Controller Implementation of a PEM Fuel Cell System

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INTRODUCTION

Widespread applications of FC technology including aviation, space, and automotive and stationary power production are available in US, Japan and Europe. In addition, FC technology represents an alternative and attractive approach for clean power production from an environmental standpoint [1]. However, such industrial advances in fuel cell technology are not yet widely utilized due to needed practical and cost effective solutions. Issues associated with water management, membrane longevity, and cost need to be addressed in order for the PEMFC to be seriously considered as a viable alternative to current carnot-cycle/heat engines. As a result, a lot of activity within the fuel cell community is centered on improving membrane and electrode materials, developing methods for managing product water levels and implementing novel controller techniques to reduce cost. Design and analysis of fuel cells involve the understanding of electrochemistry, thermodynamics, fluid flow and heat transfer, system dynamics, electronics and controls on both theoretical and experimental levels. The multi-dimensional coupling of PEMFC electrochemistry to reactant flow temperature and moisture conditions, to electric load, to supply pressure and back pressure, to membrane design and instantaneous conditions requires a system approach to design and analysis.

The membranes currently used in PEM fuel cells depend on the presence of water in electrolyte to facilitate proton transport. This includes perfluorinated membranes such as Nafion, Gore Select, etc. Since, the increase in the water quantity in the cell usually reduces the resistance to proton condition, there is a clear advantage to maintain the membrane in state of complete saturation. Such condition requires that either the gas in contact with the membrane is saturated with the water vapor, or that the membrane is in contact with liquid water. However, the present a high volume of water within the cell is not desirable, since the water can cover the surface of the electrocatalyst, blocking access for gases and water droplets in small passage can cause pressure fluctuations. As the result, water management has been a major concern to PEM fuel cell developers from the beginning of the technology. There are several available approaches for the control of the water quantity in a fuel cell stack, each with it's own advantages and disadvantages.

In this extended abstract, the implementation of a fuel cell controller is presented in order to optimize [2] the performance of the fuel cell. In general, most of the processes in engineering have to be controlled either in the open loop or the closed loop sense to provide an adequate and optimal performance of the system based on specification of the system.

VARIABLES IN THE CONTROL SYSTEM

The FC Laboratory at FAU [3] features a fully instrumented PEM Fuel Cell fabricated and supplied by several manufacturers. The available FC test station features significant and unique capability. Multi-pressure supplies of hydrogen and air/oxygen can be connected through a series of high speed solenoid valves to create pressure and/or oxygen-to-air ratio pulses [4]. In addition, the National Instrument's *Labview* which is our data acquisition can implement various control strategies through active control of a number of input parameters. This capability will be used in implementing several controllers in the near future. In this paper, various elements of a controller implementation are presented.

In general, the operation of the fuel cell is controlled via available variables measured by the sensors. The controllers are implemented at FAU Fuel Cell Laboratory in order to increase the efficiency and performance of PEM Fuel Cells. The variables were controlled using Labview computer software in conjunction with NI interface(A/D, D/A), and electronic circuits. Figure 1, shows the general black diagram of the input/ output variables..

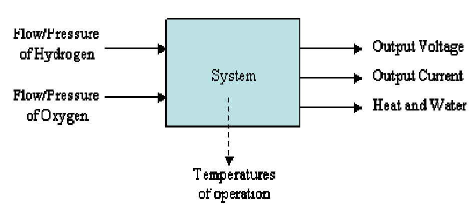

Figure 1. General structure if the input/output variables.

Performance characterization of a PEM fuel cell system can be analyzed by the shown Polarization curves (figure 2) [5]. The graph represents the cell voltage – current relationship (voltage versus current density, scaled by geometric electrode area) as well as the kinetic, ohmic, concentration and crossover potential losses for a fuel cell. The shown results are scalable between differently sized cells.

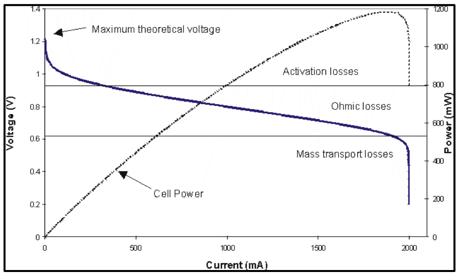

Figure 2. Example of polarization curve.

IMPLEMENTATION A FUEL CELL CONTROL SYSTEM

In this section, the major steps to construct a basic fuel cell control System are described. The first step is to install the parts of the system. Different elements that compound the physical system for the fuel cell include the followings:

1- Hydrogen and Oxygen Sources- Hydrogen and Oxygen are often provided to the fuel cell station by cylinders with variable valves to control the flow. The flow is automatically/ manually regulated by valves through a pipe by opening or closing its aperture.

2- Sensors and transducers - A board is built in the Lab to integrate all the sensors and transducers. In this board control valves, sensors for flow of Hydrogen and Oxygen, sensors for pressure of Hydrogen and Oxygen, sensors for temperature of Hydrogen and Oxygen are installed (figure 3). The signals are managed by transducers that operate with a physical input signal and electrical output signal. In this integrated board, it is necessary to install an electrical panel (or bus of connection) for the management of all electric output signals.

Figure 3. Sensors and transducers integration board (Fuel Cells Laboratory @ FAU)

3-Stainless Steel Pipelines- Hydrogen and Oxygen are transported to the main stack of PEMFC via the appropriate pipelines. The electrochemical reaction directed by Faraday's Laws. The general fuel cell reaction is as follow:

$$H_2 + \frac{1}{2} O_2 \rightarrow H_2O$$

The output signal (voltage generated by the stack) is connected to the connection bus (figure 4).

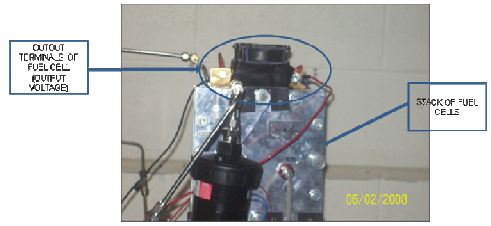

Figure 4. Output terminal for a fuel cell (Fuel Cells Laboratory @ FAU)

4- Electronic Connection- All signals from the sensors and transducers are connected to the central computer via interface devices.

5- Labview Software- Management of all signals as well as the implementation of the controller are carried out by the labview software. With this software tool, the monitoring task of voltage, pressure, temperature, flow and other signals can be achieved. In addition, the data can be utilized to design and implement the appropriate controller for the system.

Conclusions

In this extended abstract, the description of various parameters and variables to monitor the operation of a PEM fuel cell is presented. Furthermore, the controller implementation for the improvement of the performance of system efficiency is discussed.

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