World Academy of Science, Engineering and Technology
International Journal of Energy and Power Engineering
Vol:19, No:01, 2025

A Comparison of Direct Water Injection with Membrane Humidifier for Proton Exchange Membrane Fuel Cells Humification

Authors : Flavien Marteau, Pedro Affonso Nóbrega, Pascal Biwole, Nicolas Autrusson, Iona De Bievre, Christian Beauger

Abstract : Effective water management is essential for the optimal performance of fuel cells. For this reason, many vehicle systems use a membrane humidifier, a passive device that humidifies the air before the cathode inlet. Although they offer good performance, humidifiers are voluminous, costly, and fragile, hence the desire to find an alternative. Direct water injection could be an option, although this method lacks maturity. It consists of injecting liquid water as a spray in the dry heated air coming out from the compressor. This work focuses on the evaluation of direct water injection and its performance compared to the membrane humidifier selected as a reference. Two architectures were experimentally tested to humidify an industrial 2 kW short stack made up of 20 cells of 150 cm^2 each. For the reference architecture, the inlet air is humidified with a commercial membrane humidifier. For the direct water injection architecture, a pneumatic nozzle was selected to generate a fine spray in the air flow with a Sauter mean diameter of about 20 µm. Initial performance was compared over the entire range of current based on polarisation curves. Then, the influence of various parameters impacting water management was studied, such as the temperature, the gas stoichiometry, and the water injection flow rate. The experimental results obtained confirm the possibility of humidifying the fuel cell using direct water injection. This study, however shows the limits of this humidification method, the mean cell voltage being significantly lower in some operating conditions with direct water injection than with the membrane humidifier. The voltage drop reaches 30 mV per cell (4 %) at 1 A/cm^2 (1,8 bara, 80 °C) and increases in more demanding humidification conditions. It is noteworthy that the heat of compression available is not enough to evaporate all the injected liquid water in the case of DWI, resulting in a mix of liquid and vapour water entering the fuel cell, whereas only vapour is present with the humidifier. Variation of the injection flow rate shows that part of the injected water is useless for humidification and seems to cross channels without reaching the membrane. The stack was successfully humidified thanks to direct water injection. Nevertheless, our work shows that its implementation requires substantial adaptations and may reduce the fuel cell stack performance when compared to conventional membrane humidifiers, but opportunities for optimisation have been identified.

Keywords : cathode humidification, direct water injection, membrane humidifier, proton exchange membrane fuel cell
Conference Title : ICFCG 2025 : International Conference on Fuel Cells and Generators
Conference Location : Paris, France
Conference Dates : January 25-26, 2025