Ultracapacitors Save Energy in Transportation Applications

Mass transportation such as metros, buses and trams experience repeated braking and acceleration events. Traditionally, in the case of light rail vehicles, the braking energy is either burned in a braking resistor or given back to the network. Recapturing the braking energy in the network is only efficient if, at the same time, close to the braking vehicle another vehicle is accelerating. Otherwise, the recaptured energy is lost by the network cable resistance. By storing the braking energy in transportation applications, either on vehicle or at the track-side, and reusing the energy during acceleration, the total energy consumption can be greatly reduced. This also brings great environmental benefits and reduced pollution. **Adrian Schneuwly, Maxwell Technologies, Rossens, Switzerland**

In the case of buses improved fuel economy, emission reduction such as CO_2 and noise reduction are key targets for hybrid electric or even fully electric drive systems required for use in cities. Other transportation applications can also benefit from ultracapacitors, including fork lift trucks, elevators, straddle carriers and cranes. For hybrid fork lifts, ultracapacitors can be combined in parallel with a fuel cell or a battery, or in a hybrid drive train with a fuel or diesel engine. They can deliver and receive power peaks, optimising the primary energy source size, and the ultracapacitors can also be used for energy recuperation to save fuel and increase the operating time of the fork lift.

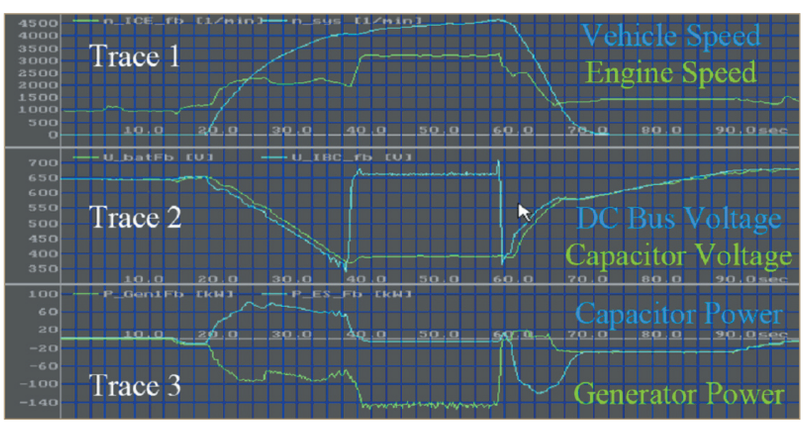

Figure 1: Operation of hybrid electric bus with ultracapacitors

Ultracapacitors for energy storage

For heavy transportation applications, there are specific demands for energy storage devices: robustness, reliability under harsh conditions, long lifetime and low maintenance. The storage devices must be able to operate on a high duty cycle with frequency deep discharging. Perhaps most importantly, they must be able to deliver the high current required to meet the peak power demands of the application.

Ultracapacitors, or double-layer capacitors, are an energy storage device that has key advantages over batteries for transportation. They can deliver much higher power and can be charged faster than batteries, are more reliable with less maintenance, are more efficient (up to 95% compared to below 70% for batteries) and perform better at low temperatures down to –40°C.

Ultracapacitors provide up to 10 times the power of batteries, meaning they can provide sufficient power for acceleration. They can also be used successfully in combination with batteries, which provide lower power for longer periods of time.

The life cycle of an ultracapacitor is very long, usually the life time of the vehicle they are designed into, thus reducing maintenance costs. An ultracapacitor can typically be used for 1 million or more charge cycles, which typically equates to tens of thousands of operational hours or more than 15 years of useful life. Based on 3,000 Farad cells operating at 2.7V, the BOOSTCAP 125V HTM ultracapacitor module is specifically designed for transportation applications.

Application examples

Ultracapacitors have been proven to have a successful effect over a period of years in a number of bus applications, both full electric and hybrid electric (see Figure 1), and in light rail vehicles.

In one example, ISE Corporation's hybrid electric buses operate in the US cities of Elk Grove and Long Beach, and have been shown to recuperate 38% of the propulsion energy. Other bus systems with ultracapacitors include those from MAN, which have been trialled in Karlsruhe, Germany.

China is also expected to be a huge market for ultracapacitors in this kind of hybrid drive system, particularly for low floor buses where batteries can not be used due to volume issues. Hybrid buses are being promoted by the Chinese government to overcome environmental issues, and all the major cities in China are looking for hybrid buses.

Another application is trolley buses, which are found in a number of European cities. Ultracapacitors can be used to help improve energy efficiency with regenerative braking, and also to drive short distances without power from the overhead power line. This is of great assistance for a crossing or junction, or if it is difficult or undesirable to use an overhead line in any particular section of the system.

Innovative approaches are being taken by some organisations to urban transport problems. The Fraunhofer Institute in Germany has developed a prototype vehicle called the AutoTram (Figure 2),

Figure 2: Fraunhofer AutoTram vehicle

which uses a fuel cell with a nominal power of 80kW as the primary energy source.

Ultracapacitors are used by the AutoTram in a trackside docking station to store energy from the supply system and provide it quickly to the vehicle when it is stationary at a passenger stop. The ultracapacitor system can provide a usable energy of 2.4kWh, which takes 4 to 5 minutes to collect from the supply system at 33kW. This is then delivered at 325kW to the vehicle, taking only 27 seconds. This is achieved with 1,536 ultracapacitors rated at 2600 Farads and operated at 2.5V. The system has a capacity of roughly 60F at 600V. Future plans include using ultracapacitors as on-board energy storage and integrating them into the vehicle's energy management system.

For light rail applications, regenerative braking can improve the energy efficiency of systems, providing significant cost savings. Ultracapacitor-based energy storage systems also improve network reliability through rail network voltage stabilisation.

Siemens Transportation Systems' Sitras SES system has successfully used ultracapacitors in stationary system beside tracks in cities including Cologne and Madrid. This again uses trackside units, which each unit containing 1,344 of 2600 Farad BOOSTCAP capacitors operating at 2.3V. The system provides a peak power capacity of 1MW, and operates at an efficiency of 95%. The concept has been reliably proved over a period of several years, operational up to 22 hours a day, with the maintenance-free ultracapacitors giving a 10-year lifetime.

A further example is the MITRAC prototype light rail vehicle, developed by Bombardier Transportation, which has been in passenger operation in Germany since 2003. This has shown the potential for energy savings of up to 30%, as compared to a modern regenerative light rail vehicle, which translates to typically 45,000 Euros per year per vehicle for a metro application, or more than 2 million Euros for a 50 vehicle fleet. Figure 3 shows the energy savings obtained by a MITRAC vehicle. As well as reducing energy cost, this could also enable an increased substation distance by a factor of 1.4 to 1.7, significantly reducing costs, reducing overhead line cross-section, adding more vehicles in existing networks, or using more powerful and longer vehicles.

Finally, let's compare lead acid batteries in fork lifts with a fuel cell/ultracapacitor solution. Use of the fuel cell/ultracapacitor pack removes the need for multiple battery modules and charging stations. Re-fueling is as easy as a normal vehicle, which means there is minimum down time and increased productivity. Figure 4 shows that the fuel cell/ultracapacitor solution gives about 8% increase in run time. This increase in run time equates to about 1,100 Euros saving per month per truck, or 13,200 Euros annual saving per forklift. For a warehouse with hundreds of forklifts this saving is well over 1 million Euros.

Literature

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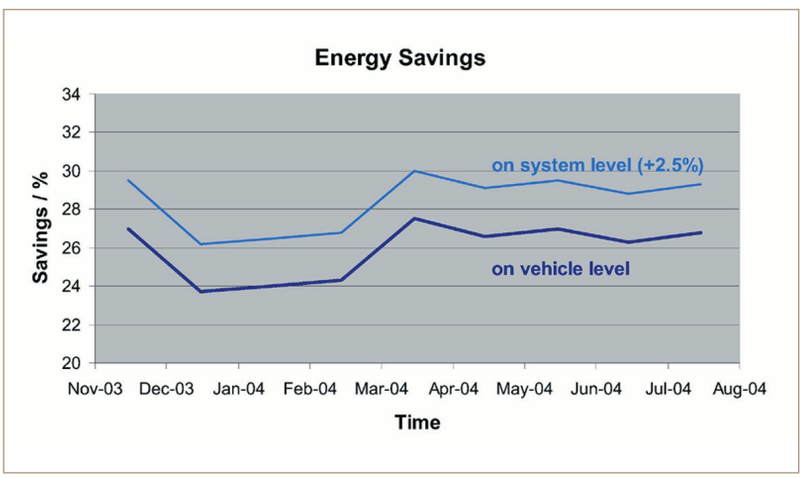

Figure 3: Energy savings of Bombardier MITRAC light rail vehicle in Mannheim, Germany

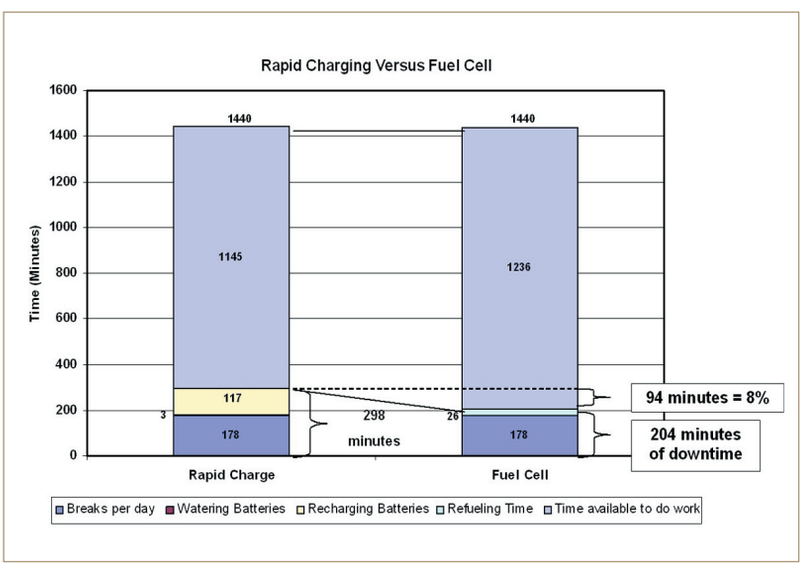

Figure 4: Time savings due to fuel cell/ultracapacitor solution in fork lift trucks