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An Effect of H2 Flow Rate by PEM Fuel Cell & 4-Serpentine channel control panel

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Abstract

Energy is an inescapable part of today's society and economy. Accomplishment of every work depends on the sufficient and incessant supply of energy. But the conventional fossil energy sources like oil are ultimately limited. Moreover, the increasing demand and flinching supply of oil has made the sustainable energy supply more vulnerable. So this vulnerability of conventional source of energy conducts the thinkers to think about reliable sources of fuel like fuel cell and renewable energy. It can forestall the minus impacts of global climate change, the growing risk of supply interruptions, price fluctuations and air pollution that are associated with today's energy systems. Bring in the hydrogen economy by hydrogen and fuel cell in the minor level like household activities can be a promising solution of energy crisis in a quite unique way which also can ensure our concerns over energy supply security and climate change

Keywords: PEM Fuel Cell, 4-Serpentine channel, control panel and Effect of H2 Flow Rate.

1. Introduction

Global energy demand is springing up so scurrying in the last few decades. Global primary energy annual growth rate is 1.8% within the period 2000 to 2030 [1]. This rapid increasing rate is met largely from traditional fossil fuels. These fuels emit different gases which very harmful for the environment. But ultimately these fuel reserves are depleting and the energy price become increasingly expensive. Latterly, the CO2 emission level of developing country is 20% per capita then of the major industrial nations [1]. But within the year 2030 this will be more than half of the world's CO2 emissions. Moreover, Energy security is a cardinal topic. Fossil fuels like crude oil, natural gas is unevenly distributed which is sometimes governed by the ecological, economic and political factors. These factors lead the price of fuel to a high place and on the other hand the environmental policy demands to reduce the toxic gas emission. A combined energy policy is necessary by highlighting the energy demand, energy supply, fuel production, fuel transmission and distribution, energy conversion and the consequences on energy tools manufacturers and the minor users of energy systems. To meet this goal our aim is to establish a renewable efficient system by hydrogen and hydrogen powered fuel cell from the end user level like household. In the long run hydrogen based fuel cell system for the end user has a great impact on all other sectors. Some developing countries are struggling to provide a sustainable energy supply to its citizen [10]. But for giving the top priority to the industrial sector sometimes the domestic users are deprived by getting interrupted power supply. For any power deficit country sometimes it's very difficult to provide power uniformly to all the sectors. So at that case the domestic user can think the fuel cell and renewable hydrogen energy beside national power grid for power demand in household activities. Uninterrupted energy supply to all the sectors of any country has a great advantage on the economy.

So if the developing countries make an effort to give an uninterrupted power to its citizen then it should be an optimum system to introduce hydrogen and fuel cell to the domestic user without hampering the industrial sector power. This paper highlights the need for strategic planning and enhanced effort on research, development and deployment of hydrogen and fuel cell technologies. It also makes wideranging recommendations for a more structured approach to developing countries for education and training and also for developing political and public awareness. Energy supply security is the major concern for the developed as well as developing countries. The technocrats have already observed the limitation of nonrenewable fuels. So in this case hydrogen based energy system is a great potential which can secure a stable future, but designing an efficient, effective and friendly system for transition is a little bit tortuous. We have to initiate now to scrutinize that path to secure a sustainable future. In the initial stage of this research global current energy status by source has been depicted. But this energy consumption is different in different region and also different in sectors. So this paper tries to give a good sense by giving some visual statistics about the

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global energy scenario. The paper also shows some comparison of energy consumption in different sector. Our main goal of the research is to reveal the importance of renewable and hydrogen and fuel cell in the household activities. So a typical household energy consumption structure has also shown. The paper also shows a typical house load and then the necessary installation to meet the energy of that house by hydrogen and fuel cell.

2. Related Work

Currently global energy mainly mixed with coal, gas, oil, nuclear and renewable energies. At present the large scale of fossil fuel is a cardinal feature of industrial sectors. It is regarded as essential for the growing, distribution and preparation of foods, for construction, manufacturing, communication and organization and many other activities. There was estimation in 1992 which revealed that global annual primary energy consumption is 400 EJ which is equivalent of 9500 million tons of oil per year [4]. So in the electricity generation the use of oil becomes vulnerable to sustainable supply. Coal contributes 40% of electricity production and gas accounts 20% of the electricity production [2]. Nuclear energy contributes 6% to the global energy and 13% to the electric energy [2]. The non-fossil and non-nuclear energy sources already accounted 3.300 TWh from total 18800 TWh electricity productions by the year 2005 which is 18% of the total. From this amount of energy around 2800 TWh are from hydroelectricity. The non hydro contributes approximately 500 TWh which is around 3% of the total electricity generation. We rate renewable energy as a best for the electricity scarcity solution. But currently the use of hydrogen energy and fuel cell in the domestic level become a promising alternative to retain the sustainable society.

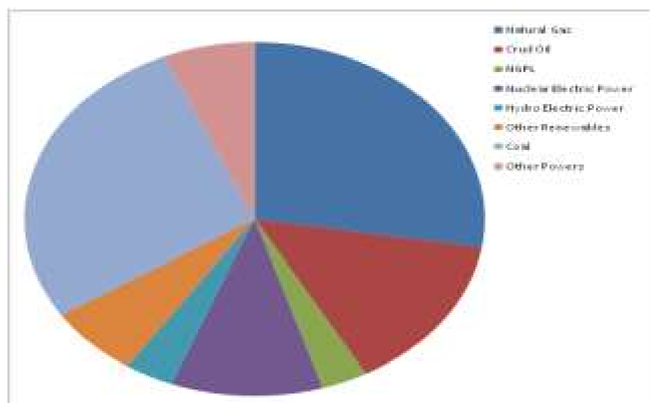

Figure 1. World Primary Energy Consumption by Source, 2010 [3].

3. Implementation

Description of experimental setup:

The experimental set up consists of a single PEM fuel cell with active surface area 9.8 × 9.6 cm of a membrane electrode assembly (MEA) sandwiched between flow field plates, current collector plates and end plates is shown in Fig.2. The experimental set up also consists of three storage cylinders containing hydrogen, oxygen and nitrogen respectively, which are to be used in the fuel cell. Fuel cell test station is used to measure voltage, current and power. Humidification chambers (bottles or tanks) are provided to humidify the hydrogen and oxygen before they enter the fuel cell

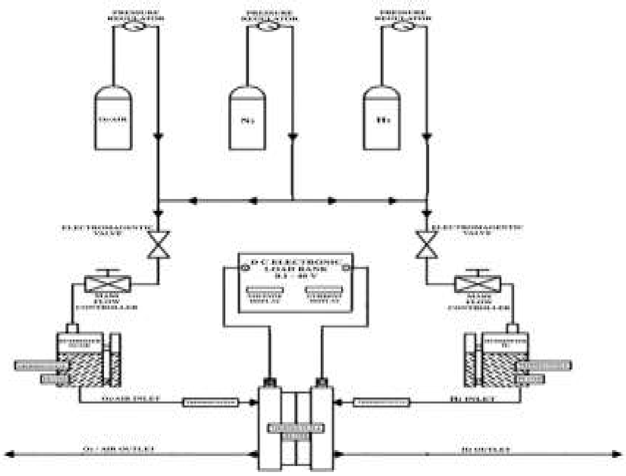

Fig.2: Diagram of experimental apparatus for testing of PEM Fuel Cell.

The photograph of single PEM fuel cell used in the experiments is shown in Fig.3. The membrane electrode assembly (MEA) consists of the polymer electrolyte membrane (Nafion 1135, 88 µm), the anode and cathode catalyst layers, and the anode and cathode gas diffusion layer (GDL). The electro catalyst used is carbon-supported Pt. The catalyst ink is prepared from platinum-carbon powder with ethyl alcohol. The catalyst ink is applied as a layer on the gas diffusion layer (which is a carbon paper). The catalyst loading on the anode side is 0.15 mg/cm2 with a thickness of catalyst layer of 20 µm. A catalyst loading of 0.3mg/cm2 is used on the cathode-side with a thickness of catalyst layer of 40 µm. Carbon papers having thickness of 400 µm are used as gas diffusion layers on both sides. The membrane electrode assembly (viz., membrane, GDLs and catalyst layers) is placed between two graphite plates and is pressed between gold-coated copper plates.

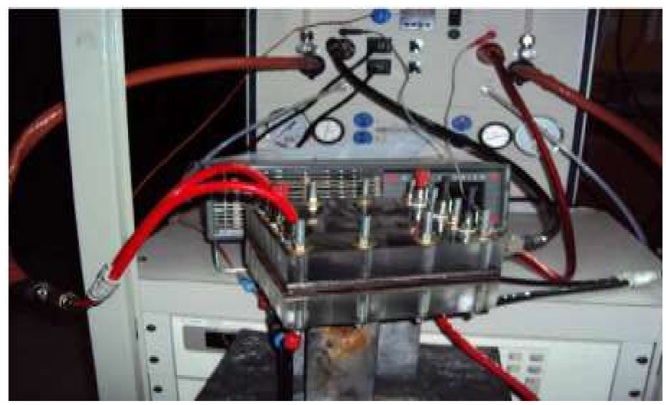

Fig.3: Photograph of single PEM fuel cell Experimental set up.

Flow field plates made of graphite are pressed to MEA on both sides. These plates are grooved to create flow channels in them, through which the gases flow. Hydrogen passes through the flow channel in the plate on the anode side. Oxygen flows through the passages in the plate on the cathode side. Different flow arrangements have been tested by researchers with the aim of achieving good diffusion of hydrogen ion across the membrane. Experimental studies are conducted with 4- serpentine (4-S). A

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photograph of the 4-serpentine flow field is shown in Fig.4.

A fuel cell test station is used to set and control the fuel cell temperature, humidification temperatures and flow rates of reactant gases at the anode and cathode sides with the aid of a computer. The test station is supplied by Fuel Cell Technologies Inc., Chennai. The reactant gases (hydrogen and oxygen) drawn from the respective storage tanks are humidified by bubbling through water tanks or bottles. A provision exists to control the extent of humidification of the reactant gases by regulating the temperature of water in the tanks. Fuel cell temperatures and humidification temperatures are controlled by a microprocessor-based temperature/process controller, named CN76122 T/C. Back pressures are controlled by backpressure regulators. The test station also includes a computer-based control and data acquisition system based on Labview TM based application software. The computer system is connected to flow rate controllers, which are located before the humidifiers. The mass flow rates are set and read through the software. A control panel is provided in the PEM fuel cell test station. The values of all the parameters, which are controlled and monitored, are shown in the control panel. A photograph of the control panel is shown in Fig.5.

Fig. 4: Photograph of 4-Serpentine channel.

The fuel cell polarization curves are obtained from this program as well by controlling the HP6050 Electronic Load, which measures the voltage versus current response of the fuel cell.

Fig. 5: Photograph of the control panel.

Experimental procedure:

Experimental data of voltage versus current are recorded with different values of the input parameters, such as oxygen flow rate, hydrogen flow rate, anode humidification temperature, percent excess of oxygen flow rate over the

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theoretical quantity. All these experimental data are obtained with 4- serpentine flow field plates. The sequence of steps for each experimental run is as follows:

1. Power on the Fuel Cell Test Station and open the valves of the gas cylinders of hydrogen, nitrogen and oxygen.
2. Before starting experiment, purge the anode side with nitrogen to ensure no oxygen is present.
3. Set the experimental parameters of mass flow rate, fuel cell temperature, humidification temperature and backpressure.
4. All these parameter readings are noted down from digital meters. Accuracy of these parameters are anode and cathode humidification temperatures up to one decimal, flow rate up to two decimal, voltage and current values with an accuracy up to 3 decimals.
5. Set the minimum value of voltage or current and give increment in voltage or in current. These are selected in the control panel in the fuel cell polarization data panel in the test software interface.
6. Set the time delay between two successive input voltages (or currents).
7. Press the 'Start' button to initiate the experiment and collect data.

Time delay: It is critical to select a proper delay between every two data points to make sure every point of voltage vs. current is obtained when the fuel cell has reached a relatively steady state. Hence, experiments with different time delays were conducted to select the duration of delay between measurement points. By comparing variation of the voltage and current with time, a delay of 200 s was selected.

4. Experimental Work

Effect of H2 Flow Rate:

The experimental data for voltage and power as functions of current for single fuel cell are presented in Figs. 6 and 7 respectively for four different flow rates of hydrogen. The flow rate of oxygen is maintained at 0.4 lpm. The cell temperature, anode and cathode humidification temperatures are maintained at 60oC. The experimental data for V-I and P-I curves are also shown in Figs. 5 and 6 respectively. The results indicate that the performance increases steadily as H2 flow rate increases. It can be observed from Figs. 5 and 6 respectively that one can increase the limiting current and power by increasing the flow rate of hydrogen. A sudden drop in the voltage indicates zero concentration of hydrogen on the catalyst surface. The current corresponding to this point of zero concentration of H2 is called limiting current. A fuel cell cannot produce more than the limiting current because no reactants exist at

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the catalyst surface beyond this point on the V-I curve.

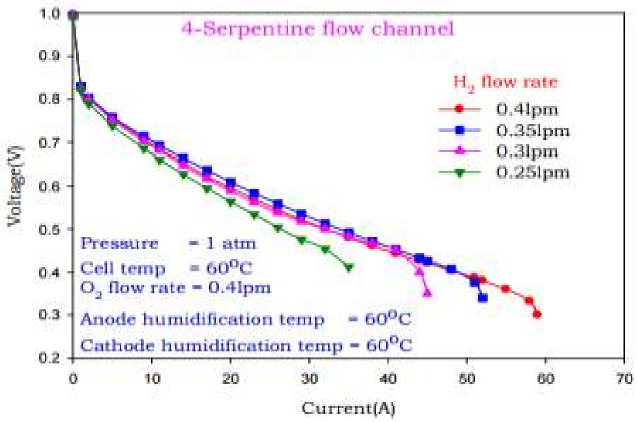

Fig.6: Effect of H2 flow rate on fuel cell performance in 4- Serpentine flow channel (V-I curve).

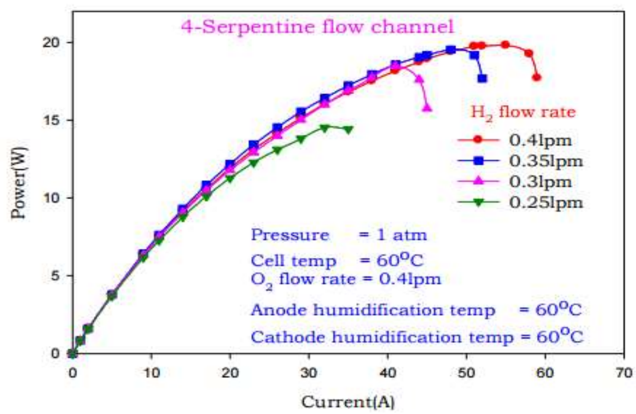

Fig.7: Effect of H2 flow rate on fuel cell performance in 4- Serpentine flow channel (P-I curve).

Effect of Anode Humidification Temperature:

Hydrogen gas is humidified by bubbling it through water which is present in a bottle. A heater is placed in the bottle to heat the water to a required temperature. The humidity acquired byhydrogen is controlled by either increasing or decreasing the temperature of water in the bottle. Polarization curves with different anode humidification temperatures, viz., 35, 40 and 45oC are presented in Figure. 7. It can be found from Figure. 8 that the voltage decreases as the humidification temperature increases due to an increase in the saturation humidity of hydrogen gas. A comparison of the V-I curves at 35 and 40oC indicates a slight downward shift of the curve. The mole fraction of hydrogen decreases and mole fraction of water increases with an increase in anode humidification temperature resulting in decrease in performance. Fig...9 show that power decreases with an increase in anode humidification temperature.

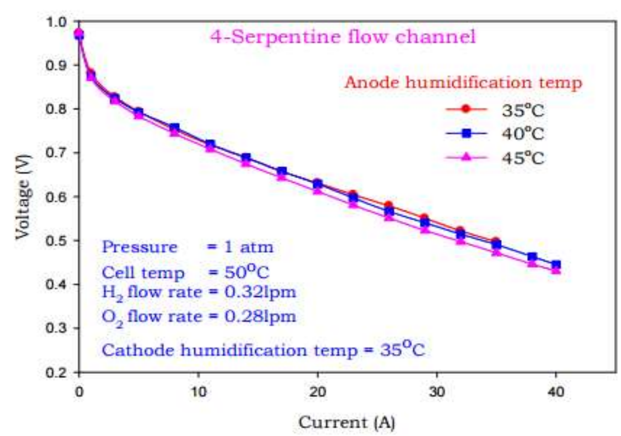

Fig...8 Effect of anode humidification temperature in 4- Serpentine flow channel (V-I curve).

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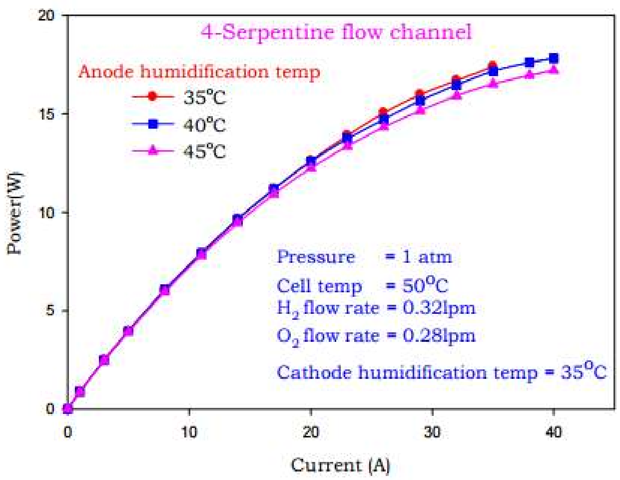

Fig.9: Effect of anode humidification temperature in 4- Serpentine flow channel (P-I curve).

The experimental data for voltage and power as functions of current for single fuel cell are presented in Figs 7 and 8 respectively for three different anode humidification temperatures. Both the cell temperature and cathode humidification temperatures are maintained constant at 50oC and 35oC respectively.

5. Conclusion

The performance increases steadily as H2 flow rate increases. One can increase the limiting current and power by increasing the flow rate of hydrogen. At 0.25 lpm of H2 flow rate the power obtained is 14.5W from the cell. When the flow rate is increased to 0.4 lpm, a 40% increased is obtained in power (20W). The voltage decreases as the humidification temperature increases due to an increase in the saturation humidity of hydrogen gas. As the oxygen flow rate is increased, there is an increase in the cell voltage due to maintaining sufficient oxygen is maintained on the cathode catalyst layer and carryover of water by oxygen. When the flow rate is doubled (0.2 to 0.4 lpm) a 10% increase is found in power production (17.7 to 19.4W).

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