PERFORMANCE TESTING OF SELECTED COMMERCIAL ULTRACAPACITORS

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Ultracapacitors, because of their potential for high rates of charge and discharge, and high power capabilities, are being studied for potential use in premium power sources, battery–powered electronics, and as load-leveling power sources in electric vehicles. The U.S. Department of Energy sponsored Partnership for a New Generation of Vehicles (PNGV) Program has also expressed renewed interest in their use in hybrid electric vehicles. This paper will report on the results of performance testing of selected, recent generation commercial ultracapaitors.

Recent models (as of March 2001 and later) of commercial ultracapacitors from Maxwell Technologies Company (USA), SAFT (USA/France), CCR Corporation (Japan), NESS Corporation (Korea), and Panasonic Industrial Company (USA/Japan) have been tested using some of the test protocols as given in Reference 1. The constant-current charge/discharge test from 10 A to 500 A at test temperatures of –20°C, +25°C, and + 50°C was used to measure the charge and discharge capacitance, the charge and discharge equivalent series resistance (ESR), the charge and discharge energy density, as well as the discharge energy/charge energy efficiency as a function of test current and test temperature. The constant-power discharge test conducted from 50 watts up to 675 watts at the three test temperatures was used to measure the specific energy of the capacitors as a function of specific power. Leakage-current and self-discharge tests at the three test temperatures were used to measure the time dependence of the leakage current, and the self-discharge energy loss factor [1]. Tests from the recent version of the PNGV Battery Test Manual [2] were also used during the testing of the ultracapcitors. The low-current and high-current Hybrid Pulse Power Characterization (HPPC) Test adjusted for the PNGV Power assist goals were used to determine the dynamic power over the ultracapacitor's useable charge and voltage range. The PNGV Cold Cranking Test (conducted at –30°C) was used to measure the 2-second power capability of the ultracapacitors for comparison with the PNGV Cold Cranking Power Goal [2].

Shown in Figures 1 and 2 are the test results for a Maxwell Technologies Company Model #PC-2700 ultracapacitor. This device was rated at 2700 farads capacitance, with a voltage range of 0 to 2.7 V. In Figure 1, are shown the measured capacitance of the device as a function of charge/discharge test currents ranging from 10 A to 500 A, and for a charge/discharge voltage range of 0.03 V to 2.7 V. Three consecutive charge/discharge test cycles were used and, thus, permitted the calculation of the capacitance from three tests. As can be seen in the figure, the discharge capacitance at +25°C is ~2700 farads at 10 A, which decreases in a linear manner with increasing discharge current until at 500 A the capacitance is ~2375 farads. All of the data sets at the three test temperatures have been fit to a linear function of the discharge current. The best fit to the three data sets and the R^2 correlation parameter are given in the figure. The capacitance measured at +50°C is slightly lower that that measured at +25°C. The decrease in capacitance also followed a linear relationship with increasing discharge current. The measured capacitance at –20°C was lower than at the other two test temperatures. Its rate of decrease was also more rapid as the discharge current increased. The measured specific energy (Wh/kg) as a function specific power and test temperature for the same cell is shown in Figure 2. The specific energy was found to decrease in a linear manner with increasing constant-power discharge (the parameters of a linear fit to the data are shown). At +25°C and +50°C the specific energy has a value of ~2.9 Wh/kg at ~75 W/kg that decreases to ~2.0 Wh/kg at ~940 W/kg. The specific energy at –20°C was observed to decrease at a much greater rate. Note that the PNGV energy and power goals at +25°C are 7.5 Wh/kg at 625 W/kg respectively [2]. The discharge ESR values at +25°C and +50°C were observed to be ~0.0007 ohms and did not change appreciably with increasing constant-current discharge current. The –20°C ESR values are considerably higher, ~0.00145 ohms at 10 A that decreases in a monotonic manner to ~0.0011 ohms at 500 A, thus indicating that at the lower temperature the ion diffusion processes that influence the double layer formation at the electrodes are greatly affected.

The paper will present these and the other test results for the previously mentioned commercial ultracapacitors. Where possible, a comparison will be made to the current PNGV performance goals.

References

1. Electric Vehicle Capacitor Test Procedures Manual, Revision 0, DOE/ID-10491, October 1994.
2. PNGV Battery Test Manual, Revision 3, DOE/ID-10597, February 2001.

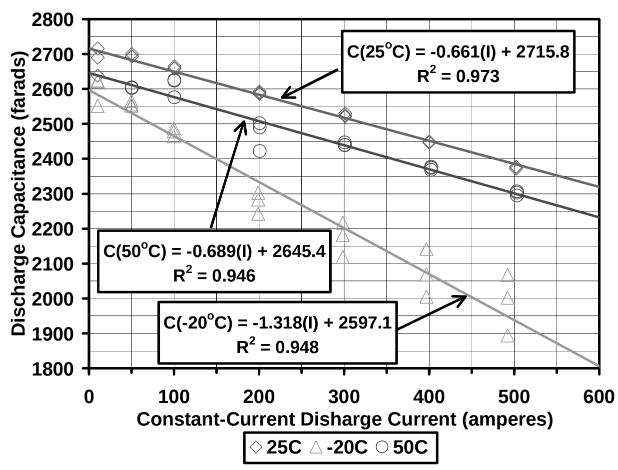

Figure 1. Discharge capacitance as a function of constant-current discharge current at three test temperatures for a Maxwell Technologies Company Model #PC-2700 ultracapacitor.

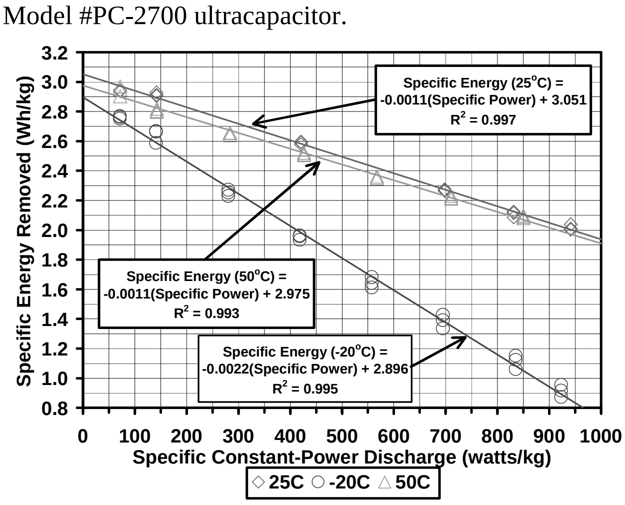

Figure 2. Specific energy as a function specific constant-power discharge at three test temperatures for the same Maxwell Technologies Company Model #PC-2700 ultracapacitor shown in Figure1.