Fuel Cell Based Vehicle

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Abstract.

The effective usage ofreversible PEM fuel cell for vehicle application is presented in this paper. The PEM fuel cell is anunconventionalenergy carrier, particularly for transportation and stationary power generation applications because of its higher efficiency, the operating temperature is less, power density is more, quick startup, and system robustness.The reversible PEM fuel cell will act as electrolyzer to produce hydrogen gas and oxygen gas. When the electrical energy is required, the stored hydrogen gas is given as input fuel to the fuel cell to generate electrical energy. An investigation on the performance ofelectrolyzer, hydrogen flow rate and fuel cellare presented. The generated electrical energy from the fuel cell is given as input to DC motor which is connected to the wheel of vehicle. The vehicle model and its performance are also discussed. The byproduct of Fuel cell vehicle is water and thus there is no emission of harmful gases.

Keywords.Electrolyzer, Fuel cell, Fuel cell vehicle

1. INTRODUCTION

On the renewable energy source the intermittent problem is a major drawback; to overcome the issues a suitable energy storage system is used. The energy storage in the form of hydrogen is appropriate for long term storage compare to battery storage system. Hydrogen [1] is an emerging renewable energy resource which contains high efficiency, high calorific value and clean gas which is become as a replacement for gasoline. It is plentiful but is not a naturally occurring gas, it passes through a number of processes that allow it to be produced as a free gas and stored safely and efficiently inside the tank [2]. There is various ways to generate hydrogen gas from renewable resources. The most suitable one is electrolysis method. Here the water is used, the electrolyzer separate the hydrogen and oxygen gas. The separated hydrogen is stored in hydrogen tank in form of gas. The stored gas is used in fuel cell. Fuel cell is a device where electrochemical reaction takes place which converts free energy as electrical energy.

The dynamic modeling of electrolysis process for the effect of temperature and flow rate in both analytical and experimental way the results were shown [3]. The fuel cell integration with grid was simulated and results are shown [4]. The hydrogen production using PEM electrolyzer and filling fuel cell car using compressor model was simulated [5]. In the literature [6], the innovative idea of Fuel cell car based on renewable energy sources was discussed. The conventional vehicles, hybrid vehicle, electric vehicle and hydrogen fuel

cellbased vehicles are compared based on their economic performance and environment impact [7]. The literature [8] represents investigated results of economic efficiency on using hydrogen fuel cell. The Fuel cell vehicle was controlled by fuzzy logic controller is illustrated in [9-13]. Energy management system is developed and simulated to prevent the lifetime of the storage system in fuel cell vehicle [14]. In these paper, Mini reversible PEM Fuel cell characteristics on both the electrolyzer and fuel cell process is discussed in first section and the second section presents the results of Fuel cell based vehicles.

2. REVERSIBLE PEM FUEL CELL

In the reversible PEM Fuel cell, it can function as electrolyzer and also as a fuel cell. The hydrogen gas and oxygengas act as input to the fuel cell togenerate electrical energy andbyproduct as water is produced [4]. When it act as an electrolysis device,on applying electrical energy it seperate water as hydrogen ion and oxygen gas. The Schematic diagram of Reversible PEM Fuel cell is shown in Figure 2.1.

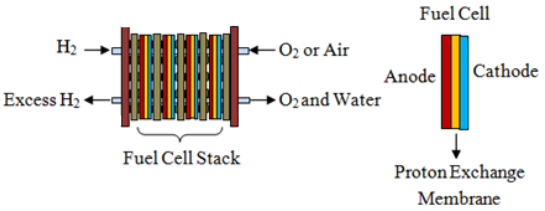

Figure 2.1. Schematic Diagram of Reversible PEM Fuel Cell

In a plastic housing, PEM fuel cell has two electrodes placed together within gaskets and held tightly together. The twoElectrodes function as electrical contact points. In the two electrodes, different electrochemical reaction occurs on them. The electrode on the hydrogen side is named asan anode;another electrode is the oxygen side so it is named as the cathode. During the process, the anodeelectrode electrically separates the neutral hydrogen molecules aselectrons [3]. A chemical reaction occurs at the catalyst. The positively charged hydrogen ions move through the polymer membrane and reach the negatively charged cathode. The electrons pass throughthe circuit from the anode to the cathode. The splited hydrogen ions are known as protons. The photons are small pass through the holes of membranes, but oxygen ions are larger in size cannot move through the membrane hole. Hence, it is called as Proton Exchange Membrane [3]. At the cathode side, the hydrogen ions combine with the oxygen molecules and separated electrons passes through the external circuit. As a result of reaction, water is formed. That is the hydrogen and oxygen ions are again combined to produce water molecules.

In the electrolysis process, the energy is needed to split the water molecules and thesame energy is producedduring the recombination of ions. In such a way, an electrical voltage is produced in the fuel cell. On connectingan electrical load (the electric motor)on the anode and cathode, the electrons move from the anode to cathode [5]. Thus an electric current passes to the motor and it starts to run. The conversion takes place catalytically, whereas the electrodes do not change during the chemical reactions. There are no flames, so heat is not produced. The following electrochemical reactions occuron the electrodes of the fuel cell [4],

Anode: $2\ H_2 \rightarrow 4\ H^+ + 4\ e^-$

Cathode: $O_2 + 4\ H^+ + 4\ e^- \rightarrow 2\ H_2O$

Net Reaction: $2\ H_2 + O_2 \rightarrow 2\ H_2O$

The water production at the cathode (oxygen side) can be easily collected. When the fuel cell generates current proper care should be considered. On increasing the current flow, the water is regenerated faster from the hydrogen and oxygen gases.

2.1 Fuel Cell based Vehicle

The vehicles working on hydrogen gas are increased due to reduce the environmental pollution. Fuel cells for transportation have also been verified in public bus systems. There have been some prototypes buses on the road around the world are available. Majority of these buses are produced by UTC power, Toyota, Ballard, Hyrogenics and the Proton Motor. In the recent study of United States National RenewableEnergy Laboratory, it has proven that the fuel economy of hydrogenfuel cell based buses is higher for the factor of 1.8 to 2.4 than the fuel economy of diesel or compressed naturalgas buses [15].

Fuel cell vehicle is use hydrogen gas to generate electric power with the help of this electric power motor run. Unlike conventional vehicle which runs on gasoline, fuel cell combines hydrogen and oxygen which is used to generate electricity to run motor. But range of fuel cell vehicle is comparable to conventional trucks and buses. Hydrogen fuel cell vehicle have a significant potential to reduce emission from the transportation sector, because they do not emit any greenhouse gases during vehicle operation [14]. The Fuel cell vehicle has four wheels, dc motor with gear set up and gas tank.

3. RESULT AND DISCUSSION

The experimental study is done separately for two processes as electrolyzer unit and fuel cell unit. Initially, an electrolyzer process is done for segregating the water molecules as hydrogen gas and oxygen gas. The process includes the electrolyzer stack; distilled water is to be filled in 30ml tank, and two separate tanks with 24ml and 12ml to store hydrogen gas and oxygen gas respectively. The electrical energy is given as input to the electrolyzer. On supplying electrical power, the water split into hydrogen ion and oxygen separately stored in two tanks. The hardware setup of electrolyzer process is shown in Figure 3.1.

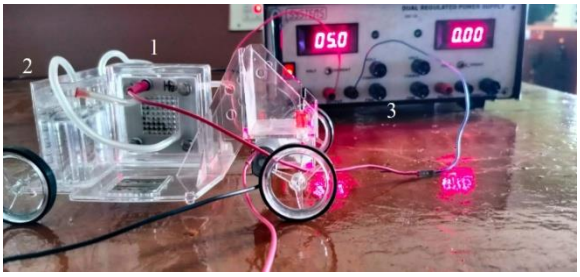

Figure 3.1. Hardware Setup for Electrolysis process
1. Electrolyzer stack 2. Tanks 3. Regulated Power supply

The cell voltage and current density characteristic is shown in Figure 3.2. From the Figure 3.2, it is shown that on increasing the current density the cell voltage also increases. The cell voltage is depending on equilibrium voltage, activation loss, ohmic loss and concentration voltage.

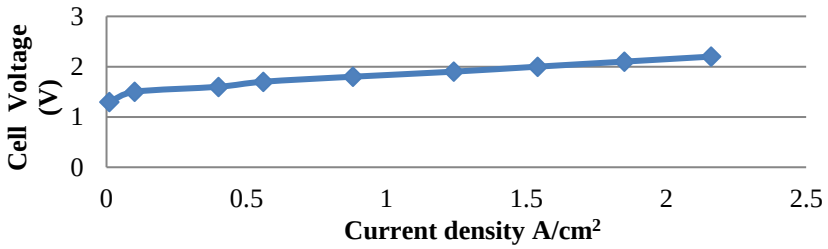

Figure 3.2. V-I characteristics of Electrolyzer

The hydrogen and oxygen flow rate from electrolyzerfor the input voltage 1.5V is shown in Figure 3.3. The both gases are separetely collected in two tanks of 30ml and 15ml respectively. In order to maintain the temperature, the tank is circulated by distilled water.

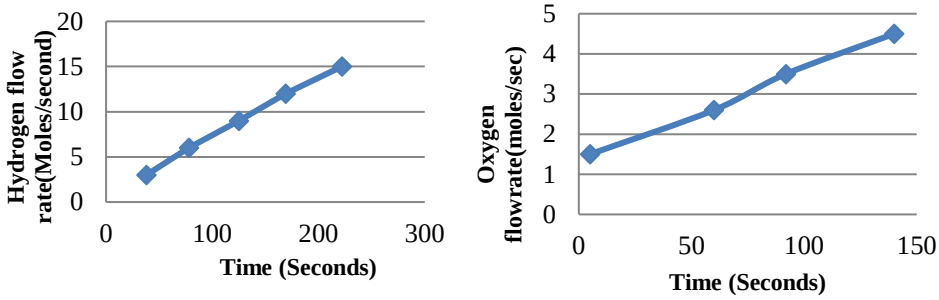

Figure3.4. Hydrogen and oxygen flow rate from electrolyzer

The stored hydrogen gas is passed as input to the fuel cell for the variable load (Decade resistance Box). The V-I characteristics of fuel cell is shown in Figure3.5.

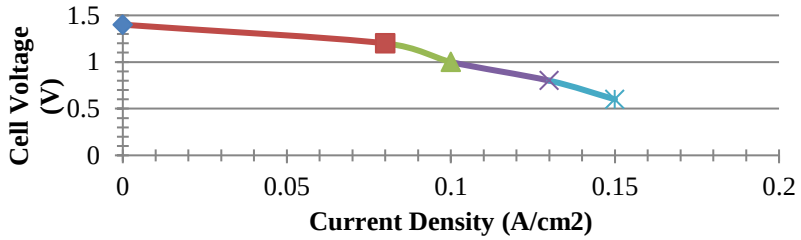

Figure 3.5. V-I characteristics of Fuel cell

To run the fuel cell based Vehicle, the fuel cell is connected to 5V DC motor. The DC motor linkedwith the wheel shaft. The vehicle can cover a distance of 12 feet in 25 seconds. The model of fuel cell based vehicle is shown in Figure 3.6.

Figure 3.6. Fuel cell based Vehicle

4. CONCLUSION

In this paper, the experimental study of both electrolyzer process and fuel cell process is carried out using reversible PEM Fuel cell. The hydrogen and oxygen are produced from electrolyzer and the flow rates are shown in the result. When the motor connected to fuel cell the electrochemical reaction carried out, the electrical energy is produced due to the movement of electrons.Thus the vehicle starts to move for a distance of 12 feet. The toxic gases production from vehicle is drastically reduced and environmental friendly vehicle.

5. FUTURE SCOPE

In future the vehicle model is designed with large tank capacity to cover long distance with suitable controller for better performance of vehicle.

6. REFERENCES

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