Review Of Proton Exchange Fuel Cell Using Mat lab Simulation

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Abstract--- In the near future some fuel cell systems could be an accessible and attractive alternative to conventional electricity generation and vehicle drives. fuel cell systems can be made in mw to kw capacities; hence a wide range of applications can be covered by this type of fuel cell. This is a major advantage of this type of fuel cell, because once the technology was developed it can be more or less easily scaled up or down for various applications. fuel cell has attracted a great deal of attention as a potential power source for automobile and stationary applications due to its low temperature of operation, high power density and high energy conversion efficiency. In this Paper Matlab-simulink of fuel cell stack used to analysed the phenomena occurring in fuel cell stack and the factor affect the efficiency of fuel cell stack.

Keywords: PEM Fuel Cell; Matlab-Simulink; Model

I. INTRODUCTION

A Fuel Cell is an electrochemical energy conversion device which converts the chemicals Hydrogen and Oxygen into water and in the process, it produces electricity.[6] In its simplest form, a single fuel cell consists of two electrodes - an anode and a cathode - with an electrolyte between them. At the anode, hydrogen reacts with a catalyst, creating a positively charged ion and a negatively charged electron. The proton then passes through the electrolyte, while the electron travels through a circuit, creating a current. At the cathode, oxygen reacts with the ion and electron, forming water and useful heat. This single cell generates about 0.7 volts, just about enough to power a single light bulb. When cells are stacked in series the output increases, resulting in fuel cells anywhere from several watts to multiple megawatts. There are many different types of Fuel Cells, each with their own unique operating characteristics.[1]

II. WORKING PRINCIPLE OF PEM FUEL CELL

PEM fuel cell consists of two electrodes - an anode and a cathode - with an electrolyte between them.

The Redox reaction occurring in the PEM fuel cell is given below:

At Anode : $2H_2 = 4H^+ + 4e$

At Cathode : $4H^+ + 4e^- + O_2 = 2H_2$

Net Equation : $2H_2 + O_2 = 2H_2O$

The redox reaction gives us heat, water and electrical energy. The quantity of electrical energy produced depends on the Gibbs free energy of the above reaction.

$$E_0 = -\Delta G / nf$$

G, n and F are constants so the voltage of a single PEM fuel cell can be calculated.

$$E_o = 1.229 \text{volts at STP}$$

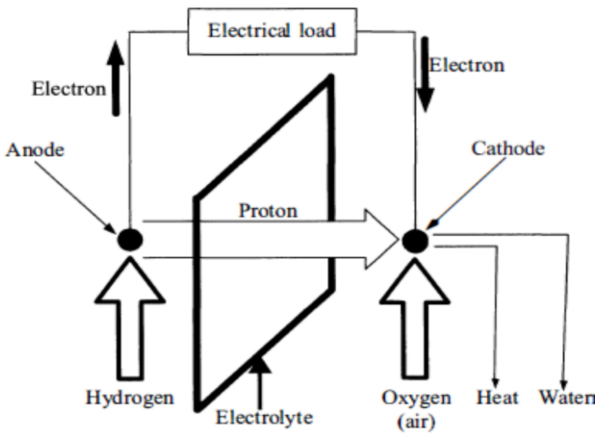

Fig. 1: Working Principle of PEM Fuel Cell

III. MATHEMATICAL MODEL

PEM fuel cell Modeling is very usefull in the development and improvement of any technology. Fuel cell modeling is important for the improvement of efficiency and cost of fuel cell technology. fuel cell able to improve efficiency.

Some important factors that affect the fuel cell performance must be included in any fuel cell model. The factors such as pressure, temperature, humidity, composition and flow rate of fuel and oxidants and number of cells in stack.

IV. MATLAB MODEL

Matlab model of PEM fuel cell stack has been suited in this paper.[7]

V. BASIC BLOCK DIAGRAM

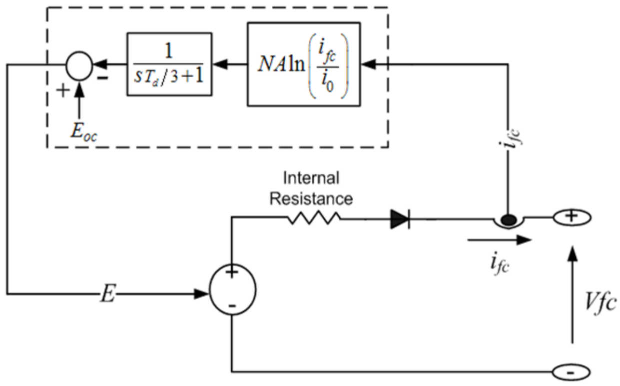

Fig. 2: Basic Model Of PEM Fuel Cell stack

In a simplified model, only current and voltage signals are available.The diode is used to prevent the reverse current into the stack.

A. Block A:

In Block (A) factors like fuel flow rate, Air flow rate, Partial Pressure of fuel, Partial pressure of air, Operating Temperature, Percentage of hydrogen in fuel, Percentage of oxygen in the air utilization are obtained .

B. Block B:

In Block (B) the open circuit voltage and current is obtained based on the fuel and air utilization from block (A).

C. Block C:

In Block (C) Tafel slop values are obtained by taking under consideration parameters like Charge transfer coefficient α, Gibbs free energy ΔG and reaction equilibrium constant (Kc).
Obtained from Polarization curve from Manufacturer datasheet moreover other parameters like low heating value efficiency of stack , temperature , pressure , composition of fuel and air.

VI. EQATIONS

1). Open circuit Voltage :

$$E_{0c} = K_c E_n \qquad (1)$$

2). Exchange Current:

$$i_0 = \frac{zfk(PH2+PO2)}{Rh} e^{\frac{\Delta G}{RT}} \qquad (2)$$

3). Tafel Slop**:**

$$A = \frac{RT}{Z\alpha F} \qquad (3)$$

4). Utilization of hydrogen (UfH2) and oxygen (UfO2) are determined in Block (A).
The fuel and air utilization in this section is based on Absolute values.

$$Uf_{H2} = \frac{60000RTNI_{fc}}{zFP_{fuel}V_{imp(fuel)}x\%} \qquad (4)$$

$$Uf_{o2} = \frac{60000RTNI_{fc}}{2zFP_{air}V_{imp(air)}\%} \qquad (5)$$

5). The partial pressure of oxygen, Hydrogen, water and the Nernst voltage is find as:
Partial pressure is the Pressure of specific gas in a mixture of gases in this model ideal gas is considered so Pressure of gas is the partial pressure.
Nernst voltage(En) is basically the cell voltage obtained from the standard cell voltage minus factors which effect standard cell voltage.
The values we get from the following equations for Partial Pressure and Nernst voltage calculation is used to calculate new values of open circuit voltage & Exchange current.

$$P_{H2} = (1 - Uf_{H2})\, x\% P_{fuel} \qquad (6)$$

$$P_{H2o} = (w + 2y\% U_{fo2}) P_{air} \qquad (7)$$

$$P_{O2} = (1 - Uf_{O2})\, y\% P_{air} \qquad (8)$$

$$E_n = 1.229 + (T - 298)\frac{(-44.43)}{zF} + \frac{RT}{zF}\ln (P_{H2})(P_{O2})^{\frac{1}{2}} \quad \text{when } T \le 100^0\text{c} \qquad (9)$$

$$E_n = 1.229 + (T - 298)\frac{(-44.43)}{zF} + \frac{RT}{zF}\ln \left(\frac{P_{H2}P_{O2}}{P_{H2o}}\right)^{\frac{1}{2}} \quad \text{when } T \ge 100^0\text{c} \qquad (10)$$

6). The nominal rate at which conversion of gases occurs calculated as follows**:**
Equation 11 and 12 are for calculation of, rate of utilization of fuel and oxidants.
Unlike Equation (4-5) Nominal values of current, voltage, partial pressure are used and percentage of Hydrogen in the fuel and Oxygen in the air is not considered.

$$Uf_{H2} = \frac{\eta_{nom\Delta h}(H_2o(gas))N}{zFV_{nom}} \qquad (11)$$

$$Uf_{O2} = \frac{60000RT_{nom}NI_{nom}}{2zFP_{Air(nom)}V_{imp(Air_{nom})}.0.21} \qquad (12)$$

7). Modified Nernst voltage:
For modeling the effects of oxygen depletion, Voltage undershoot (Vu) and peak utilization of oxygen is used, Due to which the Nernst voltage equation is also modified as follows :

$$E_n = E_n - K(Uf_{o2} - Uf_{o2}(nom))$$

$$E_n \quad Uf_{o2} > Uf_{O2}(nom) \qquad (13)$$

$$Uf_{o2} \le Uf_{O2}(nom)$$

$$K = \frac{V_u}{k_c(Uf_{O2(peak)} - Uf_{O2(nom)})} \qquad (14)$$

VII. SIMULATION ANALYSIS

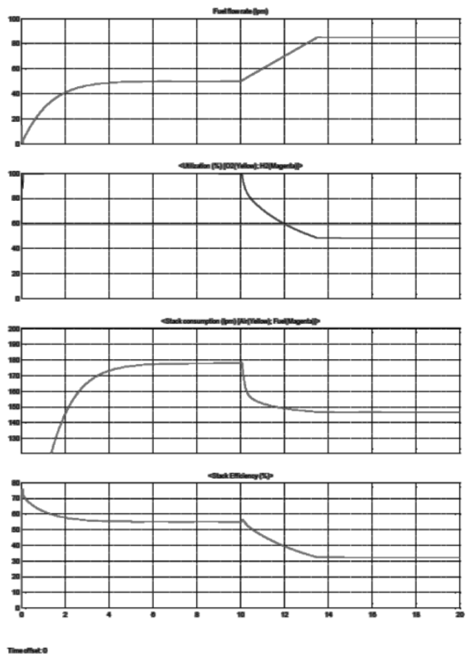

Fig. 3: Fuel flow rate, Hydrogen and oxygen utilization, fuel and air consumption, and efficiency Of PEM

The nominal Fuel Cell Stack voltage is 45Vdc and the nominal power is 6kW. The converter is loaded by an RL element of 6kW with a time constant of 1 sec. During the first 10 secs, the utilization of the hydrogen is constant to the nominal value (Uf_H2 = 99.56%) using a fuel flow rate regulator. After 10 secs, the flow rate regulator is bypassed and the rate of fuel is increased to the maximum value of 85 lpm in order to observe the variation in the stack voltage. That will affect the stack efficiency, the fuel consumption and the air consumption.

At t = 10 s, the fuel flow rate is increased from 50 liters per minute (lpm) to 85 lpm during 3.5 s reducing by doing so the hydrogen utilization. This causes an increasing of the Nerst voltage so the fuel cell current will decrease. Therefore the stack consumption and the efficiency will decrease.

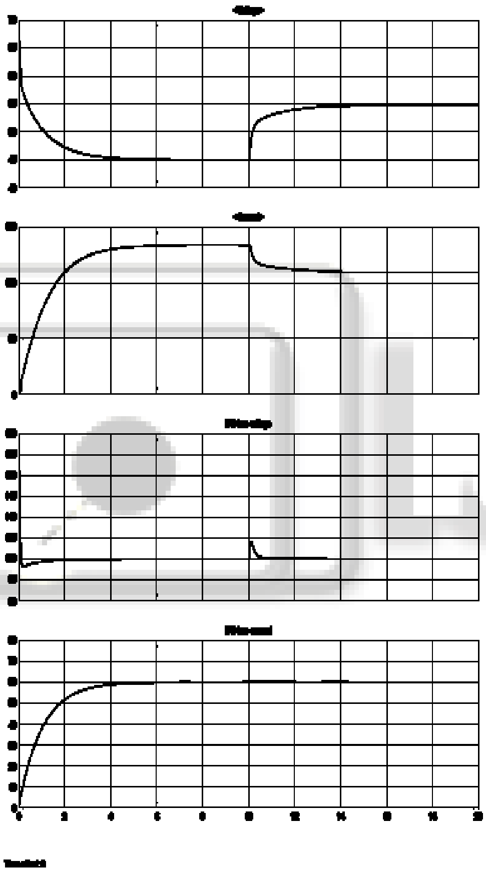

Fig. 4: Fuel cell voltage, current, DC/DC converter Voltage and DC/DC converter current signals

At t = 0 s, the DC/DC converter applies 100Vdc to the RL load (the initial current of the load is 0A). The fuel utilization is set to the nominal value of 99.56%. The current increases to the value of 133A. The flow rate is automatically set in order to maintain the nominal fuel utilization. Observe the DC bus voltage (Fig-4) which is very well regulated by the converter. The peak voltage of 122Vdc at the beginning of the simulation is caused by the transient state of the voltage regulator.

VIII. CONCLUSION

In this project MATLAB simulation of PEM Fuel cell has done. It is analysed different parameter such as Flow rate, utilization of fuel cell and air, stack consumption of air and fuel. This work will be further expanded by designing of vsc inverter with control strategy. then fuel cell will be integrated with utility grid. permits fault analysis with utility grid.

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