A Statistical Approach to Diagnose Humidification-Related Failures for PEMFC

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Water management of fuel cell is a crucial issue. A proper hydration is essential for membrane to keep ionic conductivity. When the water removal rate exceeds the water generation rate, membrane drying out occurs. On the other side, excess of water may cause flooding, causing water flooding. Both the failures of water management will induce the degradation of the performance. Diagnosis of the water management failures is significant for the practical applications of fuel cells.

The water saturation (s), which shows the liquid water level inside the fuel cells, can be expressed as the function of the variables: pressure drop (ΔP), air flow rate (Q), temperature (T), inlet air humidity (H), load current (I). Since the function is dependent on the design of air flow field and series of parameters need to be estimated with high accuracy. A specific definition of critical value s between normal state and fault states by analytical means seems to be a complicated task. Statistical method principal component analysis (PCA) is an alternative solution for fault monitoring [1]. However, the conventional PCA assumes that the monitored system is operating in one normal state point, and the data must be normally distributed in this state. In practice, fuel cell is operating in a wide load range. Data in the multiply operating points may not follow a normal distribution. In addition, PCA can be inadequate to handle nonlinear problems, which exist in fuel cell system.

In order to overcome the shortages of the physical model and the conventional PCA, in this paper, we propose a novel statistical approach to detect water management failures. The approach is realized by combining Kernel Principal Component Analysis (KPCA) and Gaussian Mixture Model (GMM) [2]. Specifically, select ΔP, Q, T, H, and I as original variables for fault diagnosis. The data obtained in normal condition of a wide operating range are firstly projected to low-dimension feature space by KPCA. After that, GMM is adopted in feature space to approximate the distribution of the transformed data. To make use of the results of GMM, the overall Hotelling's T^2 statistic and Q statistic are used to determine the boundary of normal state. Additionally, the flooding and drying out can be distinguished by contribution plot [2].

Experiments were carried out over a 20-cell PEMFC stack to verify the proposed approach. Data in normal condition are used respectively for training the KPCA and GMM models, and compute the critical values between normal and fault states. Data in flooding process are used to test the trained model. From the results, it can be seen that the water management failures can be easily detected and discriminated by the approach.

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