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THE CONSTRUCTION AND CHARACTERIZATION OF A HYDROGEN FUEL CELL SYSTEM USING WATER ELECTROLYSIS

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Abstract: **In this work, we constructed and characterized a hydrogen fuel cell system using water electrolysis. We investigated the effects of electrolyte concentration, space between the pair of electrodes on the amount of solar hydrogen produced and the overall efficiency of the electrolyser system. Aluminium/Copper materials were used as the electrodes because of their high performance in the electrolyser system and Potassium hydroxide (KOH) was used as electrolyte. 10% concentration of potassium Hydroxide was used with electrode spacing of 5mm. Results showed that hydrogen production was highly dependent on electrode gap distance, electrolyser efficiency and current/Voltage characteristics. The maximum efficiency achieved was 29.8%. The smaller the gap between the pair of electrodes the higher the rate of hydrogen production and the more efficient is the system. The findings presented here can help direct research and development efforts towards the fabrication of deployable solar-hydrogen generators that are cost competitive with commercial energy sources.**

Keywords: **Hydrogen Fuel Cell, Aluminium/Copper, Potassium Hydroxide and Efficiency.**

1. INTRODUCTION

Under the sun, we have different sources of energy that are renewable and non-renewable. Examples are crude oil, natural gas, wind power and solar energy etc. The use of these energy contribute to environmental hazards faced by humankind today. The effect of this usage could lead to air pollution and global warming. Both have a direct link with our current overdependence on fossil fuels. Pollutants produced from combustion of hydrocarbons now cause even more health problems (National Oceanic & Atmospheric Administration (NOAA), 2017). Today, there is urgent need to develop alternative fuels. Among various alternatives, Hydrogen fuel offers the highest potential benefits in terms of diversified supply and reduced emissions of pollutants and greenhouse gases (Gupta B., 2009). It can be used in fuel cells to generate electricity, with water as the only by product. Major current applications of the commercially produced hydrogen are in oil refining, where hydrogen is used in hydro-treating of crude oil as part of the refining process to improve the hydrogen to carbon ratio of the fuel, in food production for hydrogenation, in treating metals, in producing ammonia for fertilizer and other industrial uses (Lipman T., 2011). Hydrogen can be produced using a variety of certain materials, derived from both renewable and non-renewable sources. Example of those sources are coal gasification, natural gas reforming, and

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nuclear-powered water electrolysis but the production of hydrogen from renewable energy sources has strong sustainability advantages because of low net greenhouse emissions, the long-term availability and security of supply.

Literature reviewed that different studies related to the topic have been carried out by many researchers. Most researchers studied the Current – Voltage relationship for solar hydrogen fuel system, effects of distance variation between two electrodes of the electrolyser, electrode materials used, as well as efficiency and power of the system but in this work; we developed a solar-hydrogen generator with an increased performance and is cost competitive with commercial energy sources using Water Electrolysis. This was achieved using Roy Le's approach. In this approach, we used aluminium/copper electrodes for the electrolyser in order to achieve the above aim.

2. MATERIALS AND METHODOLOGY

Here, materials used are; Solar panel, Electrolyser, **A**luminium and Copper, Potassium Hydroxide Solution (KOH), Gas drier, Gas Storage Tank, Digital Multi-meter, Gas flow meter and Variable resistor.

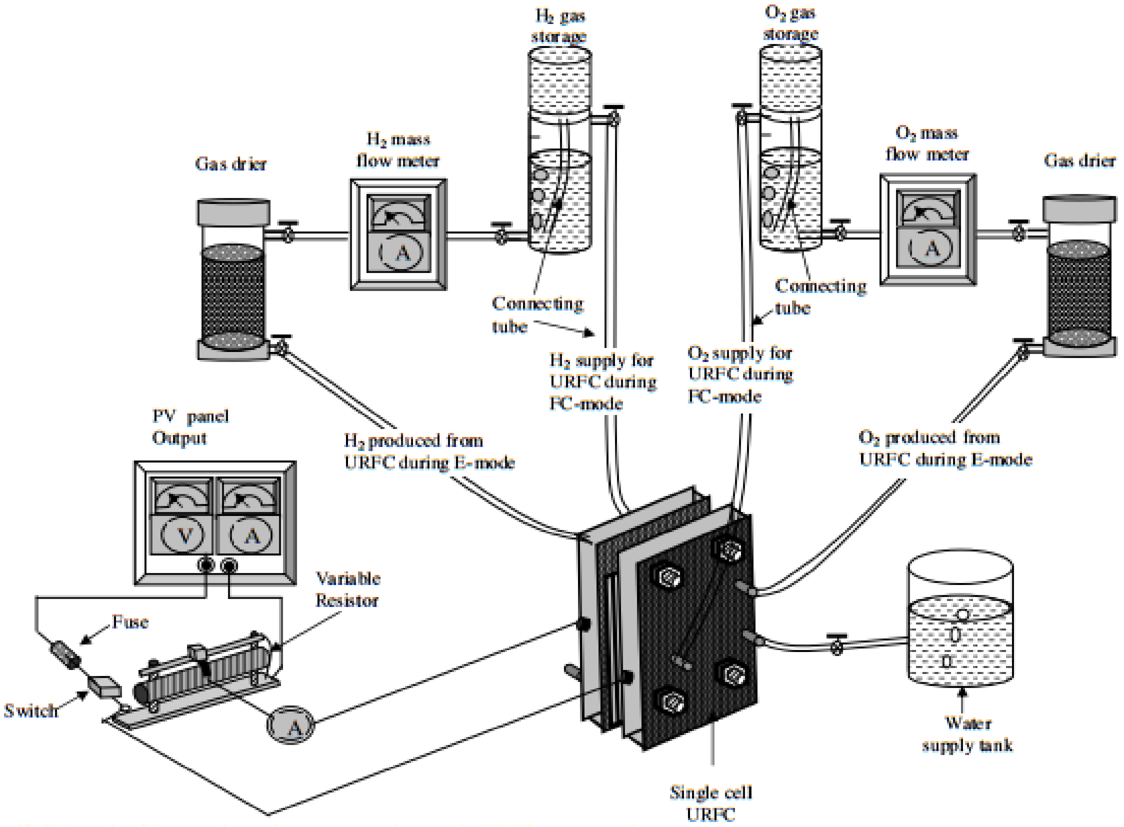

Fig. 1.1.: Figure 65: Schematic of the experimental apparatus used to produce Solar-Hydrogen Fuel Cell, (Nikolic M. et.-al., (2010).

3. RESULTS AND DISCUSSIONS

Here, we calculated the V-I characteristics of the electrolyser and flow rate but due to variation in solar irradiation, the applied power was not the same at each time interval. In analysing our curve, we discussed the following parameters; electrolyser power with respect to time, hydrogen & oxygen flow rates with respect to time, electrolyser efficiency with respect to time and voltage & Current with respect to time. We determined electrolyser efficiency using the relation;

$$\eta = \frac{Vol_{H_2} \times 28600\,(J/mol)/24000(cm^3/mol)}{V \times I \times time} \quad \text{Nikolic m.et al(2010)} \quad (1.1)$$

While Power (P) = I x V (1.2)

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Table 1.1. Data obtained from the electrolyte concentration at 10% with electrode gap distance of 5mm

Time (hr)	Voltage (V)	Current (A)	Power (W)	H_2(Liter/hr)	O_2(Liter/hr)	Efficiency %
8am	11.8081	5.2012	61.41629	1.9853	0.99265	10.7002
08:30	12.3333	5.3652	66.170621	2.1235	1.06175	10.6228
9am	12.7535	5.3535	68.275862	2.2667	1.13335	10.9895
09:30	13.4403	6.2013	83.347332	2.8335	1.41675	11.2534
10am	14.0806	6.8726	96.770332	3.4425	1.72125	11.7756
10:30	14.4053	7.1753	103.36235	3.3332	1.6666	10.6745
11am	14.7333	7.8708	115.96286	3.0253	1.51265	10.6357
11:30	14.6404	7.9869	116.93141	3.6403	1.82015	9.0652
12pm	14.5535	8.0958	117.82223	3.6016	1.8008	10.1186
12:30	11.9251	7.0229	83.748785	2.7633	1.38165	10.9219
1pm	9.3323	5.9015	55.074568	1.8666	0.9333	11.2189
01:30	8.5019	4.8121	40.911993	1.8333	0.91665	14.8332
2pm	7.7038	3.6467	28.093447	1.8353	0.91765	21.6249
02:30	6.4919	2.8355	18.407782	1.6565	0.82825	29.7880
3pm	5.28308	4.0125	19.619519	1.5012	0.7506	28.7935
03:30	9.2755	3.9255	36.410975	1.8675	0.93375	16.9777
4pm	13.275	5.8535	77.705213	2.2275	1.11375	9.4889

Table 1.1 above showed the data obtained from electrolyte concentration at 10% with diameter of 5mm

Table 1.1., is the data collected when 10% of the electrolyte concentration was used with an electrode spacing of 5mm. The value measured at different hours of the day (8:00 am to 4:00 pm) includes; the current and voltage as well as volume of oxygen and hydrogen produced. The power and efficiency of the system were also calculated.

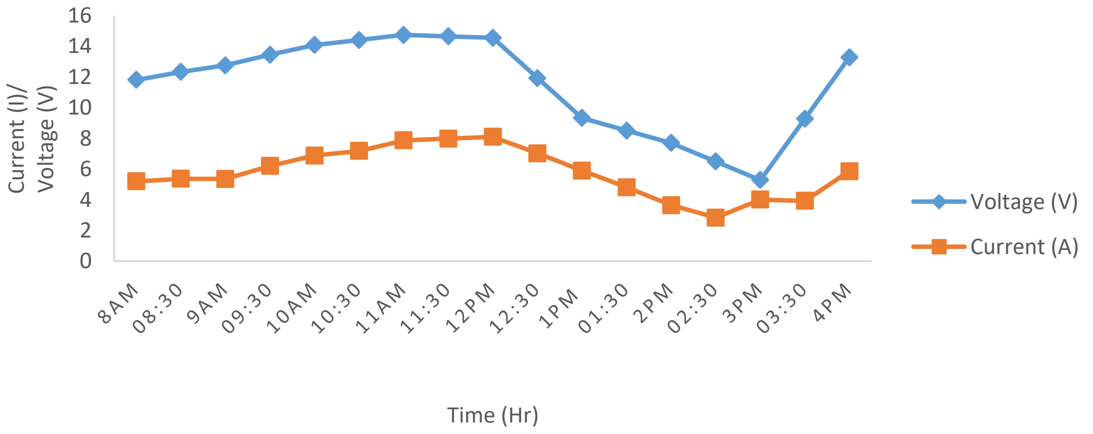

Fig. 1.3: Voltage and Current distribution (I-V Characteristics) of the electrolyser for δ =5mm and 10%concentration.

From figure 1.3, the I-V characteristics of the electrolyser by obtaining the operating voltage and corresponding current at which hydrogen production commenced. Below this voltage, there was insufficient energy to cause water molecules to dissociate. The input I-V characteristics (response) of the electrolyser were obtained by adjusting the power source. The input currents were defined at different applied voltages (0 – 14.73 V). The current only began to flow at a certain voltage of about 5 Volts, and then it fluctuated throughout the flow. The maximum current flow was observed at 12:00 pm with the value of approximately 8.1 Amp, while the peak voltage was observed at 11:00 am with the value of approximately 14.7 Volts.

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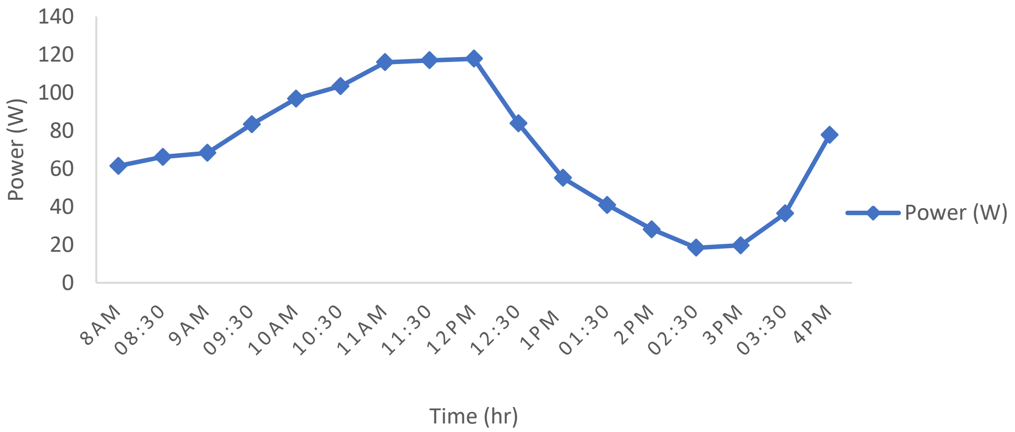

Fig. 1.4: Electrolyser Power distribution for δ =5mm and 10%concentration.

Fig. 1.4., is the power required by the electrolyser to produce a certain volume of hydrogen fuel. The minimum power needed to produce hydrogen is 18.4W and this was observed at 02:30 pm while the minimum volume of hydrogen produced was 1.5 Litre/hr. The maximum power attained by the electrolyser during the production of hydrogen fuel was 117.8 W at 12:00 pm and the maximum volume of hydrogen produced was 3.64litre/hr.

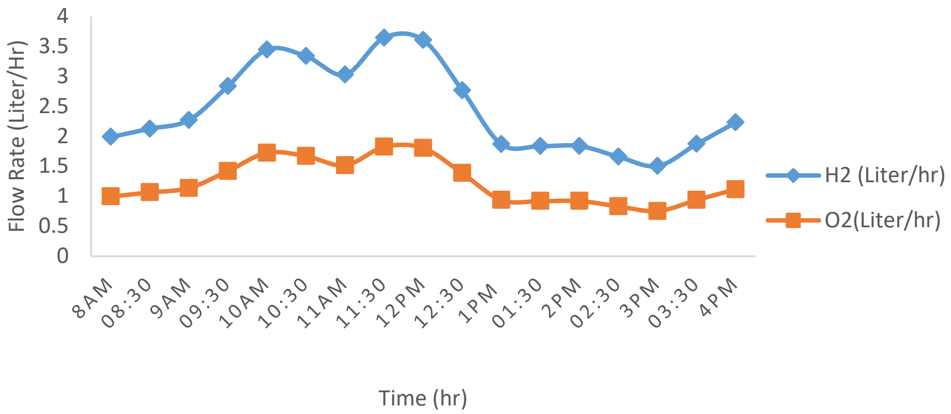

Fig. 1.5: H2, O2 flow rates for δ =5mm and 10%concentration.

Fig. 1.5 is hydrogen and oxygen flow rate variation. The maximum hydrogen flow was observed at 11.30 am with flow rate value of 3.64 Litre/hr, while maximum Oxygen flow was observed at 11:30 am with flow rate value of 1.82 Lit/hr. Also, Hydrogen flow less at 3:00 pm which may be as a result of cloudy weather.

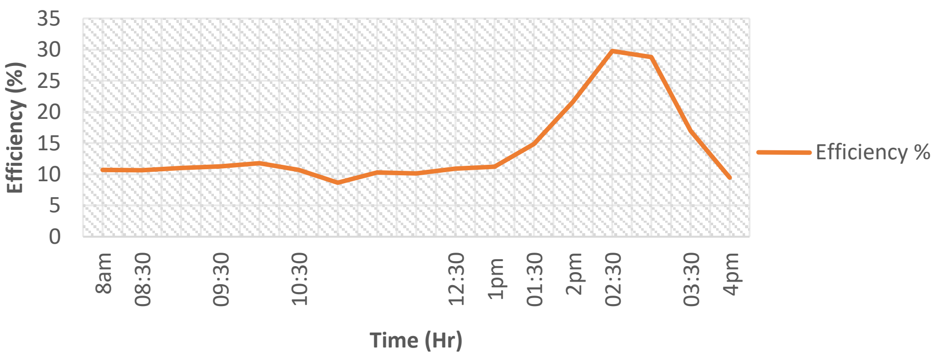

Fig. 1.6: Electrolyser efficiency for δ =5mm and 10%concentration.

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Fig. 1.6 is that electrolyser efficiency variation with time. It was observed from the graph that from 8:00 am the efficiency remained constant with a value of 11.1% until 10:00 am when a little improvement was observed. It started fluctuating till 1:30 pm when the efficiency increased to 15%, with continuous increment to 2:30 pm with an efficiency of 30% which is an improvement when compared with Roy L. et al (1979) whose maximum efficiency was 20.5%. A simultaneous decrease was noticed at 3:00 pm with efficiency of 28% and further decrease was observed till 9% efficiency which was observed at 4:00 pm. The lowest frequency was 9.1% observed at 11:00 am.

4. DISCUSSIONS

Table 1.1, showed data obtained from 10% concentration of electrolyte against 5mm electrode gap distance. The maximum efficiency achieved was 29.6% for electrolyte concentration of 10% against electrode gap distance of 5mm with hydrogen flow of 3.64 Litr/hr which was recorded at about 11:30 am. The minimum flow was 1.5 Litr/hr at 3:00 pm. and the maximum efficiency achieved was 29.8%. This showed that the electrode gap spacing of 5mm caused the efficiency to improve with electrolyte concentration of 10% while the applied voltage helped in the production of more hydrogen. Here, aluminium /copper was used for the pairs of electrode and potassium hydroxide (KOH) was used as electrolyte. When compared with Roy L., et-al. (1979) who employed stainless steel/copper as pair of the electrodes in his work. He obtained maximum efficiency of 20.5%. So, in our work, we advanced by 9.3% and this will make hydrogen available and a better energy alternative.

5. CONCLUTION

In this work, 10% electrolyte concentration were used against 5mm electrode gap spacing and the results obtained showed that reducing the concentration of electrolyte while the electrode gap distance remained at 5mm caused the system efficiency to reduce to 29.6% by producing 3.64litr/hr of hydrogen. This is an advancement when compared with the work of Roy L., et-al (1979) in terms of efficiency and litres of hydrogen produced.

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