

ChE-455/555: Analysis of Electrochemical Systems

Experiment 3: Fuel Cell Experiment

1. Introduction

The use of solar energy for our everyday electricity needs has distinct advantages: we avoid degrading the environment through polluting emissions, oil spills, and toxic byproducts. Renewable energy frees people from finite, unstable energy resources. There is, however, one disadvantage to solar energy: the sun does not always shine. Therefore, we need a way to store solar energy for times when the sun is not shining. Hydrogen provides a safe, efficient clean way to do this, by using fuel cells.

The solar hydrogen cycle works as follows: electricity from photovoltaic panels and wind turbines may be used to run an electrolyzer, a device which splits water (H_2O) into its elemental parts, hydrogen (H_2) and oxygen (O_2). The oxygen is released into the air and the hydrogen is pumped into storage tanks, where it can be kept on site or transported to sun-poor regions. At night, when solar energy is not available, the hydrogen is recombined with oxygen from the air in a fuel cell to produce electricity.

A fuel cell is an electrochemical energy conversion device. It is two to three times more efficient at converting fuel to power than conventional combustion technologies (e.g., internal combustion engine) of the same size.

Fuel cells are usually classified by the electrolyte employed in the cell. There are low-temperature and high temperature fuel cells. Low-temperature fuel cells are the Alkaline Fuel Cell (AFC), the Proton Exchange Membrane (PEM) fuel cells, the Direct Methanol Fuel Cell (DMFC) and the Phosphoric Acid Fuel Cell (PAFC). PEM fuel cell, also called SPEFC (Solid Polymer Electrolyte Fuel Cells) uses a proton exchange membrane as an electrolyte. They generally operate between 85~105 °C.

Water is the only emission when hydrogen is the fuel. As hydrogen flows into the fuel cell on the anode side, a platinum catalyst facilitates the separation of the hydrogen gas into electrons and protons (hydrogen ions). The hydrogen ions pass through the membrane (the center part of the PME fuel cell) and, again with the help of a platinum catalyst, combine with oxygen and electrons on the cathode side producing water. The electrons, which cannot pass through the membrane, flow from the anode to the cathode through an external circuit containing an electric load which consumes the power generated by the cell.

2. Objective

The purpose of this experiment is to demonstrate the use of reverse fuel cell/fuel cell systems for the production of electricity. The specific objectives of this experiment are:

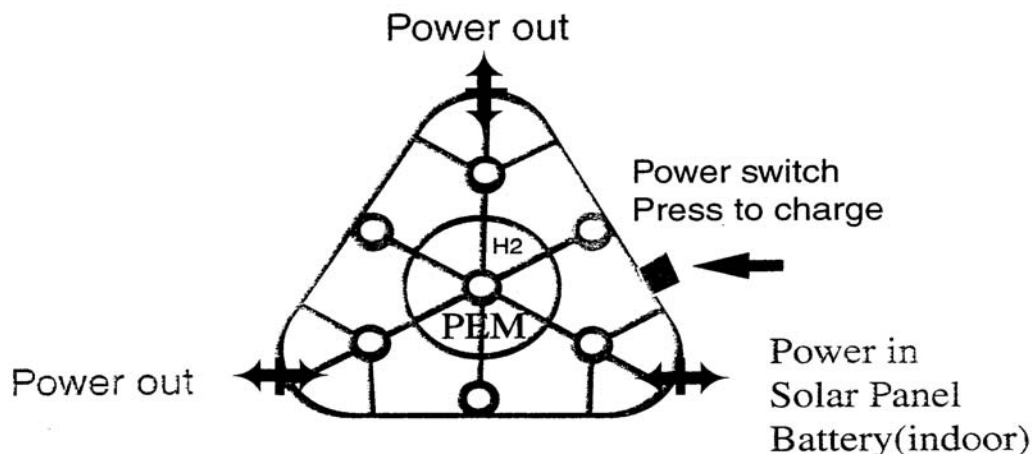
1. Determine the charge curves (current, voltage, and power as a function of time) of a reverse fuel cell
2. Determine the discharge curves (current, voltage, and power as a function of time) of a fuel cell
3. Calculate the overall efficiency of the system (reverse fuel cell/fuel cell)

3. Materials

Proton Exchange Membrane (PME) fuel cell;
Battery;
Solar panel;
Stop watch;
Digital multimeter;
Cables

4. Procedure

The figure shows a schematic representation of the reverse/direct fuel cell.



- (1) Connect the motor fan and the battery (or solar panel) to a digital multimeter (black lead to "COM" port and red lead to "10ADC" port).
- (2) Start charge procedure: depress the power switch. This button must be completely depressed to allow power to reach the PEM. Measure the charging current (I_c) every ten seconds and observe the current change trend. Measure the charging voltage (V_c) every ten seconds using an additional multimeter. Wait to see hydrogen bubbles on the surface of the PEM (60 sec.). Release the power switch after 75 seconds. (Note: do not charge for more than 3 minutes)
- (3) Start discharge procedure: connect the motor fan to either of the two power outlets and measure the discharging current (I_d) every five minutes. Measure the discharging voltage (V_d) every five minutes using an additional digital multimeter. Allow the motor fan to run until it stops. Record the complete discharging time (t_d). (Note: always discharge the PEM completely before repeating the cycle)
- (4) Repeat (1)~(3) using solar panel instead of battery. Face the solar panel to the light when the fuel cell is charged.

5. Discussion

1. Briefly explain how PEM fuel cells work and specify their advantages and disadvantages.
2. Write the charge-discharge reactions of your experiment. Calculate the minimum voltage required for the reactions to take place.
3. Build the charge and discharge curves of the system.
4. Calculate the efficiency of the system (η).
5. Investigate the cost of different sources of energy: Grid, photovoltaic, solar-thermal energy. What is the total energy cost required to charge your reverse fuel cell using these different sources? Propose alternative solutions to bring down the costs of your reverse fuel cell. Would it be appropriate to use grid energy? Why?

NOTE: Make sure to report uncertainties in your data and calculations.