An Automatic Pressure Control Method to Measurement of Hydrogen Generation System

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Abstract

The hydrogen production from water is one of the hottest topics in renewable energy world. There are three basic methods for producing hydrogen. They are electrolysis, photo-electrolysis and photo-biological. Among them, the research is based on the electrolysis method using PEM electrolyzer. The zero greenhouse gas emissions can result depending on the type of electricity used when producing hydrogen by electrolysis. The solar energy, one of the popular clean energy, is used as the electricity to generate hydrogen in the research. The purpose of the research is to know how much of the hydrogen stably generated by using the solar cell power. There are various methods to know the volume of generated hydrogen. In this work, pressure sensor, motor and load cell are used to measure the amount of hydrogen. This simple idea can help how much of hydrogen generated accurately in the cheapest way.

Keywords: Hydrogen, Pressure sensor, Motor, Load cell, Measurement of gas volume

1. INTRODUCTION

Electrolysis is a reliable option for hydrogen generation from renewable energy. It is a technique used to separate a compound or molecule into its component parts. By adding electricity to water and providing a path for the different particles to follow, the water can be separated into hydrogen and oxygen. Hydrogen production by water electrolysis can be economically viable by using electrical energy from renewable sources such as photovoltaic solar energy. Solar energy is a clean and never ending energy. It can be used as an energy source to produce hydrogen via electrolysis. Hydrogen is a colorless, highly flammable gaseous element, the lightest of all gases and the most abundant element in the universe, which makes it very difficult to measure by volume. So, it's needed to know how much hydrogen is generated. In order to know the volume of hydrogen generated, people do research for measuring hydrogen volume in many ways.

Many researchers tried to discover the simple and low cost ways to measure the volume of hydrogen. Some researchers used the simple and robust method to measure the volume of hydrogen from the reaction of solids with aqueous solutions.[1)] This method is mostly related with chemistry and it is made by chemical reactions. There are also many methods to know the volume of hydrogen.

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Pressure sensor is a digital electronic device that can be used to measure absolute atmospheric pressure. In this research, BMP085 pressure sensor is used to measure atmospheric pressure. It can help to measure hydrogen volume in a simple way. It is very active sensor and its output pressure changes every 7.5ms. Its absolute accuracy can reach 0.03hPa and power consumption is extremely low with current of only 1μA when operating in standard mode. [2)]

2. EVALUATION METHOD

When the solar energy is supplied to PEM reversible fuel cells, it can create a voltage and current to separate the hydrogen and oxygen from water by driving the water electrolysis cells. So, the hydrogen gas comes out from the water electrolysis cells and then it is collected in the hydrogen tank by water replacement method. The pressure sensor can be used to compare the room pressure with a pressure in the hydrogen tank. By comparing these two pressures, we can generate the motor pump until the pressure in the hydrogen tank and room pressure are not very different. In this way, we can drop out the excess water from the outside tank and make the water level of two tanks in the same side.

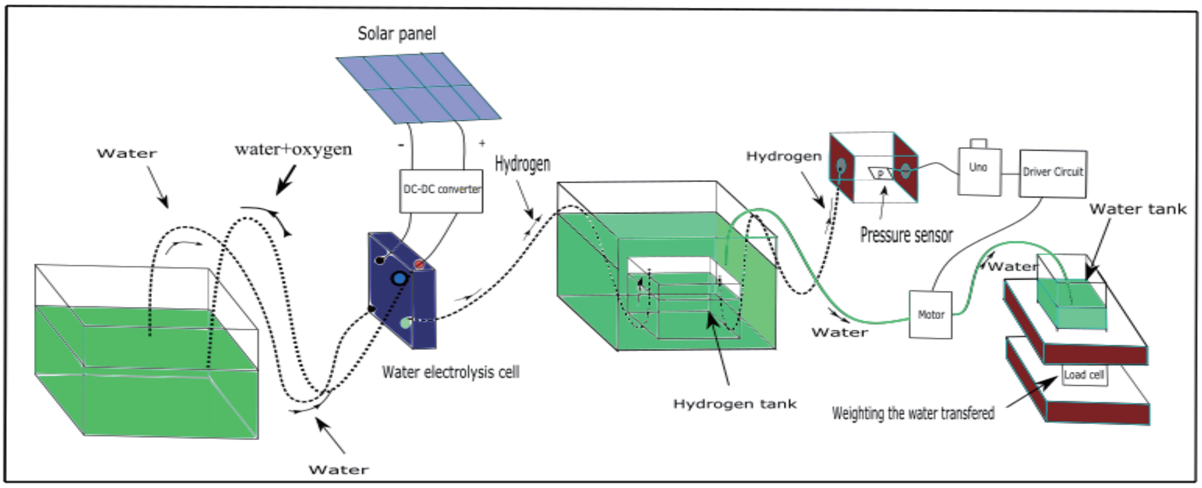

Fig 1. The hydrogen production system overall diagram

When hydrogen is generated in the tank, the volume above water in the tank tries to increase. But water surface tries to resist to the pressure by hydrogen. To solve this problem, the pressure sensor can be used to measure the atmospheric pressure and make the motor drives to drop out the excess water. Then we can find the volume of hydrogen pressure by weighting the dropping out water with load cells. The volume of hydrogen gas is the same as the weight of water transferred with load cells.

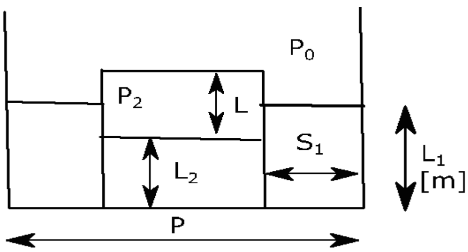

Fig 2. Pressure and altitude show diagram

$P = P_0 + S_1 \times L_1 \times 1000 kg/m^3 \times 9.8 m/s^2 / S_1$

$P = P_0 + 9800L_1$

Where, L = altitude

P_0 = room pressure

P_2 = pressure inside the hydrogen tank

Then, the pressure P_2 can be calculated as the pressure P_0,

$P = P_2 + 9800L_2$

To get the pressure inside the small tank,

$P_2 = P_0 + 9800(L_1 - L_2)$

Let assume, $L_1 - L_2 = L$

Then, $P_2 = P_0 + 9800L$ (1)

So the pressure at sea water level is assumed,

$P_0 = 100000(Pa)$

At the water level inside the hydrogen tank is down to 1cm,

$P_2 = 100000 + 9800 \times 0.01 = 100098[Pa]$

By using equation (1), the pressure can be calculated with the changing altitudes. When the water level down, the pressure must be high because pressure and altitude are inversely related. The pressure at any level in the atmosphere may be interpreted as the total weight of the air above a unit area at any elevation. At higher elevations, there are fewer air molecules above a given surface than a similar surface at lower levels. If the pressure is known, the altitude can be obtained vice versa.

With the measured pressure and pressure at sea level, the altitude in meters can be calculated with the international barometric formula[2]:

$$\text{Altitude} = 44330 \times \left(1-\left(\frac{P}{P_0}\right)^{\frac{1}{5.255}}\right) \qquad (2)$$

Where, P = measured pressure

P_0 = sea level pressure

3. ANALYSIS AND RESULT

The pressure sensor senses the data in every 7.5ms and it is very fast time. And there is a lot of noise in the atmosphere, so don't expect a smooth output from any pressure sensor unless it's in a sealed, insulated chamber. For the same reason, discussions about sensors measuring a few centimeters of altitude change are meaningless.[2]

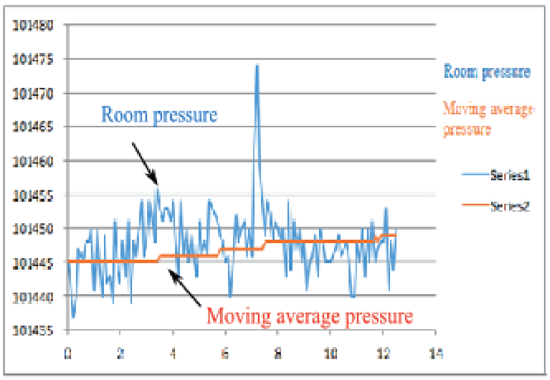

Fig 3. Room pressure sensor data

By using the equation (2), the following data can be obtained by changing altitudes.

Table 1. Increasing altitude with the decreasing pressure

At sea level 0cm	101325
3cm	101324.63
5cm	101324.39
7cm	101324.16
9cm	101323.91
11cm	101323.67

As can be seen in Fig 4, the pressure decreases as the increasing altitude.

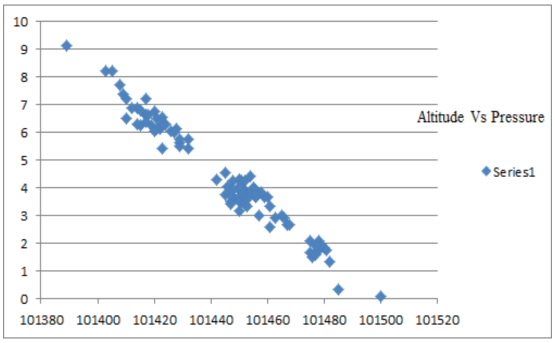

Fig 4. Altitude Vs. Pressure

When the hydrogen is generated, the water level in the hydrogen tank is lower because of the water is replaced by the hydrogen gas. In this situation, the pressure inside the hydrogen tank is higher than the room pressure. But at first, the pressure sensor is tested by putting some air instead of hydrogen. In order to know the volume of air inside the tank, the height of water level down must be known. This is because the air is collected by water replacement method.

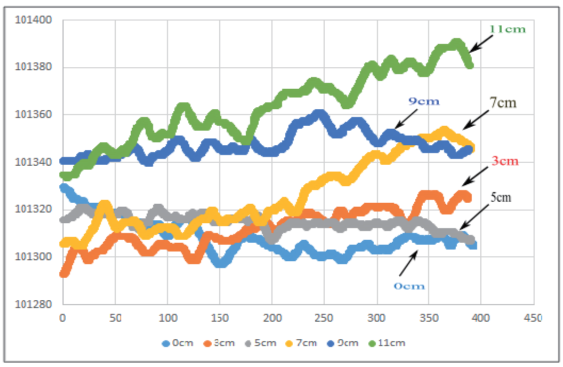

Fig 5. The moving average pressure at 0cm, 3cm, 5cm, 7cm, 9cm and 11cm down

The pressure at 0cm is the room pressure above the sea level. When the water level down, the pressure inside the tank is increased but it is not very different between 0cm and 5cm. This is because of a few centimeters change. The pressure sensor works from 7cm to 11cm. So, the minimum altitude that the pressure sensor can work is from 7cm to higher. When the water level down to 7cm, the pressure sensor reads the higher pressure than room pressure at 0cm.

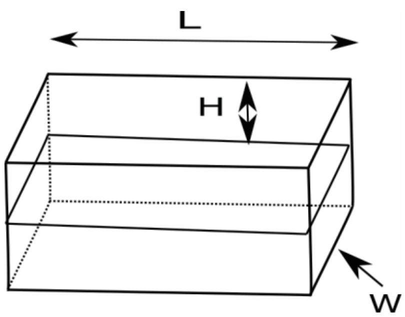

Fig 6. The volume of hydrogen tank

At 1cm water level down, volume of air inside the tank:

$$\text{Volume (cm}^3) = \text{width(W)}\times\text{length(L)}\times\text{height(H)}$$
$$= 13\times20\times1 = 260\text{cm}^3$$

Table 2. The volume of air with respective water level down

Water level down(cm)	Volume of air (cm^3)
1	260
3	780
5	1300
7	1820
9	2340
11	2860

The density of a substance (mainly gases) depends on temperature and pressure. Gases are usually compared at a standard temperature and standard pressure. These are the freezing point (0 °C) and normal air pressure at sea level (101325Pa), respectively. The density of dry air at sea level is 1.293 kg/m^3 or about 1/800th the density of water. But as altitude increases, the density drops dramatically. This is because the density of air is proportional to the pressure and inversely proportional to temperature.[3)]

$$1\text{m}^3 = 1.293\text{kg of air} \qquad (3)$$

The density of air can be calculated by using the volume of air from the above equation (3). The following table shows that the more water level down, the more density of air gets.

Table 3. The density of air with respective water level down

Water level down (cm)	Density of air (g)
1	0.336
3	1.01
5	1.68
7	2.35
9	3.14
11	3.69

4. CONCLUSION

The goal of this study is to get the volume of hydrogen accurately. In order to get this, the pressure sensor must be worked properly. By testing with the air instead of hydrogen gas, the pressure sensor cannot operate properly in a small range. And also it must be placed in a flexible sealed chamber so that its volume can't expand when the air is increasing.

In this way, we can get the correct pressure when the situation inside the hydrogen tank changes. We have investigated that the pressure change and the volume of gas with the air instead of hydrogen. So, the goal of this research can be achieved by analyzing these situations.

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