

Simulation of pem fuel cell performance using matlab

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ABSTRACT

This paper presents the simulation of fuel cell performance using MATLAB. Firstly, a brief literature review about the fuel cell performance has been conducted. Then the analytical model adopted to describe the polarization curve and power curve has been discussed. Based on this model, a parameter analysis has been done, and it has been shown that three parameters of the cell polarization curve and power curve model can be simultaneously estimated, the current density, the voltage and the power for 2D simulation graph. Then, from the data 2D and the 3D simulation graph have been done by collected 2D data. The 2D simulation shows the maximum voltage, maximum power and maximum current is different. The polarization graph shows the current density increase voltage decrease while the power graph shows that the higher current density flows the higher power. Therefore, the simulation of performance curves can be generated using MATLAB.

Keywords - Fuel cell, polarization, current

INTRODUCTION

A fuel cell is one of the main sources in the future. Fuel cells are in high demand in every year because it has many benefits. The uses of fossil fuels provide many negative effects on humans and nature. Among the negative consequences such as pollution, a political control and domination countries that have a lot of resources.

There are varies type of fuel cells produced nowadays, they are proton exchange membrane fuel cells (PEM fuel cells or PEMFCs), alkaline fuel cells (FCS), phosphoric acid fuel cells (FCS), molten carbonate fuel cells (CFCs) and solid oxide fuel cells (SOFCs)⁽¹⁾. The famous fuel cell that has been used nowadays is polymer electrolyte membrane or proton exchange membrane (PEM) fuel cells resulting from hydrogen⁽¹⁾.

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A fuel cell is defined as an electrochemical device that could directly converts the chemical energy of the fuel and oxidant to electricity ⁽²⁾. Polarization in electrochemistry defined as a change in the equilibrium potential of an electrochemical reaction. The effect of polarization in the fuel cells can be classified into the effect of activation, ohmic and concentration polarization. The factors that affect the performance of the fuel cell and power known as loss of power ⁽³⁾. There are two types of power loss of electrical resistance between the electrodes or leakage resistance and mass diffusion between the anode and cathode ⁽³⁾.

This paper shows the simulation of PEM Fuel cell performance using MATLAB software able to produce the two dimensional graph and three dimensional graph.

RESEARCH METHODOLOGY

Mathematical Modeling

The simulation of PEM fuel cell performance using MATLAB can be represented by using mathematical modelling formula. The formulation of voltage losses represented as ⁽²⁾⁽⁴⁾ :

$$V(i) = V_{\text{rev}} - V_{\text{irrev}} \quad (1)$$

where V_{rev} is the maximum (reversible) voltage of fuel cell and V_{irrev} is the irreversible voltage loss (over potential) occurring in the cell. After that, the equation for the irreversible formula as ⁽²⁾:

$$V_{\text{irrev}} = V_{\text{act}} + V_{\text{ohmic}} + V_{\text{conc}} \quad (2)$$

where V_{act} is the activation potential, V_{ohmic} is the ohmic overpotential and V_{conc} is the concentration overpotential. The formulation for Saturation Pressure of Water as below ⁽²⁾ :

$$\log P_{H_0} = -2.179 + 0.02953 * T_c - 9.1837 \times 10^{-5} * T_c^2 + 1.4454 \times 10^{-7} * T_c^3 \quad (3)$$

where T is the cell operating temperature in °C.

Analysis of PEM Fuel Cell Performance

The analysis of fuel cell performance depends on the graph. The graph acquired from the simulation using MATLAB software. Before that, the suitable program must be selected correctly to acquire the graph.

The first step in creating the performance curve is calculation of the Nernst voltage and voltage losses using a suitable formula equation. The partial pressure of water, hydrogen and oxygen formula is used to calculate Nernst voltage.

The graph of the polarization curve is shown as graph of output voltage verses current density. However, the graphs for power curves as graph of output power verses current density.

From the calculation of the saturation pressure of water shown if the current is large, the cell voltage falls fairly rapidly due to various non equilibrium effects. The simplest of these effects is the voltage drop due to the internal resistance of the cell itself. According to Ohm's law, the voltage drop is equal to the resistance times the current flowing.

Parameter of PEM Fuel Cell

The model of fuel cell used is H-100 FCS-C100 100W. The parameter that considered for simulation is power, voltage and current density. From the datasheet, the parameter that can be used is the number of cell, rated power, rated performance, stack size and temperature. The parameters are used to calculate the area, current density and resistance.

Later, the data from calculation implemented in the 2D coding program and from the data of 2D simulation executed in MATLAB for 3D simulation using coding program.

There are two simulation graph for two dimensional, they are polarization graph and power graph. The data and analysis of 2D performance graph are shown by simulating using MATLAB software. Besides that, the graph show the relationship between hydrogen pressure and air pressure that can give effect to the performance of fuel cell. Then from the 2D graph data collected to produce 3D simulation graph.

Besides that, the three dimensional graph can produce the four 3D simulation graph. They are maximum power graph, maximum current graph, maximum voltage graph and efficiency graph.

RESULTS AND DISCUSSION

Two Dimensional (2D) Graph of PEM Fuel Cell Performance

The simulation in the MATLAB software produced the 2D graph. The simulation of 2D based on coding program which presented two graphs. The graphs presented in the simulation are polarization curve graph and power curve graph.

The polarization graph in Figure 1 shows that when the current density increases and the output voltage will decreases. It is because the voltage drops due to the internal resistance. When the current is increased to a point where the concentration at the surface falls to zero, a further increase in current is impossible. The current density corresponding to zero surface concentration is called the limiting current density.

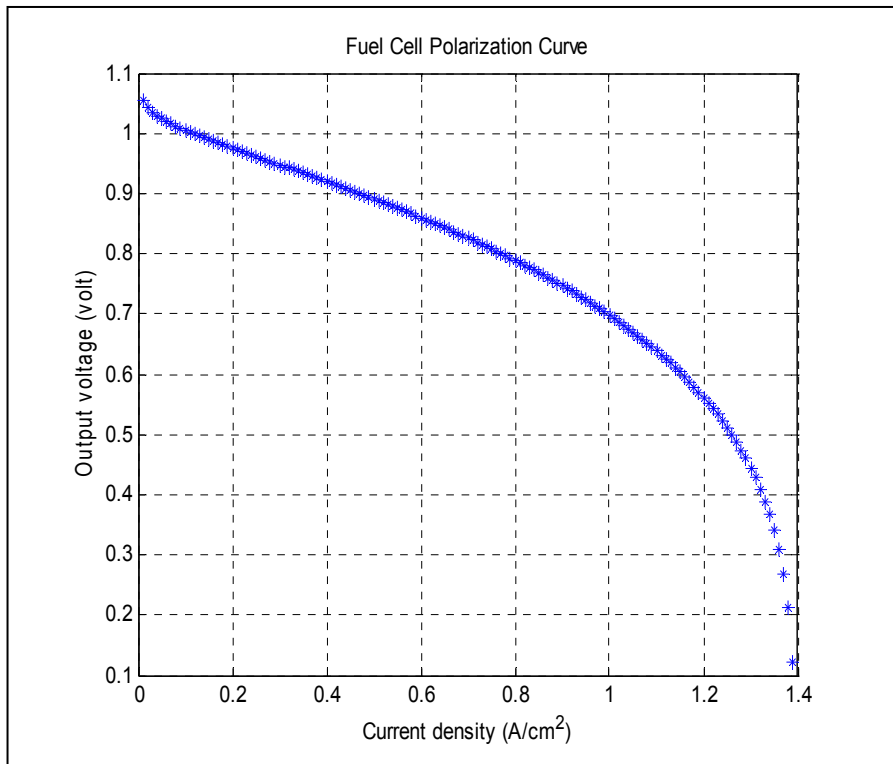


Figure 1: The polarization curve

Figure 2 shows a curve of power verses current density of fuel cell H-100 FCS-C100 100W for the temperature, hydrogen and air pressure are 80 °C, 3 atm and 3 atm, respectively. The maximum output power is 70.38 W at the current density of 1.07 A/cm². The power delivered by a fuel cell is the product of the current density and the cell voltage. It is because the size of the fuel cell is very important to describe the fuel cell performance. Specific power is defined as the ratio of the power generated by a cell to the mass of that cell.

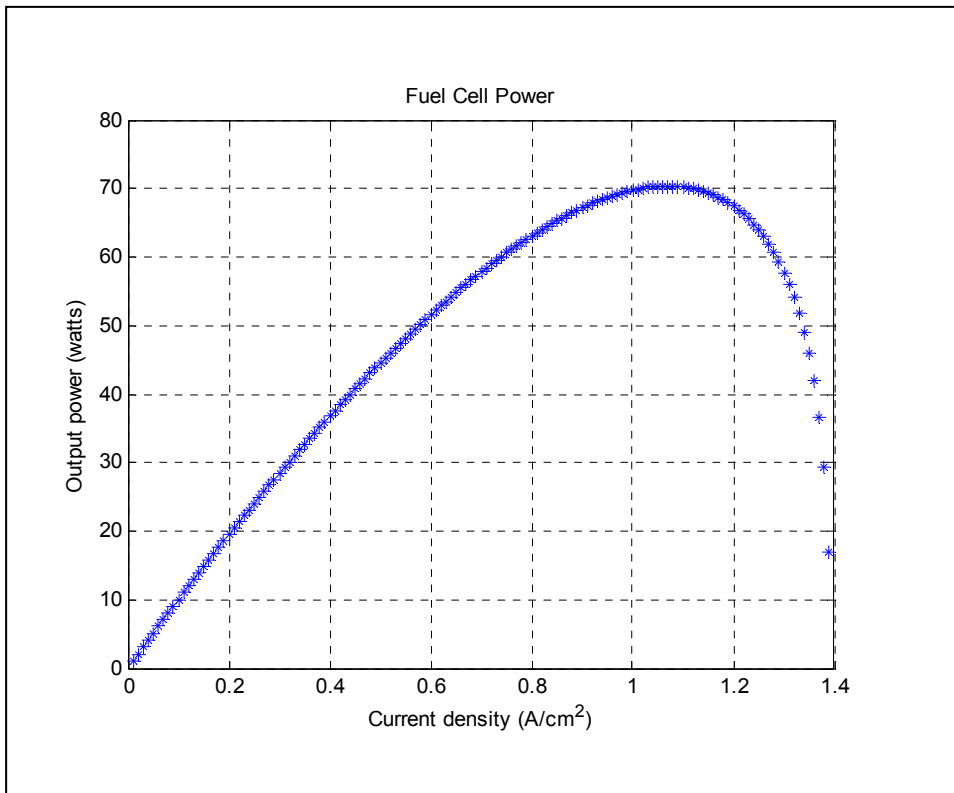


Figure 2: The power curve

Three Dimensional (3D) Graph of PEM Fuel Cell Performance

The hydrogen and air pressure affect the maximum power, maximum peak point current and maximum peak point voltage of fuel cell. They are shown in 3D simulation results as illustrated in Figure 3, 4 and 5. The resulting of 3D simulation depend on varied value of hydrogen pressure and air pressure. The value of voltage, power and current can determined by change the values of hydrogen pressure and air pressure.

The simulation in the MATLAB software produced the 2D graph. The graphs present in the simulation are polarization curve graph and power curve graph. The data of maximum voltage, maximum power and maximum current collected from the 2D simulation graph. The value of hydrogen pressure and air pressure is varying between 1 until 10 for hydrogen pressure and 10 until 100 for air pressure with cell number of 90 to produce the performance graph.

From the Figure 3, the 3D graph of the maximum power shows that when the value of air pressure and hydrogen increase, the maximum power will increase.

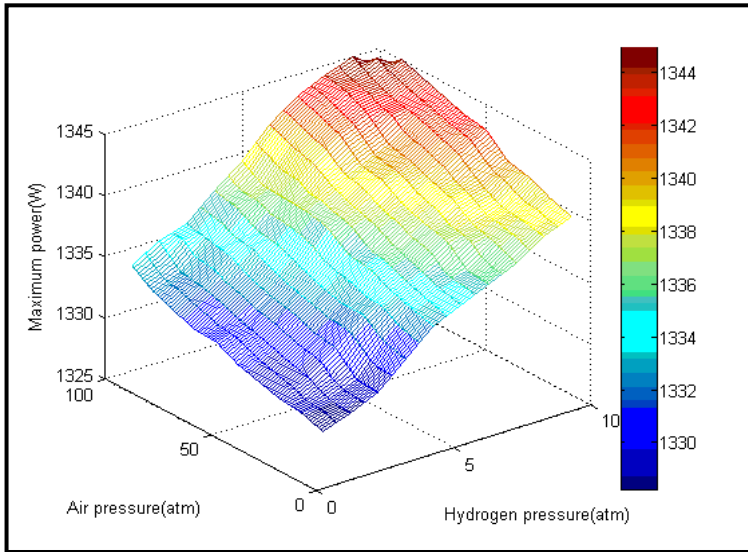


Figure 3: The 3D maximum power graph.

From the Figure 4, the 3D graph of the maximum current shows that when the value of air pressure and hydrogen increase, the maximum current will increase.

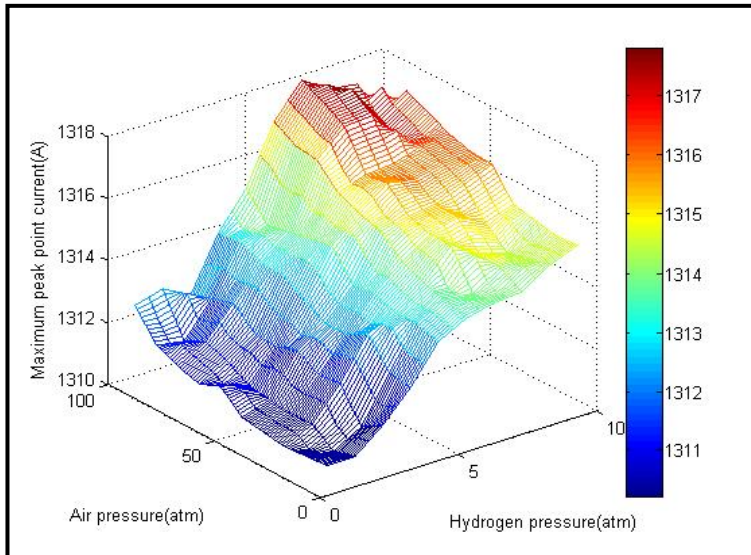


Figure 4: The 3D maximum current.

From the Figure 5, the 3D graph of the maximum voltage shows that when the value of air pressure and hydrogen increase, the maximum voltage will increase.

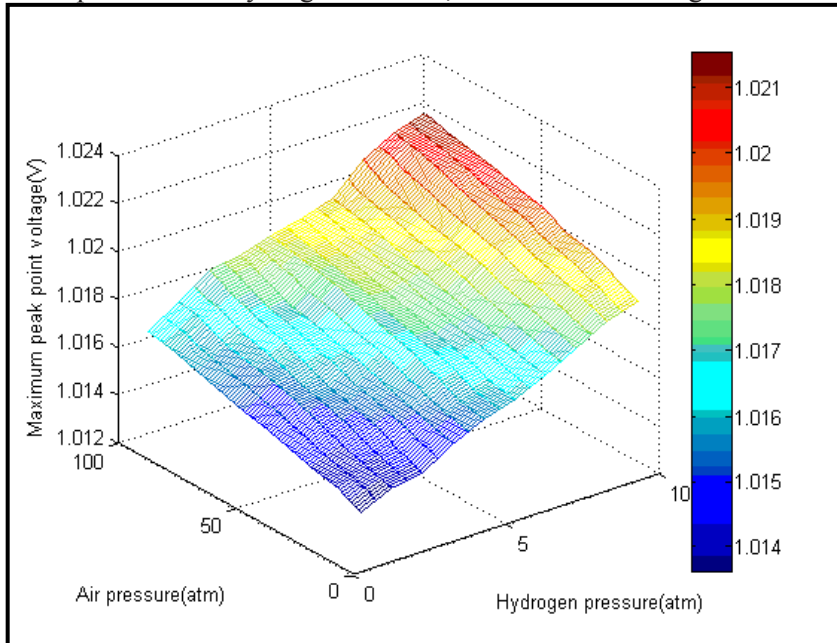


Figure 5: The 3D maximum voltage

CONCLUSIONS

The simulation using MATLAB software can produce the 2D graph and 3D graph of fuel cell performance. The 2D graphs are the fuel cell polarization graph (output voltage versus current density) and output power graph (output power versus current density). The graph show that the maximum power is as function of output voltage and current density, its achieved value indicates the specific maximum current and voltage. The 3D graphs indicate that the maximum power, maximum peak point current and voltage depend on the hydrogen and air pressure. If the hydrogen and air pressure are increased, thus the maximum power, maximum peak point current and voltage will be higher.

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