount of hydrogen produced per unit time is directly related to the current passing through the electrolyte [4, 5]. Operation of an electrolytic cell is a trade-off between energy efficiency and productivity of hydrogen. Current can be increased by increasing over potential but it causes heat to be generated and reduces efficiency of the system [5]. On the other hand, gas production is less when current is low. Experiment has been carried out to determine the input electrical power at which efficiency of electrolysis and productivity of hydrogen are to be optimum.

II. DEVELOPING PROTOTYPE OF HYDROGEN GENERATOR

A. Design of a hydrogen generator

Hydrogen generator is a stack of electrolytic cells connected in series or parallel. In a hydrogen generator, positive and negative electrodes are placed between two end plates. End plates have inlet and outlet pipes to supply water into the generator and to exhaust hydrogen gas from the generator respectively. There are separators between electrodes which provide electrical isolation and space for water. To prevent water and gas leakage, gaskets are placed in both sides of each separator. The schematic of the hydrogen generator is as shown in Fig. 1.

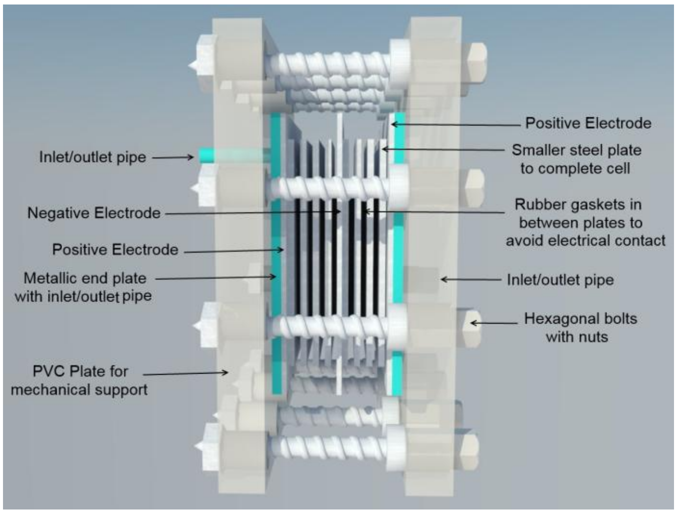

Fig. 1: Schematic of Hydrogen Generator

As shown in Fig. 1, there is a negative electrode between two positive electrodes. Hence there are two electrolytic cells and negative electrode common to both cells. Positive electrodes are connected to positive terminal of a voltage source and the common negative electrode is connected to negative terminal, which implies that two electrolytic cells are connected in parallel to the voltage source.

B. Construction of the Hydrogen Generator

In the hydrogen generator, electrodes and separators are always in contact with salty water. Therefore, these components are made up of stainless steel to protect from corrosion. Gaskets used to prevent water and gas leakage are made up of rubber. Different components of hydrogen generator are shown in Fig. 2.

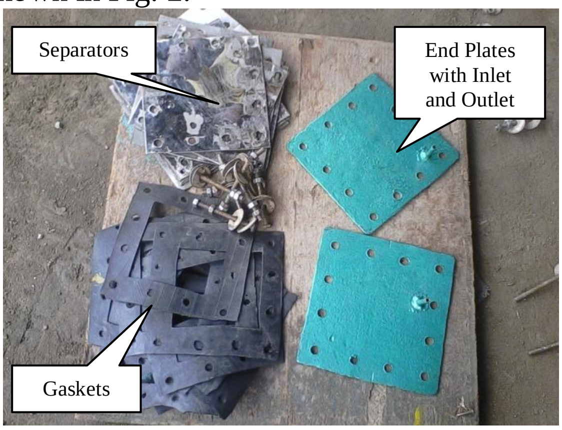

Fig. 2: Different Components of Hydrogen Generator

In an electrolytic cell, there are four separators between positive and negative electrodes. Size of each separator and electrodes are 6″× 6″ and 6.5″ × 6.5 ″ respectively. The whole setup is assembled in between of two acrylic sheets with nuts and bolts arrangement. Dimension of each acrylic sheet is 8″ × 8″ and thickness is 5 mm. Bolts used to join acrylic sheets are not in touch with any part of electrolytic cells otherwise cells are to be short circuited. Top view of the whole arrangement is shown in Fig. 3. As shown in the figure, red wires are connected to positive electrodes and black wire is connected to the negative electrode which is common to both cells.

Fig. 3: Topview of Hydrogen Generator

III. Performace Evaluation

Experiment has been performed to determine the electrical input power at which efficiency of electrolysis and hydrogen production is to be optimum. To carry out the experiment, hydrogen generator has been connected to an adjustable voltage source. Hydrogen produced in the generator has been supplied to an upside down measuring cylinder for specific period of time to measure production rate. Schematic of experimental setup is as shown in Fig. 4.

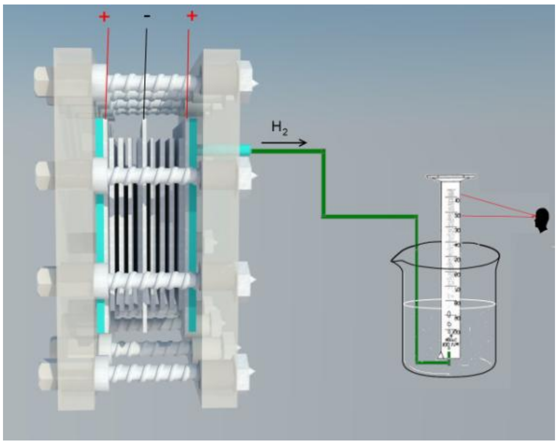

Fig. 4: Experimental Setup for Measuring Hydrogen Production Rate

The amount of gas formed is found by subtracting the current reading on the upside down cylinder from the initial reading. The readings were taken from time to time. The electrical readings were also taken to calculate the power and energy input. Input voltage has been varied from 2 to 8 V and corresponding input current and hydrogen production rate have been measured. Efficiency corresponding to an input voltage has been calculated from the measured value of current and hydrogen production rate. The sample calculation of efficiency is as follow:

Energy density of hydrogen = 0.01006 MJ/L [6]
Input voltage = 4.5 V
Input current = 2 A
Hydrogen production rate = 26.4 ml/min
Input energy = 4.5 V× 2 A × 60 Sec = 540 J
Output energy = (26.4 ml / 1000) × 0.01006 MJ/L $\times 10^6$ = 265.58 J
Therefore, efficiency = 265.58 / 540 = 49 %

IV. Result and Discussion

Input current, hydrogen production rate and efficiency of electrolysis corresponding to input voltages are listed in TABLE I. Hydrogen has been produced in measurable quantity when the input voltage is more than 4V. Maximum efficiency of 63% is achieved when applied voltage is 6.4V. But efficiency gets reduced when applied voltage is increased to 8V. It indicates that with high current, hydrogen production is increased but efficiency of the device is reduced.

TABLE I. PERFORMANCE OF HYDROGEN GENERATOR CORRESPONDING TO INPUT VOLTAGE AND CURRENT

Voltage (V)	***Current (A)***	***Hydrogen Production Rate (ml/min)***	***Efficiency (%)***
4.5	2	26.4	49
5.4	3	54	56
6.4	4	96.6	63
8	5	110	46

V. Conclusion

Prototype of hydrogen generator has been developed and hydrogen production rate and efficiency of the generator have been examined at different input voltages. The results show that optimum hydrogen production rate of 96.6 ml/min with efficiency of 63% has been achieved when input voltage and current are 6.4 V and 4 A respectively.

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