ELECTRIC VEHICLE INSTITUTE

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Why are Ultracapacitors used in the Hybrid Booster Drive?

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Ultracapacitors were selected as the on-board energy storage system for the Hybrid Booster Drive™ (HBD) because this technology offers distinct advantages compared to battery based energy storage systems. These advantages include:

- High charge rates
- High efficiency
- High power density
- Excellent low temperature performance
- Long cycle life
- Long operational life
- No maintenance

As ultracapacitors are use in the HBD system, they are charged each time the vehicle stops. This means they are charged in about 7 seconds. This is a very high charge rate compared to a battery's capability. A peak power of over 150 kilowatts is often seen during regeneration, when the ultracapacitor is charged.

Energy is stored by charging the ultracapacitor and then used by discharging it. As with any physical system, ultracapacitors have losses. More energy is required to charge than will be available on discharge. The ratio is called "round trip efficiency". The round trip efficiency for ultracapacitors as used in the HBD vehicle is approximately 80%[1]. A comparison to batteries is not possible because batteries can not be charged as quickly. Typically, batteries will have lower efficiency than ultracapacitors. Generally, the efficiency for ultracapacitors is cited to be 95%[2]. Batteries, when used in hybrid applications, are typically 65% efficient[3].

Ultracapacitors are powerful devices. As used in the HBD vehicle, compared to lead-acid batteries, they are about 10 times more powerful, pound for pound.

However, batteries store more energy than ultracapacitors. An equal weight of lead-acid batteries could store 5 to 10 times the energy as could ultracapacitors.

The HBD vehicle saves fuel by using energy normally lost, or wasted, during deceleration. So, the energy storage system, ultracapacitor, is sized to store just this amount of energy. The electrical energy storage capacity is set equal to the kinetic energy of the vehicle at 35 miles per hour. Ideally, the HBD vehicle completely recharges the ultracapacitor system each time it comes to a stop. Then, uses this stored energy to supplement the engine during the subsequent acceleration.

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[1] Cohen, Mark. "Top Ten Reasons for Using Ultracapacitors in Your System Designs". Program Director, Maxwell Technologies.

[2] Lev, Frank. "Optimal Hybrid Electric Power Train for Heavy Vehicles and Buses". Tavrima Limited, unpublished paper. October 1999.

[3] Mosely, Patrick T. "High-Rate, Valve Regulated Lead Acid Batteries – Can They Be Suitable for Hybrid Electric Vehicles?" a paper presented at Hybrid Electric Vehicles: Here and Now TOPTEC, New York, May 26-27, 1999.

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A battery sized to the energy requirement outlined above would be incapable of the power levels needed. Lead-acid batteries sized to handle the power needed for the HBD vehicle would weigh 5 to 10 times more than the ultracapacitor system, and even then not be capable of storing all of the regeneration energy during the deceleration. This means that the battery hybrid vehicle would continue to loose energy to the friction brakes, which can be recovered with ultracapacitors.

However, such a battery system could propel the vehicle much further, perhaps miles. The ultracapacitor system can only provide launch assist and offers no electric only propulsion operation.

Ultracapacitors operate over a wide temperature range because they do not rely on chemical reactions as do batteries. Ultracapacitors can function normally up to 65°C and down to -40° with only a slight increase in resistance at the low end. Battery energy and power capability suffers greatly as temperature drops below zero. From 20°C to 0°C, the battery energy is reduced by 35%. Battery energy is reduced down by as much as 80% at -20°C[4].

Ultracapacitors have excellent cycle and operational life. Over 500,000 complete charge/discharge cycles can be expected, as well as a 10 year minimum[5]. The ultracapacitor should last the life of the vehicle, with no maintenance. Batteries, on the other hand, will not last as long. It is generally accepted that at least one complete battery replacement would be required.

The ultracapacitor energy storage system consists of many ultracapacitor cells connected together, in a similar fashion as a battery consists of multiple cells. In the HBD system, several hundred ultracapacitor cells are connected in series to provide the appropriate working voltage, power and energy. Each ultracapacitor cell is sealed container with carbon, aluminum and a solvent. There is no exchange of material from inside the cell to the outside. The ultracapacitor cells are arranged in a “pack” mounted to the chassis of the vehicle. The enclosure for the pack is a durable steel box. There may or may not be ventilation of the pack for thermal management, depending on the type of ultracapacitor used.

There are several types of ultracapacitors available on the market and several more under development. Presently, about ten manufacturers offer ultracapacitor product for sale, worldwide. Markets include industrial, transportation, military, power quality and commercial applications. The production base is increasing and the cost is decreasing. This, along with process and technological improvements, will cause the ultracapacitor to displace more and more batteries. The power, size, reliability, durability and life of the ultracapacitor make it the sensible choice in many applications.

[4] From Product Data Sheet, Power Sonic Sealed Lead-Acid Batteries, web site: http://www.power-sonic.com/gencat0103.pdf, January, 2005.
[5] From Product Data Sheet, PC2500 Ultracapacitor Product Information, Maxwell Technologies, web site: http://www.maxwell.com/index.html, January, 2005.