Hydrogen pressure control in a regenerative PEM fuel cell

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***Abstract* – This paper describes the sustainable energy situation of South Africa, the operation of a regenerative PEM fuel cell and how the hydrogen pressure inside the regenerative fuel cell will be tested. The paper also shows a proposed schematic of a hydrogen production and control system.**

Index Terms—regenerative fuel cell, hydrogen pressure control

I. INTRODUCTION

Industrial countries, such as South Africa, rely heavily on energy sources. Sustainable development is therefore a strategic goal of modern society. Access to affordable and reliable energy drawn from an environmental acceptable source of supply is an important feature of sustainable development [1].

Sustainable development is defined as a process of developing land, cities, business, communities, etc. that "meets the needs of the present without compromising the ability of future generations to meet their own needs" [1]. The extraction and combustion of fossil fuels is a major threat to the environment [1].

Unfortunately, many current industries and societies are not sustainable. This problem has mainly arisen due to the depletion of fossil fuels which brings the following concerns [1]:

- It's going fast
  Substances such as coal, petroleum, shale oil, tar sands and natural gas are diminishing [1].

- Environmental pollution
  Carbon dioxide from fossil fuel burning could raise the infrared opacity of the atmosphere and thereby warm the earth [2]. From 1990 to 2004 world carbon dioxide (CO_2) emissions increased by 24% [3].

- Oil wars
  The United States imports approximately 66% of the oil consumed in their country, of which 66% percent is spent on transportation in the form of motor cars and light trucks. The price increase will seriously affect the poorer communities, resulting in a lower standard of living. Two key points to keep in mind are: (1) nations always have, are currently, and will continue to fight wars over needed resources, and (2) societies will not readily return to the life style of the preindustrialized world [1].

Emanating from the above, it becomes imperative to find a suitable and sustainable energy alternative to the present energy system. It is noted that hydrogen appears to be a promising, useful candidate to replace hydrocarbon fuels. Hydrogen can be used as a fuel to generate electricity, through use of a Proton Exchange Membrane fuel cell (PEMFC) [1].

II. REGENERATIVE FUEL CELL

Figure 1 shows a unitized PEM Regenerative Fuel Cell. The top part operates as a fuel cell and is called the fuel cell mode. The bottom part operates as a regenerative fuel cell and is called the electrolyser cell mode.

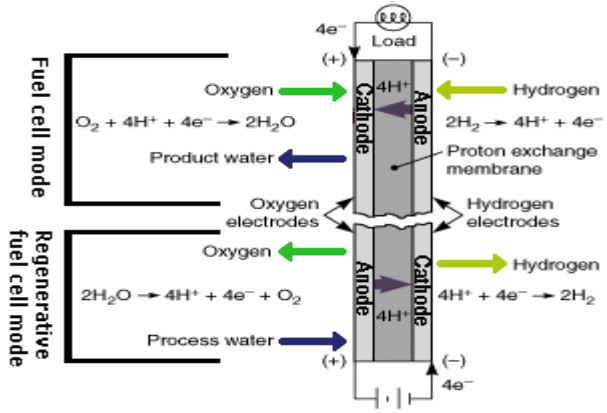

Figure 1 Unitized PEM Regenerative Fuel Cell

In principle the PEM RFC operates in the following manner. Water (H_2O) is introduced at the anode electrode chamber. A potential is placed across the anode (positive) and cathode (negative) electrodes, which must be greater than 1.23 Volt (V) for the decomposition of H_2O to take place. At the anode a catalyst in the form of platinum (Pt), allows the H_2O molecule to break down. The oxygen protons (O^+) and hydrogen protons (H^+) form weak O-Pt and H-Pt bonds at the respective catalyst sites. The electron (e^-) from the hydrogen atom is released into the external circuit. The O^+ does not lose its e^- to the external circuit but rather joins with another O^+ and its e^- to form O_2 gas [5].

The H^+ protons travel through the membrane from the anode side to the cathode side due to the voltage potential that was applied across the anode and cathode. The electrons that were previously lost to the external circuit are attracted to the hydrogen at the weak H-Pt site and rejoins with them to form hydrogen atoms. Two of these atoms join to form a H_2 molecule. This effectively is the evolution of H_2 gas at the cathode electrode [5].

III. CONCERNS TO BE ADDRESSED

In order to store the hydrogen that is produced by the regenerative fuel cell (RFC) certain concerns need to be addressed. They are:

- Regulating the pressure in the fuel cell;
- Ensuring the hydrogen released into the tank is pure; and
- Purifying contaminated hydrogen so that no hydrogen is wasted.

IV. PROPOSED SCHAMATIC

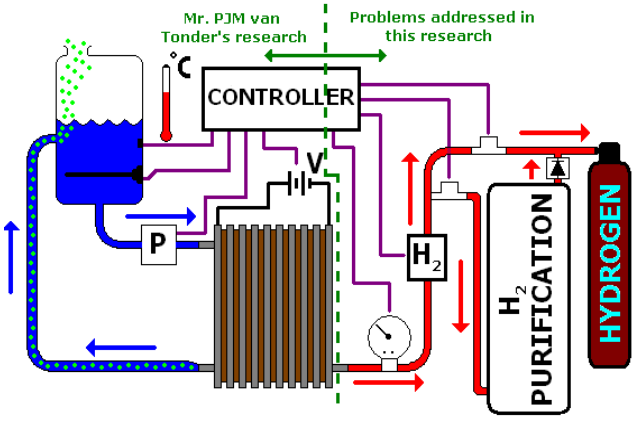

Figure 2 Hydrogen production and control system

Figure 2 explains the following:

- **Regulating the pressure**
  The hydrogen produced in the RFC must constantly be measured. If the pressure inside the fuel cell is the same as the desired pressure it should be released into the external hydrogen circuit, such as a hydrogen tank.

- **Ensure the hydrogen released into the tank is pure**
  The hydrogen released into the external circuit must be pure, otherwise the lifetime of the fuel cell would be decreased due to the poisoning of the membrane. The other major concern is to prevent other elements, such as oxygen, from mixing with the hydrogen system, as this may lead to combustion.

- **Purifying contaminated hydrogen so that no hydrogen is wasted**
  If the hydrogen released is contaminated, it should be purified and then released into the external hydrogen circuit. If the contaminated hydrogen is not purified and released into the air, it will be wasted and will bring down the efficiency of the system.

V. TESTS DONE SO FAR

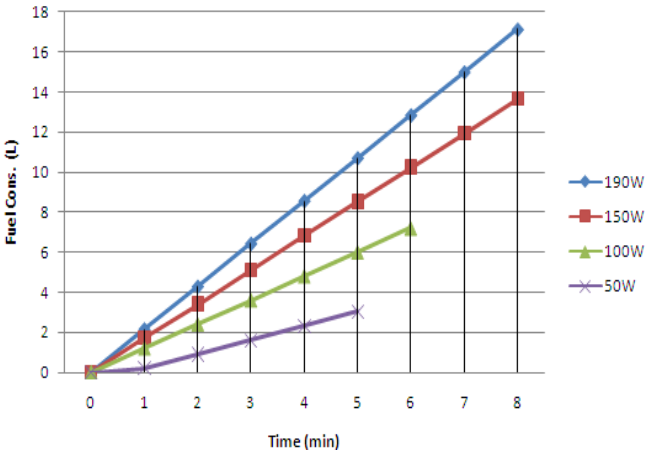

Figure 3 Hydrogen usage

Figure 3 shows a graph that indicates the hydrogen usage of the NEXA Power Module per minute under different load conditions.

The loads are applied to the Nexa Power Module by way of a DC electronic load. The loads that were used were 50W, 100W, 150W and 190W.

VI. REFERENCES

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Melanie Burger received her BTech degree in 2009 from Central University of Technology, Free State (CUT) and is presently studying towards her MTech at Vaal University of Technology (VUT), as a Telkom Centre of Excellence student doing research on Fuel Cells.