Response of Hybrid Power Supplies Combining Ultracapacitors with Direct Methanol Fuel Cells

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Introduction

Low power density has limited the practical application of direct methanol fuel cells (DMFC). Ultracapacitors can deliver high power, but commercial adoption has been limited by their modest energy density. Hybrid power supplies that combine ultracapacitors with DMFC's exploit the advantages and address the limitations of each technology. Results showing the transient voltage response of a hybrid DMFC/ultracapacitor power supply to dynamic load profiles are presented and discussed.

Experimental

The DMFC consisted of a 5 cm^2 MEA with 4.4 mg/cm^2 PtRu (Johnson Matthey) anode electrocatalyst loading and 2.8 mg/cm^2 Pt cathode electrocatalyst loading. The DMFC was operated at ambient pressure and 80°C with 0.75M methanol flowing at 3 ml/min and air at 100sccm.

The ultracapacitor consisted of 6 parallel cells. The capacitor electrodes (7.8 cm^2 active area) consisted of 20 mg of high surface area carbon deposited on conductive polymer current collectors. 30 wt% KOH was used as the electrolyte. The 6 cell configuration rated at 1.0 V with 6F dc capacitance and an equivalent series resistance (ESR) of 4 mΩ.

The capacitor and fuel cell were connected in parallel and discharged through a HP 6050A Programmable Electronic Load. The DMFC baseline current was varied as illustrated in figure 1. Baseline current draws were chosen to represent regions of kinetic, resistance, and mass transport limitation for the DMFC. The test protocol consisted of varying the discharge between a baseline current and peak values corresponding to 2X, 5X, and 10X baseline current. Pulse repetition frequency was varied from 0.66 Hz to 909 Hz with peak current duty cycles of 33%, 16.7%, and 9.09%. A scope was used to record the voltage and waveform across the load.

Results and Discussion

During steady-state operation, the performance of a DMFC is unaffected by the presence of an ultracapacitor. However, when rapid changes in current are required (Fig. 2) the voltage, and hence the power provided by the DMFC is substantially reduced from steady-state levels. A low resistance, high capacitance ultracapacitor responds rapidly to changes in current demand and reduces the voltage drop during these events, effectively increasing the power provided to the load. Once current draw returns to baseline levels, the capacitor is recharged by the DMFC.

The greatest improvements in power were observed for discharge profiles with lower duty cycles, lower frequencies and higher ratios of peak currents to baseline current. (Fig. 3).

Conclusions

Ultracapacitors can be combined with fuel cells to improve power density. The combination is ideal for applications that impose low frequency, low duty cycle peak loads. Examples include fuel cell boot-up, robot stall recovery, and wireless data transmission.

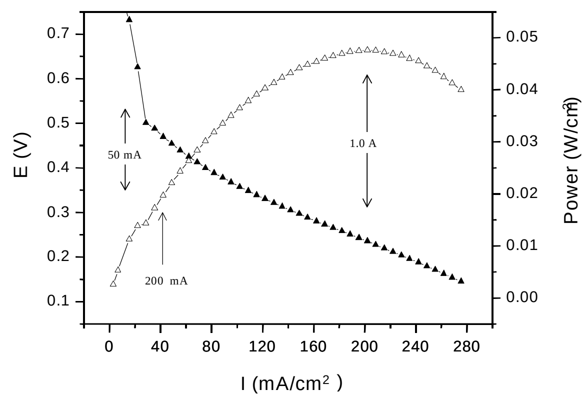

Fig. 1. Voltage and power density recorded under steady-state polarization for a 5 cm^2 DMFC. Arrows indicate baseline current levels used during pulsed discharge experiments.

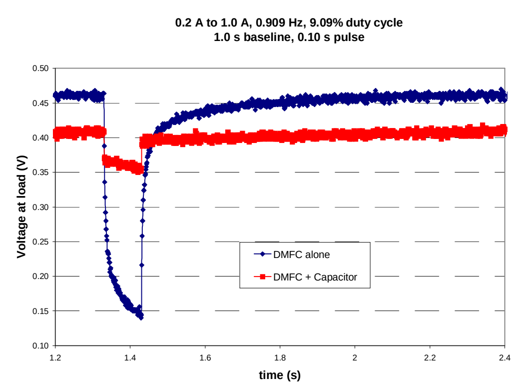

Fig. 2. Voltage recorded at the load for a DMFC and DMFC/ultracapacitor (*not corrected for lead wire resistance of 60 mΩ). Response is during repeated current pulses from 0.2 A (1.0 s) to 2.0 A (0.1 s). Power densities calculated from iR corrected voltage values.

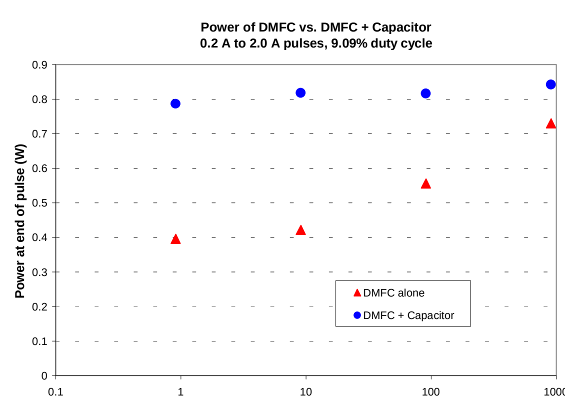

Fig. 3. Power at the minimum voltage point (corrected for lead resistance) for a DMFC and DMFC/ultracapacitor. Pulsed current discharges of 0.2 to 2.0 A (9.09% duty cycle) performed over a range of frequencies.