

## Development of Electric Wheelchair Using PEM Fuel Cell

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### Abstract

This paper presents a developed electric wheelchair using a PEM fuel cell as a power supply. In addition, it has an EDLC bank for an energy buffer. Two DC motors of the wheelchair are driven by a newly designed four-quadrant DC chopper. Performances of the fuel cell and the wheelchair have been examined by experiments. Then, it is clarified that the PEM fuel cell has enough capability and is appropriate for the electric wheelchair.

**Keywords:** wheelchair, PEM fuel cell, EDLC, DC motor, four-quadrant DC chopper

### 1. Introduction

Effective applications of fuel cells have amazingly been discussed in recent years. Meanwhile, many types of electric vehicles have already been developed by manufactures and research agencies in Japan. Therefore, combination of a fuel cell and an electric vehicle is a worthwhile topic for the future transportation [1].

This paper introduces an electric wheelchair using a PEM (Proton Exchange Membrane) fuel cell. The wheelchair also has an EDLC (Electric Double Layer Capacitor) bank for an energy buffer, and a four-quadrant DC chopper to drive two DC motors installed inside each wheel. Moreover, basic characteristics of the fuel cell and the electric wheelchair are shown in the paper.

### 2. Configuration of wheelchair

Figure 1 shows the developed electric wheelchair. The original one has the following specifications; diameter of drive wheels is 22 inches, maximum speed is 6km/h, output power of each DC motor is 90W, power supply is a Li-ion battery (25.9V/6Ah).

The electric wheelchair has been improved on several points. In particular, its power supply is replaced by the PEM fuel cell, the two DC motors are driven by



Figure 1. Developed electric wheelchair.

the newly designed DC chopper, and the EDLC bank is employed as the energy buffer.

Figure 2 illustrates the motor drive system of the electric wheelchair. Regarding the fuel cell, hydrogen is supplied from a hydrogen storage alloy, and oxygen in air is inhaled by a blower. The EDLC can be charged or discharged depending on the drive condition of the wheelchair. For example, the EDLC supplies energy if the fuel cell lacks its output power for driving the two DC motors. When regeneration of the motors occurs, a discharging resistor dissipates energy if the EDLC is fully charged. Major specifications of these equipments are as follows;

- (1) PEM fuel cell: 200W/24V (output), 41 cells (stack),
- (2) Hydrogen storage alloy: 5000l (capacity of H<sub>2</sub>),
- (3) EDLC: 1350F/2.7V (capability),
- (4) DC motor: 90W (identical to the original one).

### 3. Characteristics of PEM fuel cell

There are several kinds of fuel cells, and the PEM fuel cell is the most suitable for the developed electric wheelchair. Because the PEM fuel cell can be used at room temperature, and its size is compact [2].

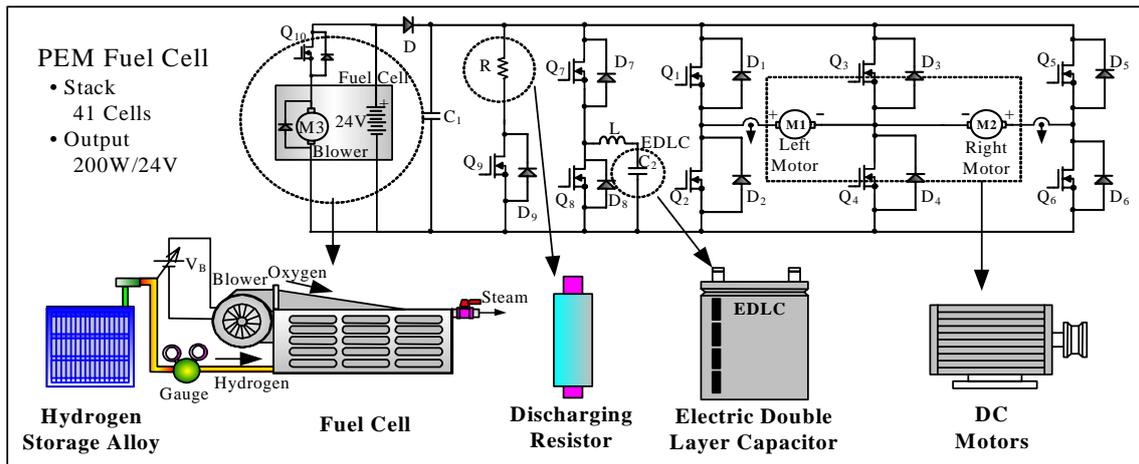


Figure 2. Motor drive system of electric wheelchair.

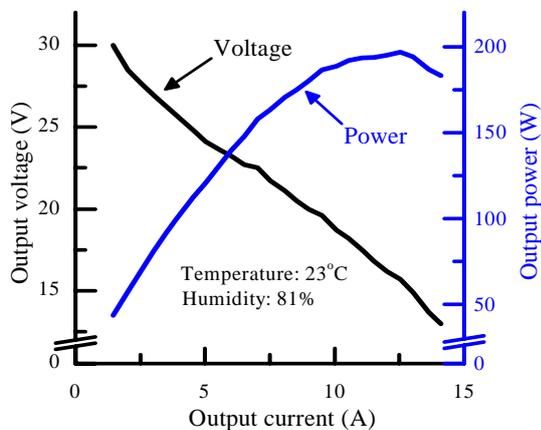


Figure 3. Characteristics of PEM fuel cell.

The hydrogen storage alloy is connected with the fuel cell, as shown in Figure 2. The figure also illustrates the flow of hydrogen and oxygen. Figure 3 demonstrates the key characteristics of the PEM fuel cell obtained from experimental results. By increasing output current, output voltage has a droop characteristic, meanwhile the maximum output power reaches around 200W [3, 4].

#### 4. Performances of wheelchair

The developed electric wheelchair has several drive modes, i. e., forward, backward, right or left turn, and pivot. The two DC motors installed inside the wheels are driven by a four-quadrant DC chopper which is specially designed to simplify the drive system. According to the experimental results, it is cleared that the PEM fuel cell has enough output power to drive the two DC motors [5].

##### 4.1 Four-quadrant DC chopper

The four-quadrant DC chopper has a combined

structure of two full-bridge chopper circuits. Thus, the number of switching device (MOSFET) can be reduced from eight to six, as indicated in Figure 4.

Figure 4 also explains an operating condition of the DC chopper when the forward drive mode is carried out. Thick arrows stand for the current path of the two DC motors and the switching devices.

Figure 5 shows the gate signals of the MOSFETs, the waveforms of voltages and currents of the two DC motors. The PWM switching frequency of  $Q_1, Q_2, Q_5, Q_6$  is 10kHz, and that of  $Q_3, Q_4$  is 1kHz. When  $Q_4$  is ON, and  $Q_1$  and  $Q_5$  are in switching operations, the two DC motors rotate in forward direction at once. It means the electric wheelchair moves ahead. For the other drive modes, appropriate PWM switching is selected, too. For example, in the case of the left turn drive mode, only the right motor (M2) rotates in forward direction, and the left motor (M1) doesn't operate. For the pivot drive mode, M1 and M2 rotate in reverse directions each other.

##### 4.2 Experimental results of wheelchair

Figure 6 demonstrates the experimental results for the output power of the fuel cell, when the forward drive mode and the left turn drive mode are carried out.

As shown in Figure 6 (a), the maximum instantaneous output power reaches about 100W, and the steady state value of it is below 60W. Whereas, for Figure 6 (b), the correspondent values are 105W and 50W, respectively. Besides, the output power is around 30W when the two motors don't operate. The reason of the phenomenon is to work the blower which inhales oxygen from air, i. e., the output of the fuel cell is simultaneously used as a power supply of the blower.

Regarding the other drive modes, experimental data

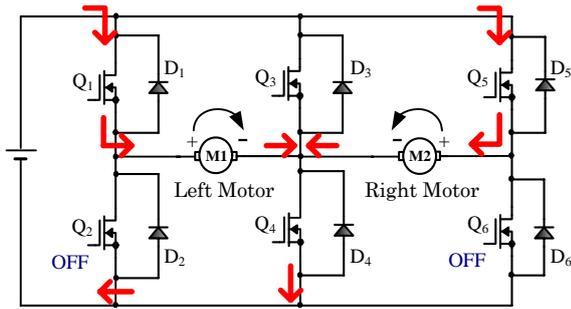


Figure 4. Operation of chopper (forward drive mode).

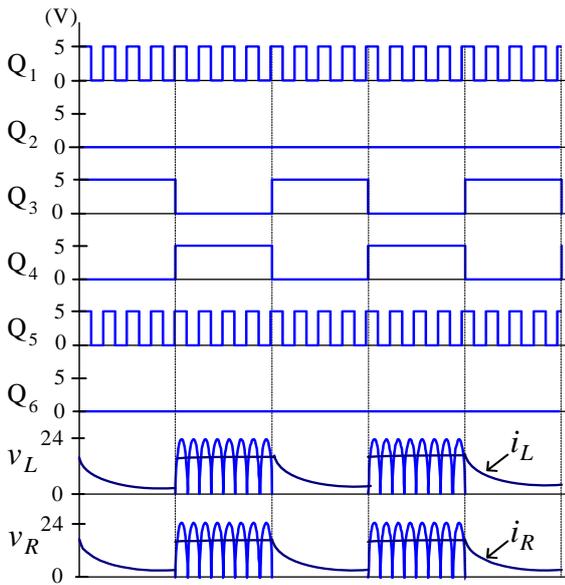


Figure 5. Waveforms of chopper (forward drive mode).

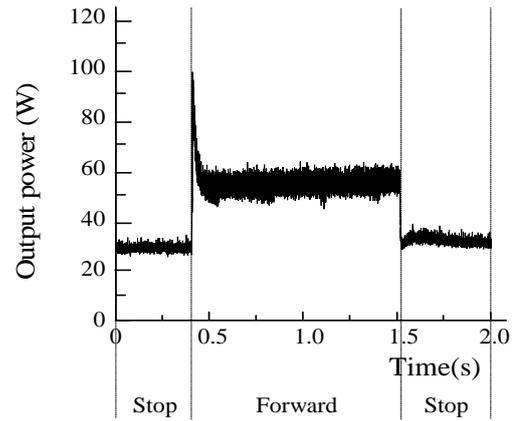
have been obtained. Measured values for the backward mode and the right turn mode are almost the same with the forward mode and the left turn mode, respectively.

## 5. Conclusion

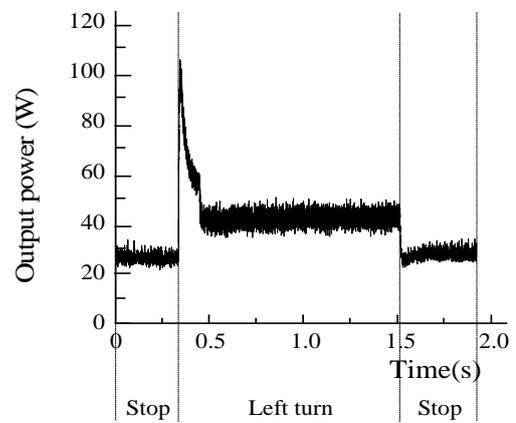
The new electric wheelchair using the PEM fuel cell has been developed. Additional ideas are applying the EDLC bank and the newly designed DC chopper. The performance of the electric wheelchair was examined by experiments. On the other hand, the characteristics of the fuel cell were investigated. As a result, it is clarified that the PEM fuel cell is adaptable to the electric wheelchair, and the basic movements of it have been achieved. In addition, it is necessary to examine the management of power flow of the motor drive system in the near future.

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(a) Forward drive mode.



(b) Left turn drive mode.

Figure 6. Experimental data of output power.

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