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# Performance improvement of PEMFC using Overcurrent Generator for internal humidification

*Jincheol Kim[1)] and Taegyu Kim[2)]

[1), 2)] *Department of Aerospace Engineering, Chosun University, Gwangju 501-759*
[1)] *taegyu@chosun.ac.kr*

## ABSTRACT

Drying of fuel cell MEA is caused by high electrical load for increasing power output, which degrades severely the fuel cell performance. In this paper, polymer electrolyte membrane fuel cell was humidified to improve the performance using overcurrent generator. The microprocessor was used to control external devices to maintain the performance of the fuel cell. In particular, the power MOSFET was used to generate the overcurrent through the cell. The fuel cell performance was evaluated at various conditions such as overcurrent intervals, and was compared with the reference case. Experiments were carried out at room temperature condition of 20% relative humidity. As a result, the maximum performance increased up to 13% by using the overcurrent generator.

## 1. INTRODUCTION

The use of fossil fuels shared human history with the development of civilization. The fossil fuels were used in various fields, but the biggest parts of fossil fuels were energy resource. Paradoxically, the exhaust gas by using fossil fuels was pointed as a source of global warming. The use of fossil fuels caused the sick of planet. So, various researches were proceeded to solve the eco-friendly and fossil fuels depletion problem. Many solutions are researched, but the fuel cell is the most realistic proposal. The fuel cell is the device that extracts electrical energy from chemical energy using chemical reaction of hydrogen and oxygen. (Larminie 2003) The fuel cell has simple structure but high efficiency, water and heat are the reaction result, which is very eco-friendly. Also, hydrogen which is main energy resource of fuel cell is abundant about 75% of the total mass of the universe. This will be an attractive alternative for oil depletion. Nowadays, fossil fuels were used to produce the hydrogen, in the near future, it will be changed using electrolysis through the renewable energy and it will be evolved into the perfect eco-system.

There are various kinds of the fuel cell including MCFC, SOFC, AFC, PAFC and

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[1)] Graduate Student
[2)] Professor

DMFC. Various types of fuel cells are being used in various fields. For example, the fuel cells are used as a main power source of large power plants and primary/ secondary power resource of ground and maritime transportation. In the field of aviation, most of researches are focused on a main power source of UAV. Especially, in Korea, KARI, KAIST and Chosun University have been studied on the fuel cell powered UAV using a hydrogen generator. (Kim 2007, Kim 2011, Kim 2012)

The fuel cell uses simple and efficient method to generate the electricity. Hydrogen in anode is divided into hydrogen ion and electron, and then through MEA hydrogen ion is combined with oxygen in cathode and finally produces water. (Zhan 2012) Controlling the inner humidity of fuel cell is very important problem because the water in the electrolyte of the fuel cell is core substance for ion transfer medium. The fuel cell performance is improved by high moisture content of the fuel cell electrolyte membrane. Conversely, the fuel cell performance is reduced with increase of internal resistance by drying of fuel cell MEA. However, too much water causes flooding effect so that water obstructs the entrance of gas diffusion layer and also decreased the fuel cell performance.

For this reason, the fuel cell system for common aircraft has used an external humidification device to control the internal humidity, but the total weight and volume of the fuel cell system were increased, which is one of disadvantages of aircraft system. The humidity controller without external humidification device that can allow adding the mission payload for aircraft was designed in the present study. The fuel cell internal humidity was controlled using overcurrent generator in order to improve the fuel cell performance. The overcurrent was generated using a control device where hydrogen from inside of fuel cell overly is reacted and the internal humidify of the fuel cell increased through the reactant water. Through this, the fuel cell will be expected to be improved on the performance.

## 2. Design and experiments

*2.1 The fuel cell control device configuration*

The fuel cell control system is configured as shown in Fig. 1. The current sensor for sensing the fuel cell current, power MOSFET for controlling the overcurrent generator, fuel cell auxiliary unit, purge valve for water discharge and cooling fan were included in the controller. A 128 bit MCU was used to control the overall fuel cell system. Control algorithm was developed to control the interval of the overcurrent generation and to manage the whole fuel cell system. Experiments were carried out to measure the fuel cell performance in various intervals of the overcurrent generation at 2, 10, and 60 sec.

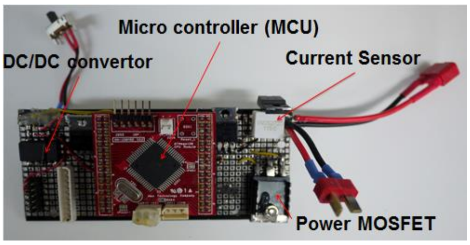


Fig. 1 Schematic of PEMFC system using overcurrent generator

*2.2 The performance evaluation of the fuel cell using overcurrent generator*

A 200W-class open cathode type PEMFC was selected to evaluate the fuel cell performance using the overcurrent generator. The oxygen was supplied from the atmospheric air for the open cathode type fuel cell. High purity hydrogen (≥99.999%) that was non-humidified was supplied from hydrogen tank to fuel cell through the regulator at constant pressure (0.6 bar). The hydrogen pressure was checked using a pressure sensor, and the hydrogen flow arte was measured using MFC. The performance curve of the fuel cell was obtained using electric load to check the change of the fuel cell performance. The experimental data of the fuel cell, such as temperature and open circuit voltage (OCV), were collected through NI's DAQ device.

## 3. Results

Fig. 3 shows the hydrogen consumption of the fuel cell with and without the overcurrent generation at the overcurrent interval of 2 sec. The hydrogen consumption was approximately 0.3L/min higher than normal operation condition. Base on this result, the correlation of the overcurrent control and hydrogen consumption could be inferred. Also, the moisture generation at the fuel cell cathode could be identified through the water discharged from the purge valve at high electrical load condition.

Fig. 4 shows the voltage drop of the fuel cell according to the interval of the overcurrent generation. The fuel cell voltage drop was increased with increasing the interval of the overcurrent generation. This was because the fuel cell was dried as the internal humidity decreased with increasing the interval, so that the voltage drop increased at high electric load condition due to the increase of the internal resistance. The voltage drop was constant at the current higher than 6A. The internal resistance was not increased because the moisture was generated due to the high electric load. A certain voltage drop interval was retracted at the longer interval of the overcurrent generation. It was considered that the fuel cell consumed more hydrogen due to the nature of the fuel cell at the high-load and thus the generated moisture humidified the inside of fuel cell MEA.

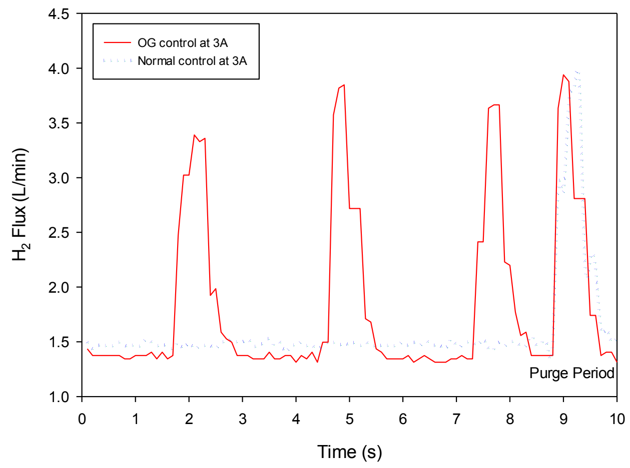


Fig. 2 Hydrogen consumption at 3A electric load

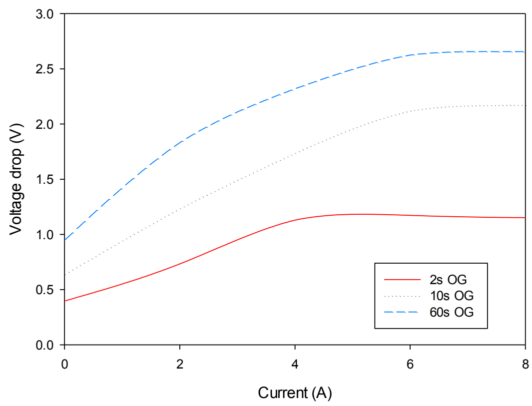

Fig. 3 Voltage drop of the fuel cell according to the interval of overcurrent generation

## 4. CONCLUSIONS

In the present study, the performance of fuel cell was improved at the short overcurrent generation interval. The performance improvement of the fuel cell system was identified by the hydrogen consumption according to generating the overcurrent. However, more fuel cell should be stacked to give the same output at the typical fuel cell systems, and this may cause the increase of the weight and volume for whole system. Thus, if the fuel cell system mounts the overcurrent generation controller, the high performance will be the advantages compared with the same weight and volume of the fuel cell system. Through this experiment result, optimization experiments to improve the fuel cell performance will be performed according to the control overcurrent generation interval and auxiliary devices.

## ACKNOWLEDGEMENTS

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