Experimental investigation of performance degradation on an open cathode Proton Exchange Membrane Fuel Cell stored at sub-zero temperatures

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The Proton Exchange Membrane Fuel Cell (PEMFC) is one of the most developed fuel cell technology in recent years **[1]** while the durability of PEMFCs still remains as a main factor that restricts their commercialization at a larger scale **[2]**. This issue becomes even more challenging under difficult operational conditions, especially in regions with extreme cold winter or wet tropical climate. For example, a potential application of PEM fuel cell in cold regions is to power a high-altitude mountain refuge, where the connexion to the grid is impossible. Coupled with a solar panel and an electrolyzer, the fuel cell can fulfill the power need of the visitors.

As the fuel cell will often be at its resting state during severe winter when there is no visitors in the refuge, the experimental research on the degradation of PEM fuel cell under this condition is necessary. Furthermore, prognostic tools are also needed to predict the state of health and to estimate the Remaining Useful Lifetime (RUL) of fuel cells, in order to make the systems more reliable, and to maintain them more efficiently with reduced costs. The aim of this work is to present the first experimental results of an open cathode PEM fuel cell gone through negative temperatures.

As a certain number of researches **[3-5]** have shown evident performance losses of PEM fuel cells after suffering freezing-thaw cycles, some studies investigated the mechanisms of degradation within the PEM fuel cells structures at micro scale (~µm). Scanning Electron Microscope images show material damages at different locations of PEMFCs, especially at gas diffusion layer, catalyst layer and membrane levels. The principal cause of these damages are due to the remaining water produced by chemical reactions within the fuel cell. During the freezing state, the formation of ice from water could lead to irreversible degradations and reduce largely the remaining useful lifetime of PEM fuel cells.

In this work, a test bench has been designed in lab to characterize two identical open cathode PEMFCs, by performing polarization curve and Electrochemical Impedance Spectroscopy (EIS) of the fuel cells. After the first characterization, one of the fuel cell will undergo negative temperature cycles as low as -30°C for 20-day-long duration in a cold-room, and then will be characterized again in order to be compared to the other fuel cell which will be stored under normal environmental conditions.

With this comparison study, the influence of extreme negative temperatures on the performance of a typical open cathode PEM fuel cell will be observed, and raw experimental data for later prognosis will be gathered in order to predict the RUL.

As a perspective, an algorithm of prognosis based on Reservoir Computing (RC), which is a new paradigm of artificial neural networks will be tested with the experimental data.

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