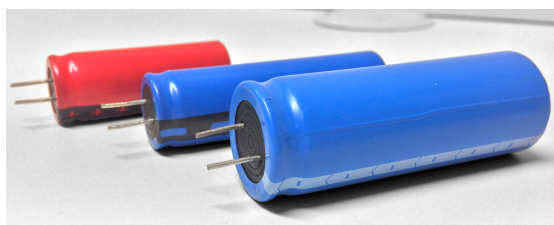


Game Changing Carbon based Power Capacitors at Work

Introduction

As the world is trying to reduce its dependency on fossil fuels, all heads are turned towards electric energy. This is not really new, most homes and factories provide us electricity comfortably delivered from huge power plants over high-tension lines. It's convenient and it enabled the electronics revolution. When we want to go mobile, without a cord attaching us to the grid, then batteries come into play. These buffer the energy we need while we are disconnected. However, batteries have limitations. They are heavy, have a limited energy content, operate badly at low temperatures, they have a limited lifetime and they can pose safety risks. The higher the power density (to deliver more current) the more the battery heats up and as it contains electrolytes, batteries can "burn", although what really happens is an escalating thermal reaction. Even under normal use, heating up (e.g. for fast charging) reduces the useful lifetime. Whether used in a portable device, a personal car or logistics vehicle, the issues are the same. Using batteries remains expensive and their issues make using them less practical than we would like to.

Is there an alternative? One that comes to mind are supercapacitors. Contrary to lithium-based batteries, lithium based supercapacitors don't use a chemical reaction (hence are safer and operate at all temperatures), but they directly store the electric energy charge. They can deliver very high peak currents in bursts but suffer from low energy densities. This results in space constraints as well as high prices.



The best of both worlds is made available by carbon based power capacitors. These devices deliver energy densities comparable with the best batteries, but with power densities that are only found with supercapacitors. Being supercapacitors, they keep relatively cool and hence share the temperature and safety benefits.

Moreover, they enable many applications that never really worked well neither with supercapacitors, neither with batteries. Simply put the benefit not only comes from the inherent safety and wide temperature operating range, but from the power density. Hence, a 1 kWh battery for example can then provide the performance of a 10 or 20 kWh battery without any risk, allowing to use a smaller battery.

Let's explore some of these applications.

1. The Car battery



While lead-acid batteries have a long history, they are not perfect batteries. Their performance drops with ageing or when stressed. Of course, they often do the job well enough, but can we do better? Gasoline engines use the battery energy to ignite the fuel using spark plugs.

So what happens when we replace the battery with a power capacitor one? First of all, when it's cold, no starting problems, even after many years of service. The most surprising result of the tests on different types of vehicles (Audi A6, Mercedes C200, Ford Transit) is a reduced fuel consumption of up to 8%, especially at higher motor regimes. The reason is that power capacitors can keep up the voltage at the spark plugs. The effects are a better ignition, a more complete burning of the injected fuel (and hence a small increase in power of 3 to 8%) but also the spark plugs remain cleaner (less deposits) and last but not least the battery is more reliable and lasts for a lifetime. Over a lifetime, a 0,5 l/100 km less fuel means that a power capacitor based car battery is a very simple way to reduce pollution and save money at the same time. It's an investment that pays itself back.

2. Power tool batteries



Anybody who is a bit of a handyman appreciates those handheld battery driven power tools. One can take them anywhere. Except when the battery is empty, then a second battery is needed while the first one charges hours at a time. With the carbon based power capacitors and matching charger, they can be charged in maybe 10 to 15 minutes while taking a short break, and with no safety risks when the battery is left overnight in the charger. What are the benefits? A lower investment in power packs

and more production time coupled with increased safety. Moreover, the power pack will also work fine when it is freezing cold.

3. Heavy traction vehicles

What applies to power tools, applies to traction vehicles as well. Today most if these are based on Lithium-ion type of cells because they have the highest energy density. However, several issues mean that using such batteries result in many practical issues. For example, they lose a lot of their capacity when the temperature drops below zero, so outside storage or parking overnight or in wintertime is not recommended. Another issue is that lithium ion cells pose a serious safety risk when heating up. This means that each battery pack requires a complex battery as well as thermal management system. And least but not least, the thermal risk also means that their power output must be limited. All this results in an over-dimensioning of the battery pack (some electric cars drive around with a 1 ton of batteries that can make up one third to half the cost of the vehicle). This adds to the weight requiring more energy to drive but also to the charging times. For vehicles with heavy traction requirements like buses, trucks, forklifts or heavy-duty tractors, this adds considerably to the cost, weight and charging requirements.



Power capacitors provide relief. While their energy density is comparable, they allow delivering sustained power at a rate of 10 to 20 times of what lithium based batteries can. This is expressed in terms of so-called C-ratings, essentially how much of their nominal current they can deliver in a sustained way. Even the best Lithium based batteries remain at 0.5C for reasons of safety and lifetime considerations. Carbon based Power capacitors can sustain 10C to 20C with no need for a complex battery or thermal

management system. What this means for traction vehicles is that a much smaller power battery can deliver all the power (read: torque) that is needed. The vehicle can stay outside

overnight and can also charge very fast (the power it can deliver is the power it can take as well). This has major benefits. It effectively reduces the energy consumption (as the vehicle weight drops with about a quarter or more) and it drastically reduces recharging times. Again, rather than having to have an unproductive vehicle for hours while charging, it can quickly charge for 10 to 15 minutes while taking a break. This reduces the need for extra vehicles and increases the productive time. Note that e.g. some electric buses already use this principle but as they are using traditional supercapacitors, the solution is costly and needs many extra charging points along their route (e.g. at the bus stops). With Power capacitors, the distance between charging points can increase as well as the weight of the battery pack, making it more practical and economical solution.

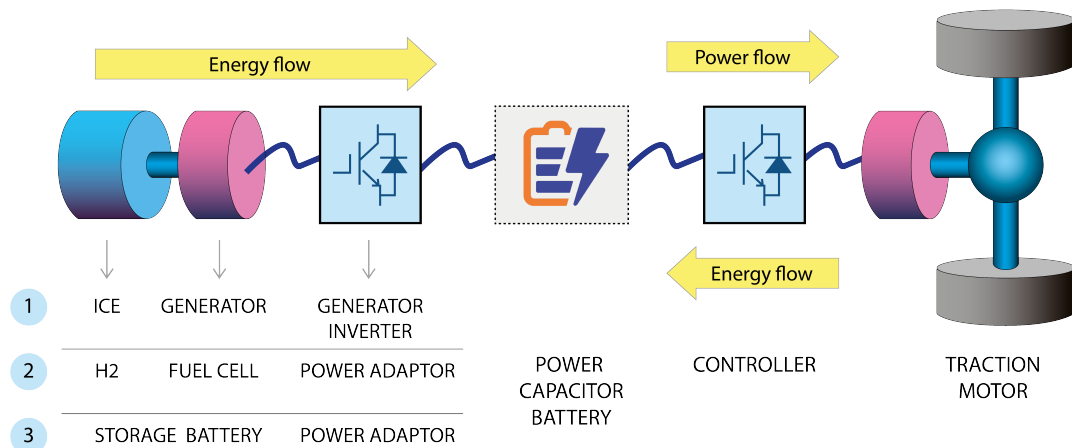
4. Serial and parallel hybrid drives.

The most spectacular results however are obtained when carbon based power capacitors are applied to hybrid drives. Since about 100 years, vehicles have been propelled by internal combustion engines (ICE). These burn fossil fuels, are noisy and pollute our air. While much progress has been made, specifically in the last 20 years, they remain fairly inefficient because they operate optimally in a relatively small operating zone. They need a minimum speed to keep running and when power and torque is needed (like during irregular stop and go traffic or when the road is hilly), the fuel consumption might increase with a factor 5 or more. Just hit the pedal and see what happens with the fuel consumption gauge on your dashboard. This is also the reason cars have gears to keep the engine closer to its optimum zone at all speeds.

On the other side of the spectrum we have fully electric vehicles. As explained in the previous section, this requires large, heavy batteries resulting in high costs and long charging times. The larger the vehicle, the more serious this issue becomes. Batteries weight several tons and require megawatt hour charging stations, enough power to provide a full block of houses of energy. How sustainable is this?

Nevertheless, electric propulsion has many benefits, if it wouldn't be for this battery+charging situation. Electric propulsion doesn't pollute, is silent and the traction at low speed is phenomenal.

Hence, it makes sense to combine both in one. We all know the parallel hybrid drives whereby a relatively small electric motor is connected in parallel with an internal combustion engine, that can be switched off (an example is the Toyota Prius). As the battery is relatively small, this is a fairly good solution when driving at low speed, at least until the battery is exhausted. In practice this is a relatively complex system. It also adds extra weight to an already heavy combustion engine (battery, electric motor, cooling system, flywheel). Hence the fuel savings are modest. Charging from the battery is the default, but to make it economical one can best charge from the electricity grid, but that also adds to the cost price.



Another solution that was tried is a serial hybrid system (see picture above) A combustion engine is then used to charge the battery while the battery drives an electric motor. Such a system is relatively simple (GM's Impera). As the combustion engine can be relatively small and can run at a constant efficient regime, fuel consumption is modest but not spectacularly low. Part of the reason for this is the extra weight, and the inefficiency of the energy conversion from fuel to power on the wheel. Hence, shall we forget about the hybrid set-up? Let's have a look at what happens if we install a carbon based Power capacitor battery.

The point is that an ICE powered vehicle has a higher average fuel consumption than it could have because the ICE engine is inefficient with dynamic regime changes. Battery powered vehicles however consume more than they should because the battery is heavy and hence the motor has to move a lot of dead weight. In battery powered vehicles the electric energy conversion to torque on the wheel is also much more efficient with no energy being used when the vehicle stands still or even better, it can recover kinetic energy when it slows down or goes down a hill. Typical driving scenarios for a city but a Power capacitor battery can do better.

As was explained above, Power capacitor batteries can be a lot smaller than classical lithium based battery because they deliver peak torque with a smaller battery. But they also recover much better the braking energy, which also means that the electric motor and its controller require less cooling.

Shenzhen Batton is a company that has been developing alternative drives, mainly for buses and trucks, since many years. We had the pleasure to visit them and test-drive their latest prototypes.

A medium sized city-bus (40 passengers) was converted from a fully electric one to a serial-hybrid one with the carbon based Power capacitors. A small 2liter ICE gasoline engine is switched on when needed to charge the Power capacitor battery through a highly efficient generator (40 kW). What are the results? Firstly a 2-ton lithium-ion battery is replaced with a 300 kg one of 15 kWh. The electric motor is rated at 120 kW, peak 240 kW. The total weight is now comparable with the original weight of the ICE-bus but the fuel consumption is in the order of 10 to 12 l gasoline/100 km. Note that most city ICE-busses run on Diesel and consume easily 30 to 50 l/100 km. Hence we have a reduction of pollution and fuel consumption with almost a factor 4. Of course, these figures depend on the driving conditions.

Similar tests with a small van, a 3 ton heavy SUV indicate similar results. Batton is now working on converting a large personal car and the expectations are that the fuel consumption will be around 2 l/100 km per ton of vehicle mass.

What does this mean? While it does not fully eliminate all pollution, the reduction is such that it makes the case for fully electric driving difficult. Such a small ICE engine, running under optimum operating conditions and economic speed, also generates a lot less pollutants. Moreover, the hybrid drive requires no change to the filling stations and no investments in a new charging infrastructure. Full battery driven vehicles remain the best option for light electric vehicles but above e.g. 1 to 2 ton, hybrid drives with a Power capacitor battery are clearly a much more economical and sustainable option. This applies to serial as well as to parallel hybrid drives. After all, its not only the batteries that pose an issue but the need for additional fast charging capacity. Even if Lithium based batteries would become much smaller and safer, it remains a challenge to build a charging network for all vehicles in an economic way, especially in less developed countries where the grid might already be stressed today.

5. Wind power turbine blade pitch control



Large wind power turbines deliver a few MWh depending on the wind conditions. They typically contain two batteries. The main battery pack acts like a UPS in case the grid connection is lost. In case this fails, a smaller battery pack often using classical supercapacitors is used to perform quickly a

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power down whereby the blades are turned into a safe position. This requires a heavy peak current (e.g. 100 A at 100 V or about 10 kW during some 30 seconds). Super capacitors are used because they can handle the current, but their energy capacity is barely sufficient for the space available to complete the operation. They are also expensive. Tests were conducted with the carbon based Power capacitors on a real wind turbine. It was mostly a plug and play integration in the space taken before by the lithium supercapacitors. The conclusion is that at three-quarter the cost the carbon based Power capacitors could complete the operation three times more often before they were depleted, hence providing a significant cost reduction while the safety margins are drastically increased.

Conclusions

The ideal battery not only has to provide sufficient energy but also sufficient power. Its operating conditions can be very demanding in terms of safety and temperature while the system should require few maintenance interventions and last a long time before its needs to be replaced. A better lifetime cost and assured reliability is what carbon based power capacitors deliver. The combination of energy and power density also enable new applications that before were not really feasible or cost-efficient. There are many more applications that will benefit. Kurt.energy is developing such solutions with as main goal to deliver practical and long-term reliable clean energy. Contact us for your specific project.

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