WHITE PAPER

ENERGY STORAGE FOR HYBRID POWER IN HEAVY TRANSPORTATION

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The hybrid electric car is today a familiar concept, and can already be seen on Europe's roads. There are clear benefits of having an electric motor working with an internal combustion engine, with an energy storage device allowing start-stop operation and the re-use of energy absorbed when braking. Fuel consumption and pollution are both lower, and the car can also have a stronger performance at low speeds where the electric motor helps the main engine.

The same principles also apply to heavier vehicles on our roads, such as trucks and buses. Public transportation such as trains and trams also stands to benefit from adopting a hybrid power train approach. In case of buses and trucks pollution and fuel consumption can be reduced, as well as cutting noise. In case of trams and trains primary energy demand can be reduced significantly, allowing longer, more or higher performance vehicles on an existing track.

The obvious energy storage device might be a rechargeable battery, but in fact they have some serious limitations for this kind of application. Batteries are heavy, large in size, have a limited charging rate and potentially high maintenance. They also can suffer degraded performance at low temperatures.

Recently, newer designs have looked at another energy storage component – the ultracapacitor. Ultracapacitors, or double-layer capacitors, provide high charge acceptance, high-efficiency, cycle stability, and excellent low-temperature performance.

Ultracapacitors for heavy transportation applications

Heavy transportation vehicles place particular demands on energy storage devices: they must be very robust and reliable, with a long lifetime and low maintenance requirements. They must be able to operate efficiently under harsh conditions, and they must be able to deliver high peak currents. They must also be able to work on a high duty cycle and cope with frequent deep discharging. Finally, they must be straightforward to integrate into a vehicle design.

Maxwell Technologies has addressed these issues with its HTM BOOSTCAP® ultracapacitor module for ultracapacitor-based braking energy recuperation and torque assist systems in transportation applications. Operating at 125V, the new module can store more energy per unit volume, deliver more power per unit volume and weight and last longer than any other commercially available ultracapacitor solution.

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The HTM module is based around 2.7V BOOSTCAP MC3000 Power cells rated at 3,000F which have a very low internal resistance, which results in excellent efficiency during charging and discharging. Up to 12 modules may be linked in series to deliver a total of us much as 1,500V. Balancing interconnectivity between modules is fully integrated within the module and requires no additional hardware, to help with system design.

A key factor in the energy storage system is thermal management. With efficient cooling, higher continuous currents are possible without compromising reliability. The dimensions and design of the 125V module were chosen for best efficiency and cooling behavior when operated at very high currents of up to 150A continuous and 750A peak. This compares to a maximum continuous current of 90A with Maxwell's 48V ultracapacitor module, an increase of 70%. This means that a much higher charge/discharge power can be delivered.

The module design ensures that there is only a 3°C temperature rise above ambient at maximum continuous current. The layout of the module results in a very stable temperature distribution over all cells in the module, and this results in greater reliability and longer life. Integrated temperature monitoring is achieved with six thermistors.

In addition to managing high current, the module is built to withstand the harsh environments and extremely demanding duty cycles that are typical with heavy transportation applications. The HTM module is designed to perform reliably through one million or more deep charge/discharge cycles, which equates to 150,000 hours or more than 15 years of operational life. It is undergoing extensive testing against rigorous transportation industry standards

Proprietary material science and packaging technology are reducing manufacturing cost, so that the price of the modules competes favourably with other energy storage designs. The HTM module is sealed from the elements in a rugged, splash-proof, IP 65-compliant, aluminium chassis, and weighs less than 50kg.

Application examples

As well as braking recuperation, energy storage can also be used to help meet peak power demands. Combination with batteries is also an option if high power and pure electric driving is required.

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Ultracapacitors have been proven over a number of years in transportation applications worldwide. In one example, ISE Corporation has used Maxwell's ultracapacitors in its hybrid electric buses, which operate e.g. in the US cities of Elk Grove and Long Beach.

The systems have functioned reliably at temperatures from –25°C to 45°C. The response of the drive system is significantly better than that of a standard bus and fuel economy is improved through the efficient capture of more braking energy. Preliminary data indicates the average fuel efficiency of a bus with an ISE ultracapacitor-based hybrid-electric drive system is significantly better than a bus with a competitive battery-based hybrid-electric drive systems and a bus with a standard drive system.

In this application, there were several key advantages of ultracapacitors as compared to batteries. Firstly, they function well in cold weather, down to –40° Celsius, whereas without heating, batteries do not operate well below 0° degrees Celsius. Secondly, they are extremely safe because a pack with equalization is discharged over night. Thirdly, they have a long life cycle, basically built to last the time of the machine into which they are incorporated. This means that they are maintenance-free which ultimately results in costs-savings. Fourthly, they are more efficient than batteries; up to 95% as compared to an average of below 70% for batteries in this application.

Ultracapacitors are also very environmentally-friendly as they are 70% recyclable and do not include any heavy metals which are detrimental to the environment. Lastly, and maybe most importantly, ultracapacitors offer up to 10 times the power of batteries and in terms of acceleration of a vehicle, this plays an important role.

As well as transportation, the new HTM module is well-suited to industrial applications including cranes, which can also benefit from rapid energy storage through braking energy recapture. This allows them to use a smaller diesel engine, reducing fuel consumption and emissions. There are also multiple other diesel powered or fully electric heavy duty vehicle applications that can utilize the peak power provided by ultracapacitors, such as large construction vehicles and equipment.

Maxwell's ultracapacitors have also been trialled in light rail applications. In Germany, a prototype vehicle developed by Bombardier Transportation has been in passenger operation since 2003, and has demonstrated the potential for energy savings of up to 30% as compared to a modern regenerative light rail vehicle. Used to store energy from braking, the ultracapacitors go through somewhere between 100,000 and 300,000 load cycles per year in a typical light rail vehicle – which means that batteries would be unsuitable for this application. Ultracapacitors are also lighter than a comparable battery.

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