SUPERCAPACITORS FOR PEAK-POWERING APPLICATION WITH A FUEL CELL SYSTEM

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Reduction of local emissions and improved fuel efficiency of passenger cars has been the driving force for new power train technologies for many years. In this context fuel cell cars turned out to be the most promising to meet future environmental demands. In addition to an efficient process to produce the mechanical energy, recuperation of energy is a potential further step to increase mileage of passenger cars. The fuel cell is not capable of energy recuperation.

For the recuperation of the braking energy a storage device is needed. If an electric machine propels the vehicle, the braking energy can be transferred in the generator mode to an electrical energy storage device, which can be a supercapacitor.

In a fuel cell / supercapacitor power train a power electronic unit is needed to adjust the voltage level of the fuel cell and the supercapacitors. The electrical energy flow can be split between the sources fuel cell and supercapacitor. For recuperation the total flow has to be transferred to the supercapacitors [1].

Within an ongoing project at the PSI a 10 kW dynamic test stand was developed in order to test the interplay between a PEM fuel cell (8 kW), a supercapacitor module (10 kW), and the power electronics controlling the flow of energies.

The supercapacitors for this application are carbon based double-layer cells with organic electrolyte. In a research collaboration of the Paul Scherrer Institute and montena SA a supercapacitor with specific electrodes has been developed with the characteristics:

U_{nom}	= 2.5 V
Capacitance	= 800 F/cell
Max. spec. power	= 6500 W/kg
Max. spec. energy	= 2.75 Wh/kg

The Ragone plot of the cell is shown in Fig. 1. 50 cells of this type have been put together to a module for testing the dynamic behavior. The cells have been arranged in a series (25 x 2) configuration to achieve a maximal voltage of the module of 60 V, a capacitance of 60 F and an ESR of 17 mOhm (@ 1 kHz). The supercapacitor module is shown in Fig. 2.

Cycle tests of the capacitor module clearly show that voltage balancing is necessary to prevent single cells from overcharging. An electronic active voltage balancing unit was developed at the EPFL Lausanne, which balances the voltage differences within a capacitor unit of 5 cells [2]. Six of such voltage-balancing units were used for the 60 Volt supercapacitor module with 25 cells in series.

For the NEDC (New European Driving Cycle) the demand of the power flow from and to the supercapacitor module can be seen in Fig. 3 in terms of the supercapacitor voltage. The power flow characteristics are defined by operating strategy of the power train. In this particular measurement the dynamic power demand of the vehicle is leveled out by the supercapacitor.

The advantage of the use of supercapacitors can be seen in high-speed acceleration and braking phases as they occur at the end of the test cycle. From our experiments we conclude that:
- supercapacitors have the potential for short-term peak leveling applications.
- the recuperation of braking energy is an ideal application for supercapacitors.
- the energy density has to be increased in relation to the power density in order to reach an optimized utilization of the supercapacitor.

REFERENCES

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[2] P. Barrade, S. Pittet, A. Rufer: Series connection of supercapacitors, with an active device for equalizing the voltages, PCIM 2000 : International Conference on Power Conversion and Intelligent Motion, June 6-8 Nürnberg, Germany.

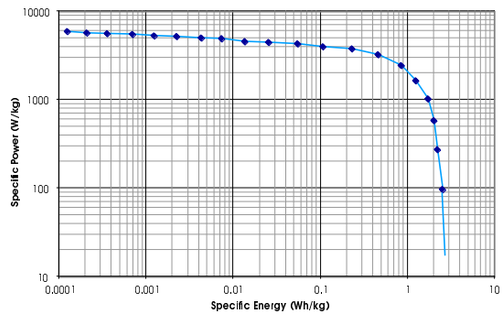

Fig. 1: Ragone Plot of the capacitors used for the 60V module measured at 2.5 V Nominal Voltage.

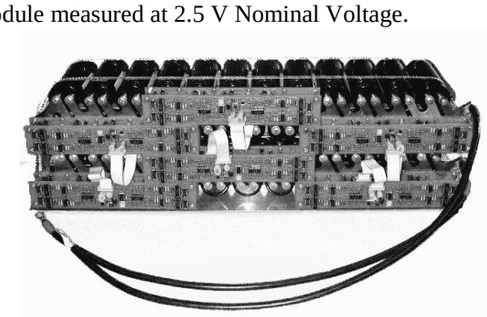

Fig. 2: Supercapacitor module with voltage balancing electronics.

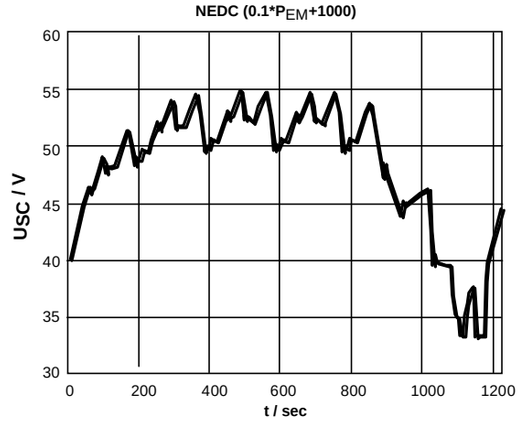

Fig. 3: Voltage flow into the supercapacitor module in a NEDC.