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Experimental Investigation of Integrated Power System of Dead-End Proton Exchange Membrane Fuel Cell H2/O2 Stack with Large Active Area and Internal Humidifier

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ABSTRACT: Proton exchange membrane fuel cells with a dead-ended anode and cathode can obtain high hydrogen and oxygen utilization by a comparatively simple system. Accumulation of the water in the anode and cathode channels can lead to local fuel starvation, which degrades the performance of fuel cell. In this paper, for the first time, a new design for proton exchange membrane fuel-cell stack is presented that can achieve higher fuel utilization without using fuel recirculation devices that consume parasitic power. Unified humidifier is another novelty that is applied for the first time. The basic concept of the design is to divide the anodic cells of a stack into two blocks by conducting the outlet gas of each stage to a separator and reentering to next stage, thereby constructing a multistage anode and cathode. In this design, higher gaseous flow rate is maintained at the outlet of the cells, even under dead-end conditions, and this results in a reduction of purge-gas emissions by hindering the accumulation of liquid water in the cells. The result shows that with this new design the dead-end mode has the same performance as open-end mode. All performance tests were carried out at an integrated power system.

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1. Introduction

Today, fuel cells have attracted much attention for their high performance, low temperature and fast start-up. Fuel cells are clean energy converters that convert energy stored in hydrogen and oxygen into electricity.

In some Proton Exchange Membrane Fuel Cells, (PEMFC) hydrogen is used as fuel and unused hydrogen is discharged into the environment along with other inert gases. To maximize efficiency and safety, it is essential to minimize the amount of hydrogen discharged into the environment.

The ratio of the amount of hydrogen consumed to the input hydrogen to the fuel cell is called the fuel consumption percentage. At the dead-end fuel cells, the fuel consumption percentage is approximately 100%, meaning that almost all hydrogen and oxygen input to the fuel cell participate in the electrochemical reaction. However, at the dead-end mode, it is possible that there will be fuel starvation at the end of the fuel cell, resulting in a decrease in voltage and cell performance [1-3]. The accumulation of water at the bottom of the anode and cathode channels is a major cause of local fuel starvation [3,4].

Hou et al. [5] experimentally investigated the dynamic parameters affecting hydrogen consumption under different electric load conditions and different purge parameters in a fuel cell developed by their group.

Chen et al. [6] analytically and empirically analyzed the anode side purge strategy based on the accumulation of nitrogen in a single fuel cell.

In this paper, a 5 kW PEMFC stack is designed, fabricated and assembled. Both the anode and cathode sides are dead-end and the performance of the flow-through and dead-end modes are compared.

2. Methodology

The anode and cathode cells are divided into two distinct stages, and with the idea that although the whole stack operates at the dead-end state, more than 87% of the cells have stoichiometry above 1 and are actually work in flow-through mode and only 13% of the cells have stoichiometry equal to 1. Internal manifolds have been used to distribute the reactants to the cells, reducing the volume of the system dramatically. Voltage fluctuations have been investigated when the anode, cathode, or both sides are in dead-end mode.

Fig. 1 shows schematic diagram of designed fuel cell stack with the stages of anode and cathode. The total number of cells in the stack is 16, with 13 cells in the first stage and 3 cells in the second stage. From left to right, the first to third cells are in the second stage of oxygen, and the fourth to sixteenth cells are in the first stage of oxygen. For hydrogen, the first to thirteenth cells are in the first stage and the fourteenth to sixteenth cells are in the second stage. The stoichiometry of the first stage is approximately 1.23, and the stoichiometry of the second stage is approximately 1.

After the activation process, the polarization curve and purge experiments were performed. These experiments were performed in an integrated power system as shown in Fig. 2.

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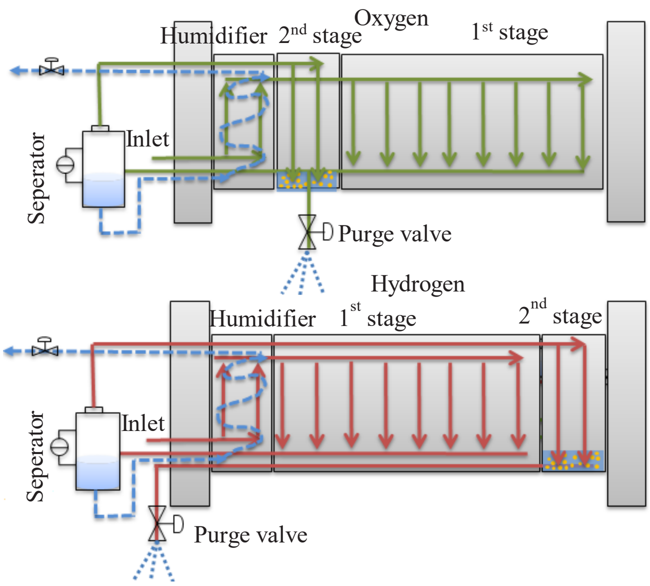

Fig. 1. Schematic digram of designed fuel cell stack

Fig. 2. Integrated power system for dead-end tests

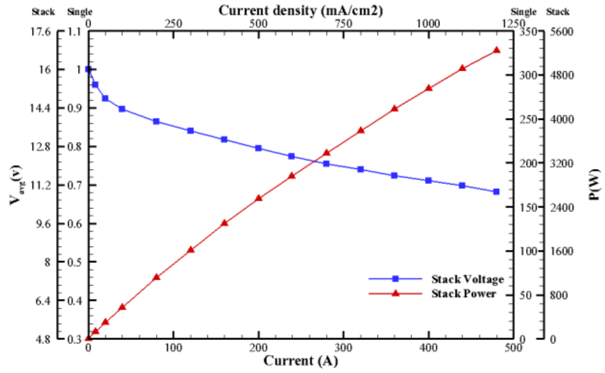

Fig. 3. Stack power and voltage curves

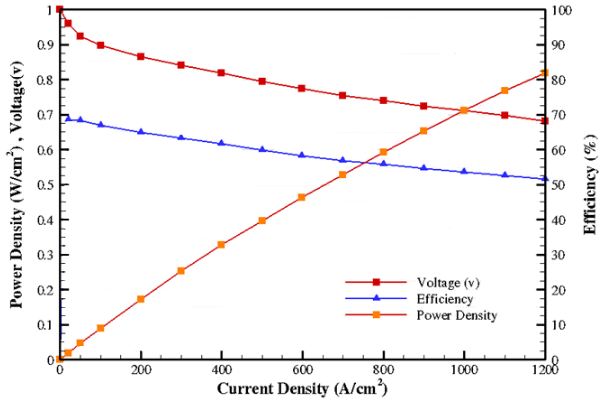

Fig. 4. Changes in efficiency, power density and voltage in terms of current density

3.Results and Discussion

Fig. 3 shows the polarization curve of the stack. The average power and voltage of each cell are also shown. The results show that by using integrated design and segmented stack, the fuel cell has been able to achieve the design objectives without reaching the limiting voltage range.

Fig. 4 shows the changes in efficiency, voltage and power density in terms of current density. The figure shows that by using this scheme, an efficiency of over 50% at a power density of 1000 mA/cm2 can be achieved.

4.Conclusion

In this paper, a stack of dead-end PEMFC with integrated humidifier and segmented design was tested after design, fabrication and assembly. All experiments were performed on a domestic testbench. After activation of MEA, fuel cell stack subjected to a variety of polarization and purge experiments. The results show that the cathode-side purge cells are highly sensitive to the purge conditions and there are severe voltage fluctuations. This indicates that the purge procedure should be different at the anode and cathode side and that the voltage-based method should be used for purge. The effect of voltage loss on cell performance was also investigated. The results show that by using the present scheme, an efficiency of over 50% can be achieved which is significant compared to other sources of power generation.

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