314g Power Control of a Polymer Electrolyte Membrane Fuel Cell

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Polymer Electrolyte Membrane Fuel Cells (PEMFC) have been projected to be the fuel cell of choice for future automotive applications. Among the most challenging aspects of the transportation application is the occurrence of severe and frequent changes in power demand. Clealy, the first objective of this controller is to have the actual power follow the set-point with minimal delay. The second dimension of the power controller design objective is to obtain a wide range of power conditions. In particular, physical limitations of the fuel cell components suggest that maximum and minimum power conditions exist. Beyond these levels the system will fail to delver the requested power and in some cases may damage the device. As a third dimension to the PEMFC power control problem, we find the important issue of energy conversion efficiency. Since power delivery output will specify only a single degree of freedom in the fuel cell system's operating space, the remaining degrees of freedom can be used to improve efficiency throughout the operating power range.

The delivered power of the fuel cell is directly related to the amount of current being produced, which in turn affects numerous operating conditions. Conditions such as the species concentrations, cell temperature, and the relative humidity will complicate power regulation in a PEMFC by shifting the polarization curve. The available range of power is dependent on these operating conditions, mainly the cell temperature. At higher powers, the removal of heat is the primary challenge while keeping the cell ignited is the challenge at low temperatures. During nominal operation, cooling may be accomplished with the use of a fluid flow through a cooling jacket. However, as more heat is produced at higher powers, the additional heat removed by the cathode air flow will become paramount.

Proper humidification is critical to PEM fuel cell operation. On the one hand, water molecule escorts are required to achieve the desired proton permeability. However, if the membrane becomes too wet, then a flooding condition will form and thus block the mass transfer of oxygen molecules to the cathode. As a result it is concluded that active control of humidity levels is critical to the attainment of PEMFC operational objectives. Clearly, the amount of current being drawn will impact the hydration level, due to its relation to water generation at the cathode. The gas temperature will also impact the amount of moisture the cathode air can hold. Other conditions, such as pressure and cathode flow rate, will also effect the membrane hydration level. Thus, toward keeping track of the aggregate impact on membrane hydration levels we propose relative humidity as a key variable, and define a relative humidity operating window, between 80% and 100%, as a control objective.

Once it is assured that power demands will be met and the fuel cell will remain ignited, it is desired to keep the efficiency as high as possible. It can be shown that a high efficiency can be attained by keeping the voltage as high as possible. At a fixed power output, this is done by manipulation of the cell operating conditions, namely relative humidity. By keeping the relative humidity elevated, the efficiency will likewise be higher.

The proposed control structure aims to improve energy conversion efficiency while simultaneously extending the range of available power outputs. Toward power load tracking it is found that using current as the manipulated variable, rather than cathode channel flow rate will yield a faster response time. To ensure proper water management a relative humidity operating window is developed and enforced through manipulation of the cell operating temperature. This water management goal will also play a role in fuel cell efficiency. Finally, it is found that proper manipulation of the cathode flow will significantly extend the range of attainable power outputs.