CONTROL SYSTEM AND PURGING EFFECTS OF SINGLE PERSON OPERATED FUEL CELL VEHICLE WITH 1kW FUEL CELLS (micro FCV)

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1. Introduction

We have developed a single person operated small fuel cell vehicle which uses 1 kW fuel cells. The hydrogen used for the fuel cells is produced by a water electrolysis hydrogen generator using solar powered energy sources. The advantage of using solar powered energy sources is that it produces power without requiring use of fossil fuels. This paper presents the measurements, the control system, and finally the experimental results of the purging effects of the fuel cells.

Most of the observed increases in global average temperatures are very likely correlated with the rise in anthropogenic greenhouse gas concentrations in the Earth's atmosphere. One of the primary contributors to the emission of these gases is fossil fuel combustion. Thereafter, a vehicle using the internal combustion engine must be replaced with more ecological system in order to reduce greenhouse gas (e.g., carbon dioxide) emissions. As a result, fuel cell electrical vehicles (FCV) are becoming one promising technologies for reducing the carbon dioxide emissions. Several large automobile enterprises and research institutes are developing fuel cell electrical vehicles [1-6]. As they are researching high powered fuel cells in the 100 kW class, the cost of these vehicles may be prohibitive for some consumers. It is essential, thereafter, to reduce the cost of fuel cell vehicles. The purpose of our research is to develop a low cost fuel cell vehicle using a low powered fuel cell. Taiwan University developed a small fuel cell scooter with two wheels [7]. The developed fuel cell scooter is permitted to run on a public roads despite its use of a small fuel cell in the 2 kW class.

Our aim is to develop a small fuel cell vehicle using four wheels which will be permitted to operate on a public road. We have already developed fuel cell vehicles for Japanese light weight electrical vehicle competitions. The designed systems were single person operated vehicles with fuel cells of rated power 200 W [8] and 20 W [9, 10]. We have been also developing a hybrid wheelchair which utilizes a photovoltaic and a fuel cell [11-13]. We have now started to develop a micro car class fuel cell vehicle which will use a 1 kW fuel cell (named the micro FCV). The micro FCV is a single person ride vehicle which will be permitted to operate on a public road. The micro FCV uses a fuel cell when operating a flat road at constant speed, however uses a battery when it accelerates or climbs a steep slope. We have improved a purchased micro car class electrical vehicle to develop our micro FCV. This paper will explain the control system designs and the experimental results of the purging effects of the developed small single person operated fuel cell vehicle.

2. The Concept of micro FCV

We have developed a single-person operated small fuel cell vehicle, which we call the micro FCV, which uses 1 kW Fuel cells. Fig.1 shows the developed micro FCV. A purchased micro car with a 600 W motor was reinforced and used as the base mechanism to develop our vehicle. Fig.2 shows the hardware system of the micro FCV. Fig.3 shows the electric system configuration. A brush DC motor of rated output of 500W and a CURTIS motor controller are used. A driver is able to select between a foot or hand accelerator with a selector switch.

The micro FCV uses the fuel cells of rated power of 1kW. The temperture and the humidity of the fuel cells are measured with the fabricated thermometer and hygrometer. The fuel cell voltage changes from 36V to 69V depending on the driving load. The changed fuel cell voltage is converted to 48 V in order to send to a motor controller. Six 200 W DC/DC converters were connected in parallel to obtain a 1200 W capacity. The converted electicity is supplied to the motor controller. Four 12V, 24Ah batteries are connected in series, and used as the power source. One of these batteries is used as the power supply to the hydrogen mass flow meter and the cooling fans of the fuel cells.

The voltage and the current of the batteries and the fuel cells are measured at the input side of the motor controller. A speedmeter was fabricted using the pulses from magnetic sensors. A measurement and control system to include the functions of the themometer, the hygrometer, the speedmeter, the purge controller and the voltage and current sensor is fabricated. A 12V, 3Ah battery is used to power the measurement and control. The voltage of the battery is converted to 5V through a DC/DC converter.

Fig. 1: Photographs of developed micro FCV

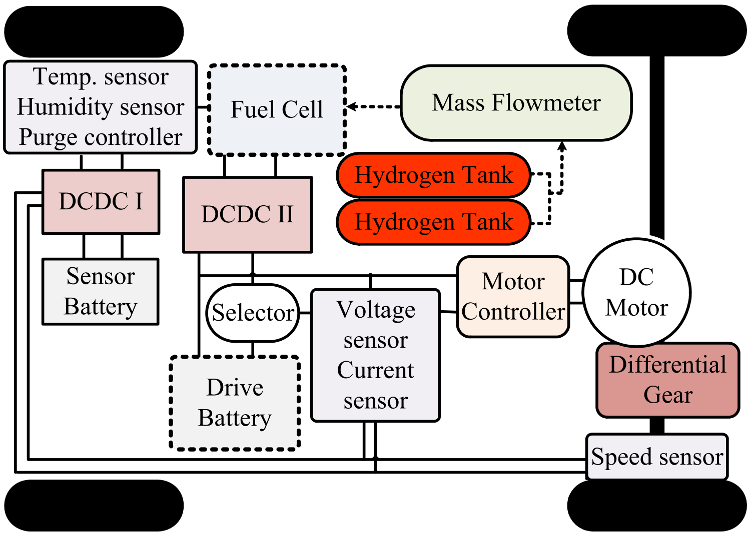

Fig. 2: Hardware system of micro FCV

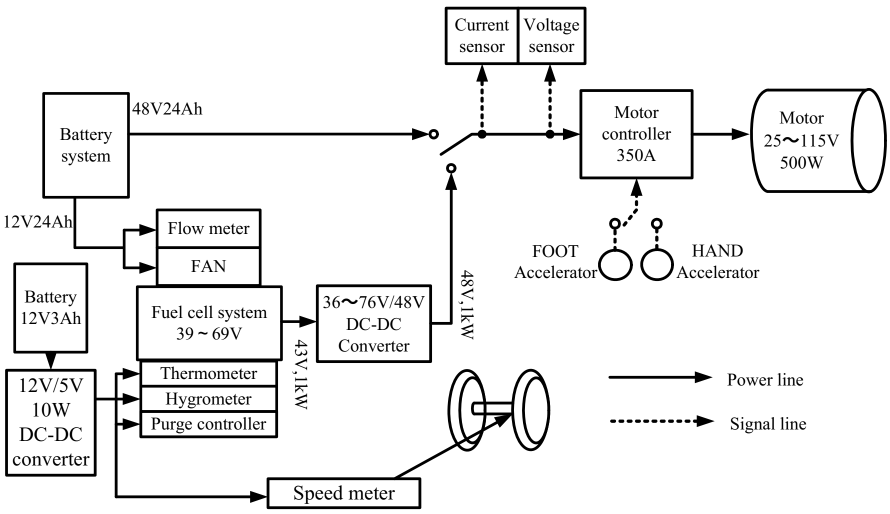

Fig. 3: Electric system configuration

3. Measurement and Control System

Fig.4 shows the developed measurement and control system. The LCD displays the temperature, the humidity, and the speed. The temperature sensor is able to read between 0 and 100 (º C). The humidity sensor is able to read between 5 and 100 %. The speed sensor is able to read between 0 and 60 km/h. The purge controller for the fuel cells was fabricated. The purge timing may be set from 1 to 30 minutes, and is displayed on an LCD. A manual purge button was also designed in order to allow the driver to manually purge the fuel cells. Wattage is calculated from the voltage and the current and displayed on the LCD. The voltage is able to be read between 0 and 70V, and current is measured from 0 to 50A.

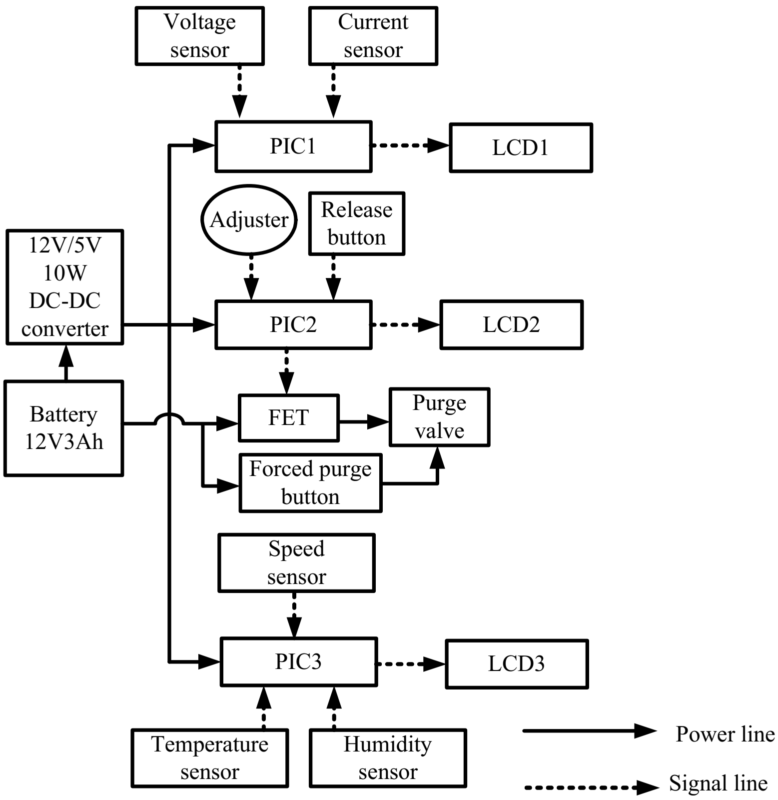

Fig. 4: Measurement and control system

4. Experiments on the Developed Sensors

Experiments on the accuracies of the developed sensors was conducted.

4.1. Thermometer and Hygrometer

The developed thermometer and hygrometer were compared with purchased sensors. The experiments were conducted at 20.2 (º C), 34.1% RH. The data were acquired every 5 minutes. Fig.5 shows the experimental results of the thermometer and hygrometer. We confirmed the maximum errors were 0.7 (ºC) and 6.8%, and the minimum errors were 0.1 (ºC) and 4.8%. As the maximum error of the thermometer was 0.7 (ºC), the permissible temperature of the fuel cells is 65 (ºC), the temperature sensor is not able to read the temperature inside the fuel cells, and the experiments were conducted under 45 (ºC), we determined the maximum error of 0.7 (ºC) to be negligible.

4.2. Voltage and Current Sensors

The accuracy of the developed voltage and current sensors are determined by using a stabilized power supply and an electronic load. Experiments were conducted in the ranges of 40 to 52 V and 0 to 25 A which are our expected ranges while the vehicle is driven. Fig.6 shows the experimental results of the voltage and current sensors. The experimental results show that the maximum errors were 0.3 V and 0.2 A, and the minimum errors were 0V and 0A.

4.3. Speedmeter

We confirmed the accuracy of the speedmeter by calculating vehicle speed from tire rotation frequency. Speeds of 10, 20, 30 and 60km/h were measured. Fig.7 shows the experimental results of the speedmeter. The experimental results show that the maximum error was 0.5km/h, and the minimum error was 0km/h.

4.4. Purge Controller

The accuracy of the timing of the developed purge controller was observed at 1, 5, 10, 20 and 30 minutes. Fig.8 shows the experimental results of the purge controller timing. The experimental results show that the maximum and minimum errors were 6 and 1 seconds respectively.

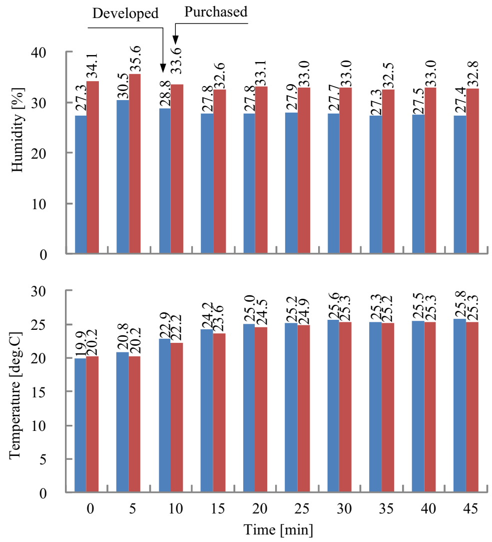

Fig. 5: Experimental results of thermometer and hygrometer

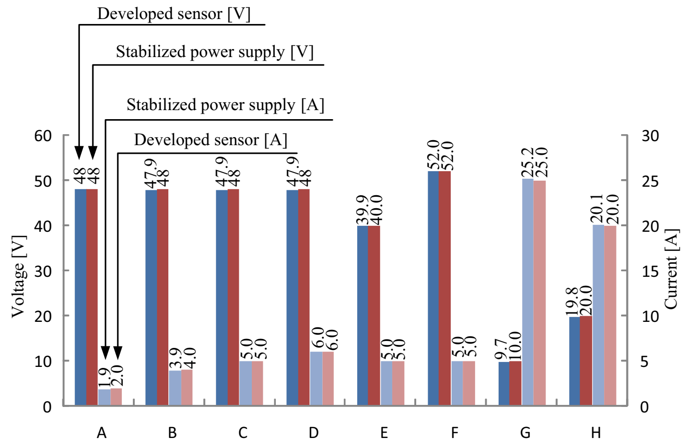

Fig. 6: Experimental results of voltage and current sensor

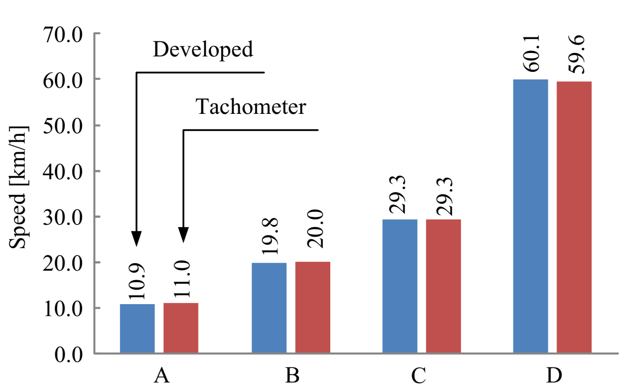

Fig. 7: Experimental results of speed meter

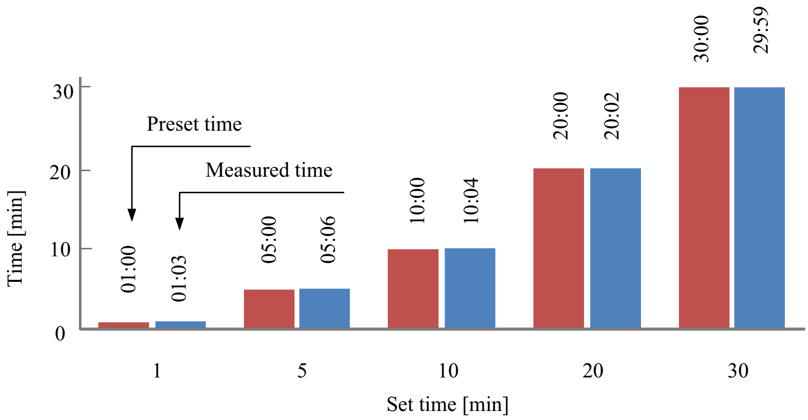

Fig. 8: Experimental results of purge controller

5. Experiments on Purging Effects of Fuel Cells

Experiments on the purging effects of the fuel cells were conducted. Three experimental conditions at 200, 400 and 600W were conducted. The fuel cells are loaded the time interval of 30 min. The enough fuel cell purging is conducted at each wattage change. The voltage was then checked again after purging. The room temperature and the humidity were 20.8 (ºC) and 27.3% RH at the 400W loading condition, 19.4 (ºC) and 38.2% RH at 200W, and 600W loading conditions.

Figs.9, 10 and 11 show the experimental results. The voltage dropped from 47.38 V to 46.20 V, and then recovered to 46.37 V after purging at 200W. The voltage dropped 43.76 V to 42.03 V, and then recovered to 42.31 V after purging at 400W. The voltage dropped 41.93 V to 40.32 V, and then recovered to 40.75 V after purging at 600W. The purging effects recovered 0.17V at 200W, 0.28V at 400W, and 0.45V at 600W. At higher wattage, the recovery was also greater since a larger amount of hydrogen was used meaning more gas was purged.

Next, voltage fluctuations over a long time interval were observed at the 600W loading condition. The experiments were conducted at 18.2 (ºC) and 36.3% RH. Fig.12 shows the fluctuation voltage and current of the fuel cells at 600W. The purging effects were 0.48V at the first time, 0.49V at the second time. Voltage recovery over a longer interval was confirmed.

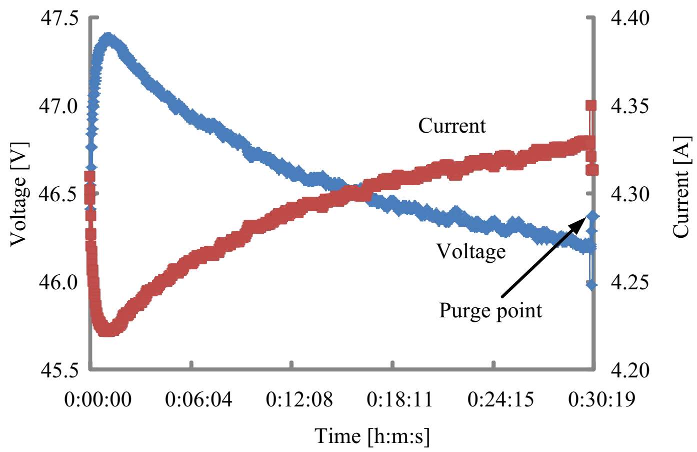

Fig. 9: Relations between voltage and current at 200W

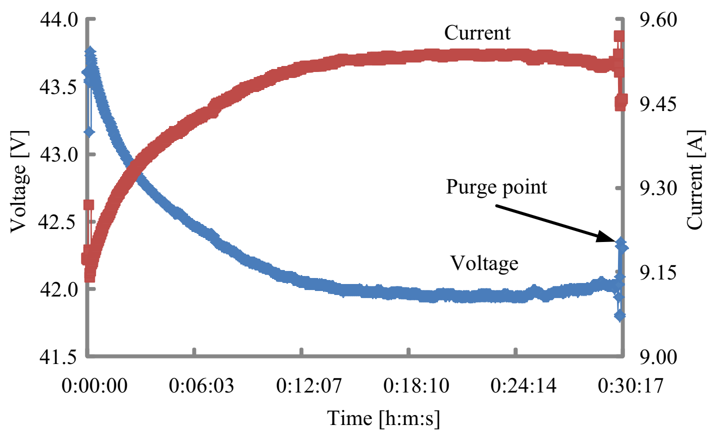

Fig. 10: Relations between voltage and current at 400W

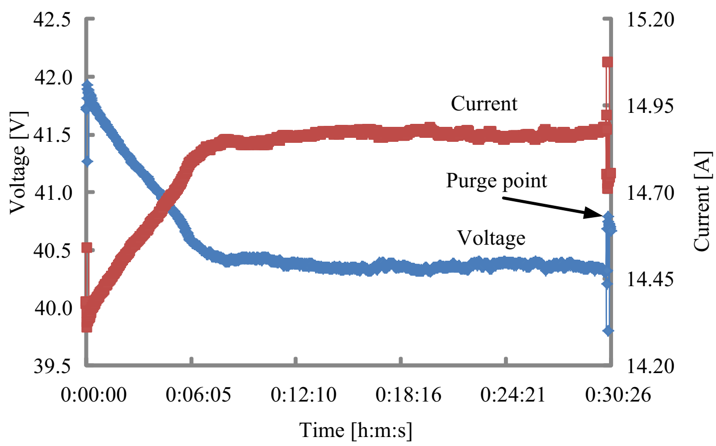

Fig. 11: Relations between voltage and current at 600W

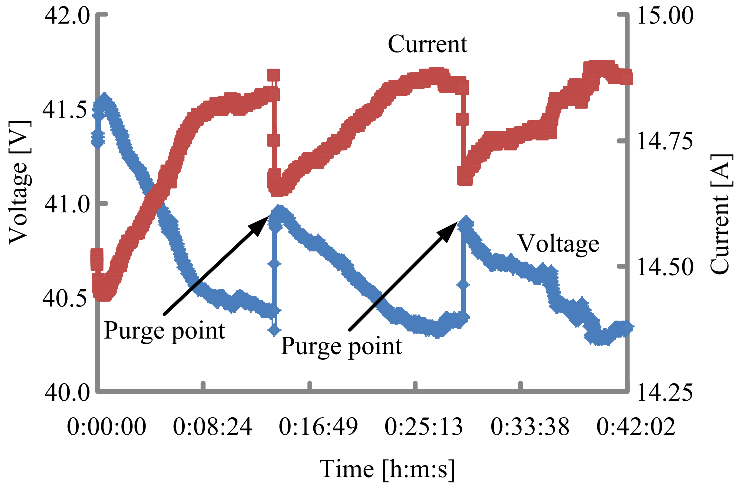

Fig. 12: Purging effects at 600W

6. Conclusions

Measurement and control system were developed for use in our developed micro car class 1 kW fuel cell vehicle. Various sensors to observe the vehicle conditions were developed, and their accuracy was confirmed. Additionally, purging effects of the fuel cell were examined, and the output voltage recovery was confirmed. The experimental results showed that the fuel cells were able to recover their voltage after purging. Improvements to the measurement and control system must be addressed in future research.

9. Acknowledgement

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