Development of Direct Methanol Fuel Cell and Improving the Efficiency

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Abstract: In this dissertation, the direct methanol fuel cell is proposed using an electrode change method to improve the performance of the fuel cell system and reduce the cost, size and weight of the power conversion system.The study proposes fundamental aspects regarding brief introduction to fuel cells and continues with a detailed description of the direct methanol fuel cell (DMFC). The basic DMFC operation principles and polarization characteristics are presented with a description of each of the components that comprise the membrane electrode assembly (MEA). The study also proposes a mathematical model is developed and implemented in MATLAB SIMULINK for a Direct Methanol Fuel cell (DMFC) system. The developed model is the integration of all possible dynamic equations, capturing the transients in the cell voltage, temperature of the cell, fuel, oxygen input/output flow rates and cathode, anode channel temperatures/pressures due to changes in load currents. The results indicate the suitability of the model in predicting the transient behavior of the molar flow rates, voltage and temperature.

Key words: Methanol · Fuel cell

INTRODUCTION

Fuel cells are chemical engines that convert chemical potential into electrical power. For optimal performance and design, accurate system modeling for prediction of performance as a function of the myriad of possible operating conditions and transients is needed, but such modeling requires an understanding of all relevant phenomena. Building on these modeling studies, a complete fuel cell level dynamic model capable of characterizing transient phenomena is proposed in this paper which incorporates simultaneously three prominent dynamic aspects, the temperature changes of fuel cell, fluid flow changes through channels and capacitor effect of charge double layers. The proposed model is implemented in MATLAB SIMULINK [1].

Objective: Develop alternative materials and components to optimize operating conditions of the direct methanol fuel cell (DMFC) to obtain maximum power density and improve fuel conversion efficiency at a minimum cost. In particular:

- Design and optimize membrane-electrode assemblies (MEAs) to enhance cell performance.
- Advance electrocatalysis of methanol oxidation and oxygen reduction to increase power density and lower total precious metal loading.
- Characterize and optimize non-Nafion polymers to reduce the crossover phenomenon and improve the fuel cell performance.
- Model, develop and demonstrate practical viability of advanced cell components.

Model Analysis and Simulation: The purpose of this work is to build a general transient model giving it flexibility in application to a wide range of operating conditions. The modeling approach is implemented using SIMULINK environment. The simulation results are analyzed and compared with benchmark results. There are three dynamic model included [2].

- InputI-stdy-ideal: ideal fuel cell load current in steady state (Simulation length: 4900s)
- InputI-stdy: real fuel cell load current in steady state (Simulation length: 3900s)

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- InputI-dynshrt4: real fuel cell load current in transient state (Simulation length: 2040s)

Real Fuel Cell Load Current in Transient State – Simulation: Model Input Quantities:

- Fuel cell load current (A), I
- Channel pressure at anode (atm), P_{anode}
- Channel pressure at cathode (atm), $P_{cathode}$
- Room temperature (K), T_{room}

- Initial temperature of FC (K), $T_{initial}$

Model Output Quantities:

- Output terminal voltage (V), V
- Output current (A), I_{out}
- Output Power (W), P_{out}
- FC temperature (K), T_{out}

Simulink block diagrams, which couple all these dynamic modeling equations, are shown in Figure.1 and Figure 2.
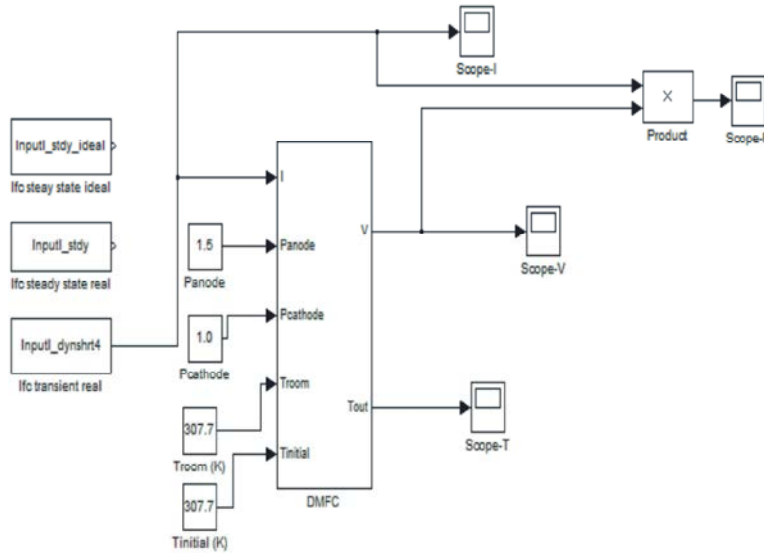

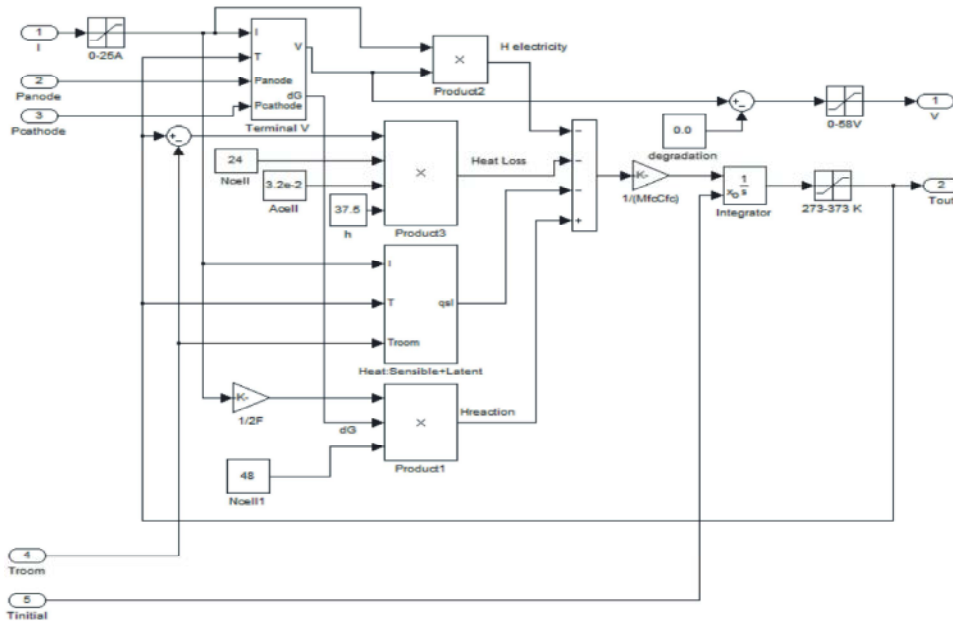Fig. 1: 500W DMFC Simulink Model In Matlab

Fig. 2: Fuelcell 500W stack model
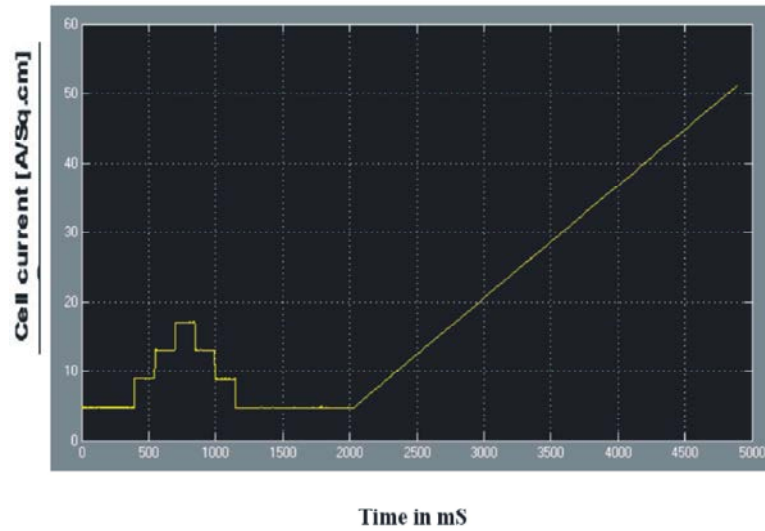
Stimulation Results:
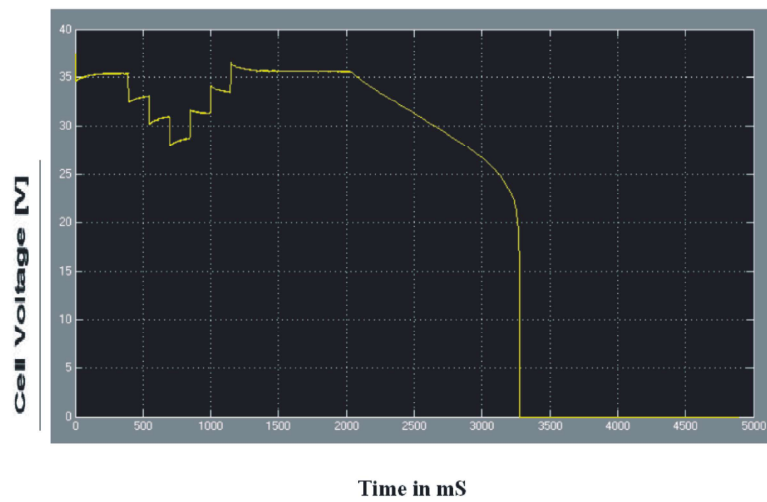

Fig. 3: Output Current Waveform
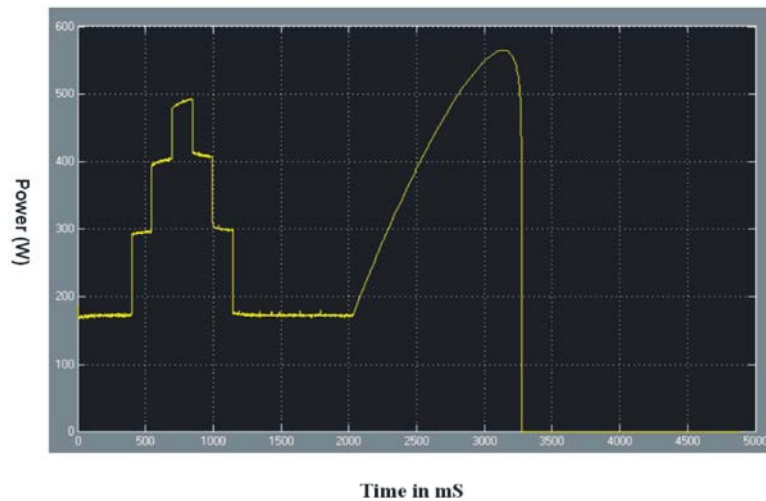

Fig. 4: Output Voltage Waveform
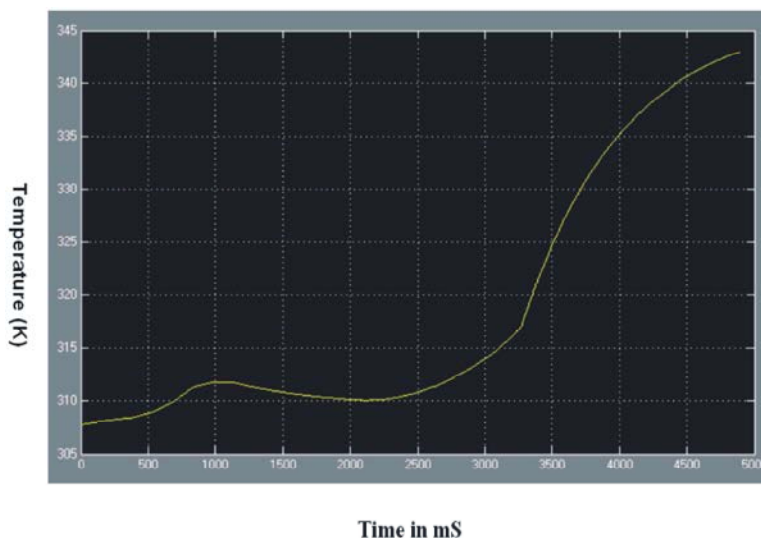

Fig. 5: Output Power Waveform

Fig. 6: Output Temperature waveform

It is found that all of the modules (subsystem level models) of this dynamic model are independent of each other, so components can be changed without rewriting the entire model. All the Figures shows the variation of voltage with time. These parameter values representing the effect of membrane humidity to the fuel cell voltage equations were obtained. A similar series of step changes in stack current results were obtained. The temperature variation in the overall system was also obtained. The results from the transient simulation are found in the nature of transient profiles of anode and cathode pressure variations [3-6].

CONCLUSIONS

It is widely recognized that fuel cells are becoming suitable for replacing common combustion processes in the near future. Direct methanol fuel cells have good potentialities for portable applications. Devices based on this technology eliminate the need of a complex reformer unit and avoids thermal and humidification problems (simplicity). However, one of the main drawbacks associated to the DMFC is the methanol crossover across the proton exchange membrane (where Nafion is commonly used) and the cost. The methanol crossover from the anode to the cathode decreases the fuel utilization efficiency and affects detrimentally the cathode performance. The present work gives a detailed study of DMFC and its components. The basic DMFC operation principles, thermodynamic background and polarization characteristics are represented with a description of each of the components. This study enables us to predict DMFC dynamic behavior under operating conditions, which lays down a foundation for optimization and control development.

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