REAL-TIME ESTIMATION, DIAGNOSTICS, AND OPTIMIZATION FOR FUEL CELL SYSTEMS

By

Judith E. O'Rourke

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: ELECTRICAL ENGINEERING

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

Dr. Murat Arcak, Thesis Adviser

Dr. B. Wayne Bequette, Thesis Adviser

Dr. Joe H. Chow, Member

Dr. Sheppard J. Salon, Member

Rensselaer Polytechnic Institute
Troy, New York

November 2008
(For Graduation December 2008)

ABSTRACT

Fuel cell systems provide an alternative power source that is both clean and efficient. They are suitable for a wide range of applications, from stationary power generation to portable electronics. As with all commercialization of products, huge efforts are made to reduce costs while improving and maintaining reliable efficient systems. In this research we aim to develop real-time estimators, diagnostic tools, and optimization methods to improve performance of fuel cell systems. Through experimental studies, we have defined electrochemical impedance spectroscopy (EIS) to be a powerful tool in the estimation of operating parameters, detecting membrane hydration conditions and as a performance optimization parameter for fuel cell systems. We present the equipment used during our research and demonstrate the fundamentals of electrochemical impedance spectroscopy with an 8 cell low temperature polymer electrolyte membrane fuel cell (PEMFC). Through experimental testing we show that the ac impedance measurements are highly sensitive to the air flow rates at varying current densities. We derive from experimental data and regression analysis a simple algebraic equation that estimates the air flow rate using impedance.

We propose and demonstrate the viability of extremum seeking algorithms to maximize net power by manipulating the air flow rate into the cathode of a fuel cell system. The advantage of using extremum seeking methods is that the algorithms do not rely on knowledge of system parameters, and adapt to changes in those parameters. We add several variants to the basic extremum seeking algorithms that include tapering the input, a penalty function for higher ohmic resistance, the ability to interrupt and restart optimization and an added manipulated input.

Our research includes a practical method of using EIS and voltage scan cards to detect fuel cell hydration faults. We propose using impedance measurements to reduce manufacturing variability during pressing of fuel cell membrane electrode assemblies.