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Characteristics and Modeling of Pem Fuel Cell

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***Abstract*--A fuel cell is an electrochemical device that is used to create electricity. Different type of fuel cell are used in different application. One of the Proton Exchange Membrane (PEM) Fuel cells, one of the emerging technologies in distributed generation. The PEM fuel cell systems offer many potential benefits as a distributed generation system. This paper focuses on Simulation of proton exchange membrane fuel cells (PEMFCs).Polymer Electrolyte Membrane fuel cell (PEMFC) system to allow the development and improvement of electrical energy generation systems using this new technology**

***Index Terms*--modeling of PEMFC**

I. INTRODUCTION

A fuel cell is a device that can directly transfer chemical energy to electricity and heat. They are considered to be suitable for both small and large scale Distributed Generation (DG) and residential applications. A battery is another electrochemical device, but the difference between the two is the source of fuel. A battery stores fuel inside, so eventually the fuel runs out and the battery is dead. A fuel cell, on the other hand, has external fuel sources that can be continuously fed to the cell. Fuel cells, one of the emerging technologies in distributed generation. The fuel cell systems offer many potential benefits as a distributed generation system. They are small and modular and capital costs are relatively insensitive to scale. The systems are very low noise levels and have negligible air emissions. Fuel cells are an important technology for a potentially wide variety of applications including micro power, auxiliary power, transportation power, stationary power for buildings and central power. These applications will be in a large number of industries worldwide.

The FC uses hydrogen as input fuel and produces dc power at the output of the stack. The losses, which are also called polarization curve, irreversibility or overvoltage, originate primarily from three sources: a) activation polarization, b) ohmic polarization, and c) concentration (mass transport) polarization curve, which gives the relation between stack terminal voltage and load current, shown as in Fig.1. Fig.1that the cell voltage decreases almost linearly as the load current increases. Therefore, the output voltage should be regulated at a desired value. To keep the polarization characteristic at a constant level, parameters such as cell temperature, air pressure, oxygen partial pressure, and membrane humidity needs to be controlled Proton exchange membrane (PEM) fuel cells combine hydrogen and oxygen over a platinum catalyst to produce electrochemical energy with heat and water as the by products. This paper considers the Simulation of a PEMFC for residential use.

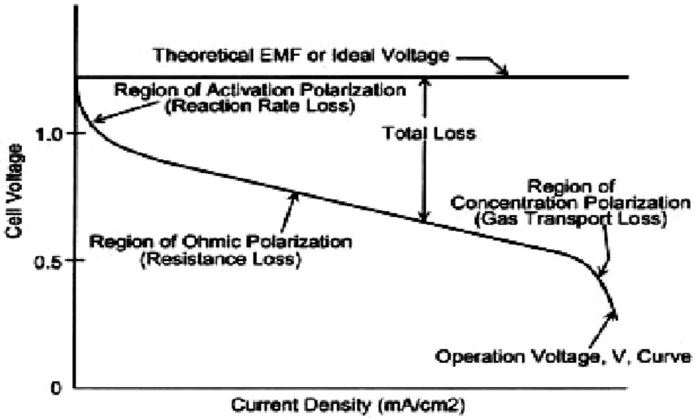

Figure 1 Cell Voltage Vs Current Dencity

II. POLARIZATION CHARACTRISTICS OF A PEM FUELL CELL

The performance of an FC is generally characterized by using the polarization curve, which is a plot of the FC voltage versus load current.(1)Activation losses(2)Ohmic losses(3)Mass transport/Concentration losses.

Activation Loss

These losses each have a different effect on the theoretical voltage of the fuel cell. Activation loss occurs because the chemical process initially has not begun, thus activation energy is necessary insure that the reaction tends toward the formation of water and electricity, as opposed to the reverse. This loss only occurs at low current densities in low temperature fuel cell.

These losses are basically representative of a loss overall voltage at the expense of forcing the reaction to completion, which is forcing the hydrogen to split into electrons and protons, and for the protons to travel though the electrolyte, and then combine with the oxygen and returning electrons.

The output voltage of a single cell can be defined as the result of the following expression

$$V_{FC} = E_{Nernst} - V_{act} - V_{ohmic} - V_{con} \qquad (1)$$

In the equation above, E_{Nernst} is the thermodynamic potential of the cell and it represents its reversible voltage; Vact is the voltage drop due to the activation of the anode and cathode (also known as activation overpotential), a measure of the voltage drop associated with the electrodes; Vohmic is the ohmic voltage drop (also known as ohmic overpotential), a measure of the ohmic voltage drop resulting from the resistances of the conduction of protons through the solid electrolyte and the electrons through its path; and Vcon represents the voltage drop resulting from the reduction in concentration of the reactants gases or, alternatively, from the transport of mass of oxygen and hydrogen (also known as concentration overpotential). There is another voltage drop associated to the internal currents and/or the fuel crossover. This voltage drop is considered in the model, using a fixed current density even at no-load operation..

Cell reversible voltage

The reversible voltage of the cell (E_{Nernst}) is the potential of the cell obtained in an open circuit thermodynamic balance (without load). In this model,E_{Nernst} is calculated starting from a modified version of the equation of Nernst, with an extra term to take into account changes in the temperature with respect to the standard reference temperature, 25^o C. This is given by

$$E_{Nernst} = \frac{\Delta G}{2F} + \frac{\Delta S}{2F}(T - T_{ref}) + \frac{RT}{2F}\left[ln(P_{H2}) + \frac{1}{2}\ln(P_{o2})\right] \quad (2)$$

where ΔG is the change in the free Gibbs energy (J/mol); F is the constant of Faraday (96.487 C); ΔS is the change of the entropy (J/mol); R is the universal constant of the gases (8.314 J/K.mol); while P_{H2} and P_{O2} are the partial pressures of hydrogen and oxygen (atm), respectively. It has to be noted that membrane temperature and gases partial pressures change with cell current: with increasing current, partial pressure of hydrogen or oxygen decreases, whereas temperature increases

Activation voltage drop

These losses each have a different effect on the theoretical voltage of the fuel cell. Activation loss occurs because the chemical process initially has not begun, thus activation energy is necessary insure that the reaction tends toward the formation of water and electricity, as opposed to the reverse. This loss only occurs at low current densities in low temperature fuel cell.

$$V_{activaction} = N_o(RT/2\alpha F)\ln\left(\frac{I_{dc}}{I_o}\right) \quad (3)$$

Ohmic voltage drop

The most common source of loss in any electrical device is also present in the fuel cell, and those are Ohmic losses. This type of loss occurs because of the resistance to the flow of electrons in the interconnect, the anode and the cathode. This loss, like all Ohmic losses, is directly proportional to the current. It appears as a major source of loss in both the low and high temperature fuel cells

$V_{ohmic} = I_{dc}R_{FC}$ is the resistive voltage loss due to the resistance of electrodes and connections and the resistance to proton flow in the PEM

Reduce Ohmic Resistance

Thus to reduce the value of the Ohmic resistance it is necessary to use electrodes with extremely high conductivities, or reducing the distance that the electrons must travel resistance is proportional to distance.

Another way to reduce the resistance is to use well-designed bipolar plates, which have high conductivities and short lengths.

III. SIMULATION RESULT

PEM Fuel cell Most of Dependent Number of cell ,Area of Cell ,Hydrogen pressure, Air pressure and Temperature And Faraday's constant, Ideal gas constant, Internal Resistance, Gibbs function in liquid form (J/mol) this notation used in above equation.

Parameter	Value
Ideal gas constant, R	8.314 J/molK
Faraday's Constant, F	96487 Columbs
Temperature, T_c	70'C
Hydrogen pressure, P_H2	1 atm
Air pressure, P_air	1 atm
Area of cell , A_cell	50.6 cm^2
Number of Cells , N_cells	90
Internal Resistance, r	0.245 Ohm-cm^2
Transfer coefficient, Alpha	0.4
Amplification constant , Alpha1	0.10
Exchange Current Density , i_o	$10^{-9.486}$
Limiting current density, i_l	1.5
Gibbs function , Gf_l_{iq}	-228170
Constant , k	1.1

Figure2 shows power vs current density graph at 70^o C temperature ,which shows that by increasing current density the output power of the fuel cell is increased and attains 2200 watt. upto some value of current density. After some time the value of power will be reduce as the current density increases

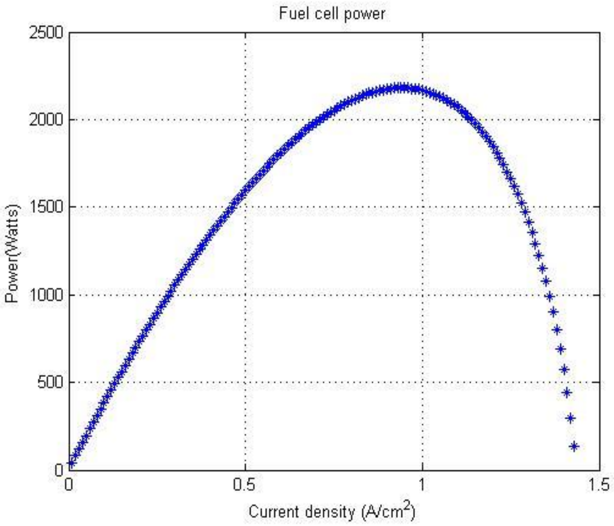

Figure 2 Power VS Current characteristics at Different Temperature of PEM Fuel Cell Model

Figure3 shows voltage vs current density graph, at 70° C temperature, which shows that by increasing current density the output voltage of the fuel cell is reduced.

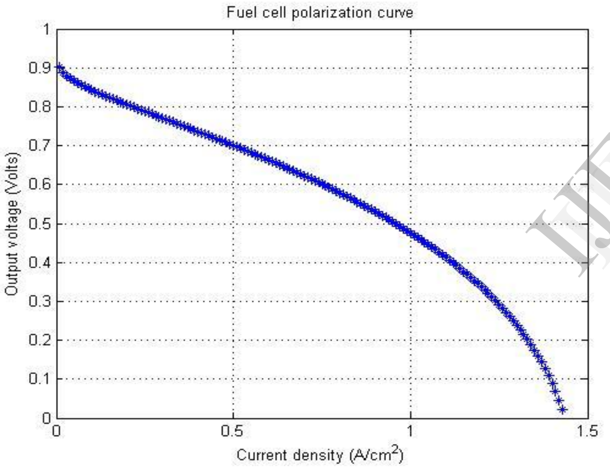

Figure 3 Voltage VS Current Characteristics of the PEM Fuel Cell model.

At tempratur 90° C,Figure4 shows power vs current density graph, which shows that by increasing current density the output power of the fuel cell is increased and attains 1950 watt. up to some value of current density. After some time the value of power will be reduce as the current density increases. By comparing figure2 and figure4 it is easy to analyze that by increasing a value of temperature the output power is decreses

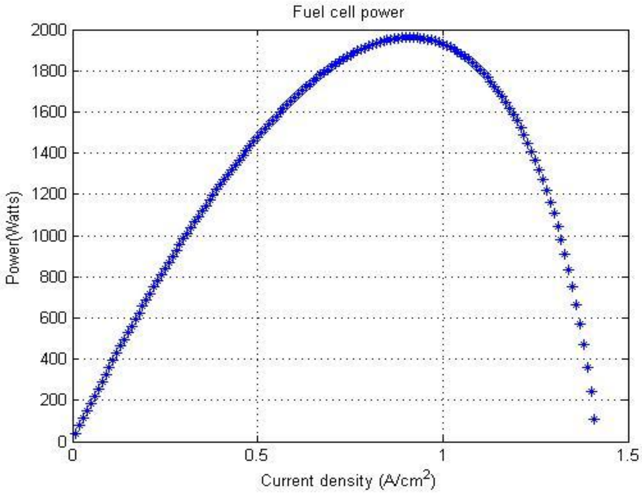

Figure 4 Power VS Current characteristics of the PEM fuel cell model**.**

Figure5 shows voltage vs current density graph, at 90° C temperature, which shows that by increasing current density the output voltage of the fuel cell is reduced

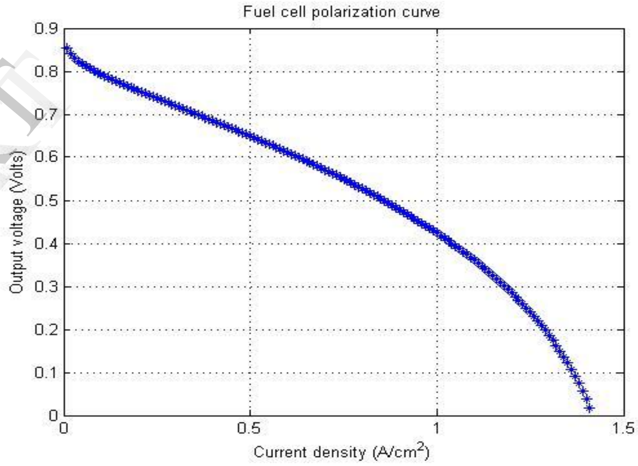

Figure 5 Voltage VS Current Characteristics of the PEM fuel cell model

As Shown in Figure6 and Figure7 the activation loss is depended on the value of temperature, by increasing the value of temperature activation loss increases.

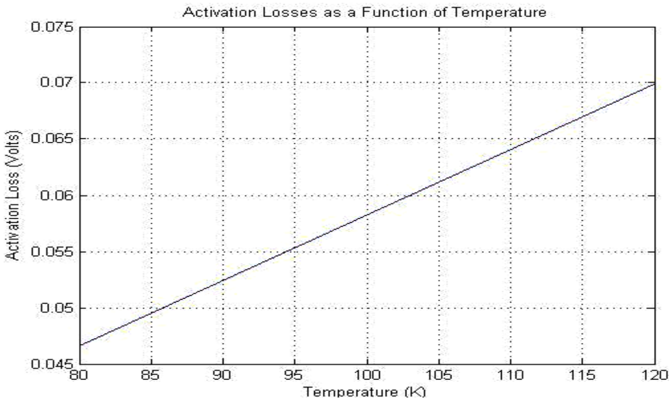

Figure 6 Activation losses as a function of Temperature

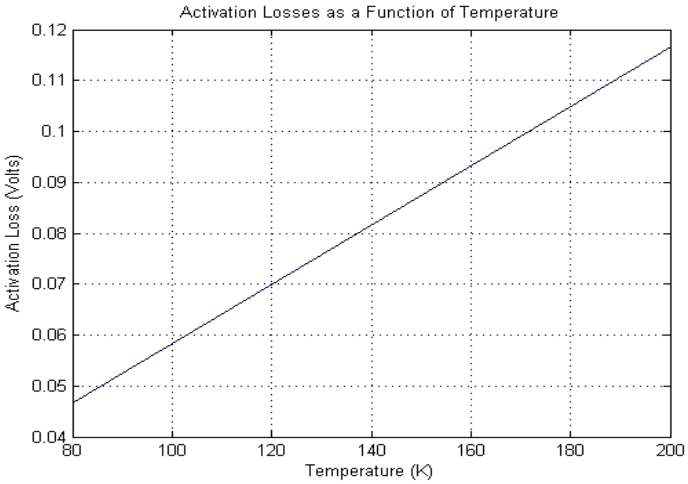

Figure 7 Activation losses as a function of Temperature

Figure8 show the relation between electrolyte thickness and ohmic loss by increasing the value electrolyte thickness ohmic loss increasing

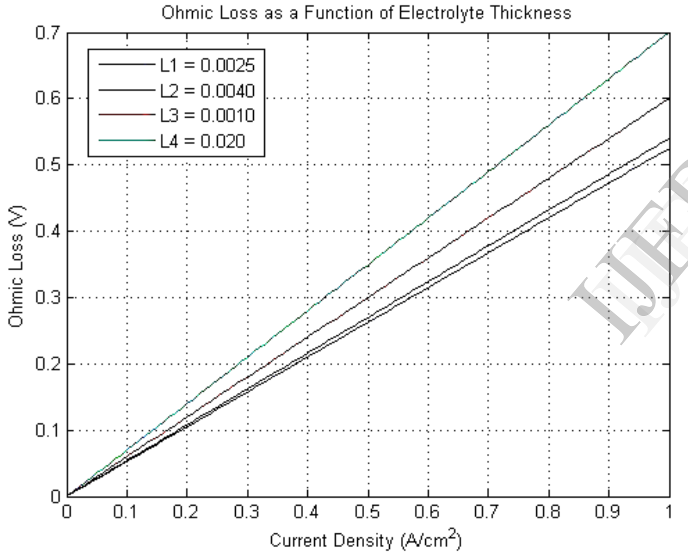

Figure 8 Ohmic loss as a function of electrolyte thickness

IV. CONCLUSION

In this Work, A Dynamic model of PEMFC has been implemented in MATLAB SIMULATION. voltage losses in the PEM fuel cell, mass balance and thermodynamic energy balance inside the PEM fuel cell, along with the formation of the charge double layer on the cathode in the PEM fuel cell are modeled. The model is then simulated for different values of input variables, and it is found that by operating the PEM fuel cell at higher values of input variables, voltage losses in the PEM fuel cell can be reduced.

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