314e Study of Dynamic Interactions of Various Phenomena in Proton Exchange Membrane Fuel Cells (Pemfc) Using Detailed Models for Multivariable Control

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Proton Exchange Membrane Fuel cells (PEMFC) are being developed, tested and benchmarked for both mobile and stationary applications. Many of the mobile applications for which PEMFC are used involve the operation of the device under varying load conditions. The PEMFC power response is however limited by airflow, heat, and water management. Hence there is a need to study and understand the dynamic control of fuel cells to deliver the required power at a specified voltage. This work addresses this issue through a study of a multivariable control strategy that explicitly addresses the water management problem. The basis for analysis of the control strategies is a new model for PEM fuel cells, where the reaction layer is characterized using a spherical flooded agglomerate geometry.

While the literature is replete with information on the various aspects of the PEMFC design such as the studies on the membrane properties and so on, very little is available on the transient load control of these systems under various operational modes. Single Input Single Output (SISO) control studies have been reported for PEM fuel cells. A key problem in PEM fuel cell operation and control is the management of water in the cell. The water balance plays a key role in both the efficiency and speed of response in these systems. This is because the conductivity of the proton in the membrane (and hence the ability to respond to various operational modes) depends on the membrane being well hydrated. Most of the models used in control fail to capture this local effect in the catalyst layer of the fuel cell. The catalyst layer is treated as ultra-thin, thus neglecting the transport of reactant gases and products. While such a simplification reduces the number of equations and complexity of the PEMFC model, these models will not be capable of predicting performance robbing local effects inside the reaction layer. In this work, dynamic studies based on a realistic model of PEM fuel cell will be presented.

Electrochemical systems differ significantly from conventional chemical systems. The response to the dynamic manipulation of voltage and current is much faster compared to the conventional manipulation of temperature or flow-rate in chemical systems (transport delays). Based on our earlier work on the dynamics of spherical agglomerate [1], we have shown that the agglomerate overpotential and dissolved concentration of oxygen inside the agglomerate equilibrate in time scales that differ by several orders of magnitude. In this work, the transient characteristics of various transport and electrochemical phenomena are studied in PEMFC cathode using its dynamic model. Interactions among the various phenomena and limiting mechanisms under various operating modes will be enumerated.

The key aspect of the proposed model is the detailed characterization of the reaction layer using a spherical flooded agglomerate geometry. This enables us to model the effect of conductivity variation with respect to hydration across the whole reaction layer. Due to the multivariable interactions resulting from the complex linkages between the transport and electrochemical phenomena, multivariable control is imperative for efficient fuel cell operation. Hence, a multivariable controller for PEM fuel cells that explicitly accounts for water management in its design is also proposed.

References

[1] R. M. Rao and R. Rengaswamy, “Dynamic Characteristics of Spherical Agglomerate for Study of Cathode Catalyst Layers in Proton Exchange Membrane Fuel Cells (PEMFC)”, to be submitted, Journal of Electrochem. Soc., 2005