1.3 - Ultracapacitors

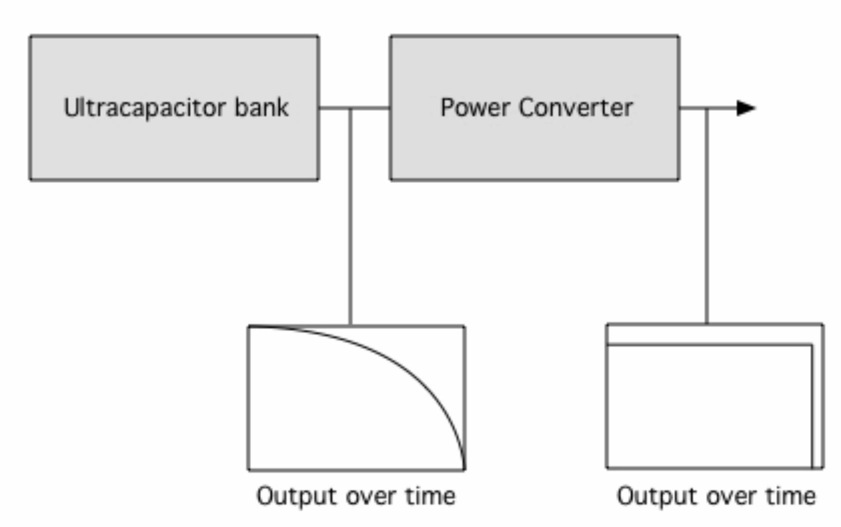
1.3.1 - The Technology

Ultracapacitors (or ultra-capacitors, ultracaps) are extremely high energy density capacitors. Capacitors store electrical energy by physically separating positive and negative charges, in contrast to the chemical means a battery uses. Until 2007, the best capacitors could not store energy in amounts even close to comparable to a battery. This is changing fast, and now we are beginning to see ultracapacitors nearing battery capacities. A company called EEStor has announced that they are on track to exceed battery capacities by a factor of more than two during 2007. This milestone is very important, because the *only* way that batteries have been better than capacitors is in their ability to store more energy.

Capacitors (and ultracapacitors) can charge much faster than a battery, discharge much faster (meaning, they can give more energy on demand), and in normal use, they do not wear out at anywhere near the rate that batteries do. They are less dangerous to handle in terms of acids and explosive gasses. They are considerably more environmentally friendly to dispose of and to manufacture, and it is worth noting that ultracapacitors are 100% re-usable. When a device fails, you can pull the ultracapacitors out and put them in something else until (or if) they actually fail. I mean this in the sense that a 7-year old ultracapacitor will work just as well as a brand new one of the same specifications, where a 7-year old battery most certainly will not.

Ultracapacitors can perform as the exact functional equivalent of a battery in a circuit — that is, as a primary source of current and voltage — with the exceptions that they have much longer life expectancies, better performance over time, and a different, but not problematic, output voltage to remaining power relationship. Batteries such as a lead-acid car battery will maintain an output voltage reasonably near 12.6 volts for most of the time the battery is discharging under load. This characteristic is a consequence of the chemical process that actually produces the output, so it is an inherent characteristic of these batteries.

Ultracapacitors steadily drop in output voltage as they discharge, so a very lightweight device called a *switching power converter* may be placed between the ultracapacitor and the devices it is providing power to. This provides a precise (more so than a battery) output voltage right up until the ultracapacitor is fully discharged. In this way, the one electrical difference between batteries and ultracapacitors is easily, reliably, and inexpensively overcome.



Power Converter Use

There is another benefit to this arrangement. Because the output voltage of an ultracapacitor is directly related to the amount of charge remaining, measuring the output voltage of an ultracapacitor or ultracapacitor bank *directly* indicates the amount of charge left, unlike the estimates that must be made for a battery, which continuously become more inaccurate as batteries age. Batteries can "lie" to us, showing full output voltage when they have very little power left to supply. Ultracaps can't do that.

1.3.2 - Electric Cars

The only thing keeping electric cars from being completely practical now is conventional battery life, and ultracapacitors should resolve that within the next few years. Ultracaps are already nearing standard battery capacities (they were at about 10% as of 2006, which was very close considering they have been increasing in capacity exponentially), but large battery equivalent ultracaps have not been commercialized as yet. The primary hurdle that needs to be overcome is single unit ultracaps that can function in the 100% or higher power equivalent range while taking up the same volume and unit weight as the equivalent amount of batteries.

Once you can fully charge an electric car in the same time you can fill it with a liquid fuel, pull virtually any amount of current you need for accelleration, exceed a 300-mile range for a one-charge excursion, and *never* have to replace the ultracaps (a huge cost advantage over batteries)... that'll be the death knell for liquid fuels.

You performance freaks will like this. With an electric vehicle, you can build in virtually any amount of horsepower and torque. In fact, some of the most powerful vehicles made today use electric motors for power. You probably think of them as "diesel" locomotives, but if you look a little closer, you'll find that what they actually are is a huge diesel powered electric generator set that drives a 100% electric motor system at the engine's wheels. Doubt me? Look it up!

Ultracapacitors have another advantage over batteries in a vehicle; because of the high rate at which they can accept charge, they do a *much* better job at capturing energy from regenerative braking systems. This is a technology that turns a vehicle's forward motion back into electricity when you use the brakes. Because batteries can only accept charge at a comparatively slow rate, regenerative braking cannot work as well with them. Ultracapacitors make regenerative braking more practical.

Think about it: The distribution network is already in place (electicity) and once in use, not only does it obsolete all the fuel tankers running around, it allows us to migrate at any rate we see fit to 100% air-pollution free energy sources from nuclear (major) to tidal, solar, wind, and other minor, but still useful, sources. You'd never come up to a service station again and find they are "out of fuel" and for what amounts to a pittance to purchase the charging equipment, you can charge your car at home once a day in probably a few minutes. More often if you're willing to go for a high-capacity electrical service... charging an ultracap could pull amazing amounts of energy, quickly, if you require a quick charge.

Considering that charging an ultracap based vehicle would pull far more energy than the typical 10 KW electrical service a home has, the way a practical home charging station would have to work is by constantly pulling current from the home service in a co-operative manner (pulling current when other devices aren't, particularly at night) until it contains a full charge; then when you plug the car in, the charging system would "dump" that charge to the car quickly, and begin recharging itself again, to be ready to re-charge the vehicle again in 24 hours. Most times, the vehicle won't need a full charge, as typically it will not have traveled 300 miles. So most charging stations will just pull a fraction of the current possible, the majority of the time. That, combined with charging at night when the overall demand for electricity is much lower and available generating capacity is high, will allow the existing electrical distribution network to service a very large number of electric vehicles before additional capacity is required, either in terms of transmission lines or power plants. Public charging stations are another matter and will have to be located near substations in order to deal with the demands they will make.

The issues associated with the high demands of recharging is one of the reasons why there will still be service stations. Service stations can invest in higher powered electrical services, while also storing energy locally in their own ultracapacitor banks like a larger version of the home setup just described for those times when demand exceeds supply. The other key reasons are that many vehicles will be away from home and will require charges at odd hours and locations, or close intervals if running long distances, and that vehicles will still require lubricants, window washing fluid, and high-powered systems will still require coolants and so forth. And you'll want snacks!

As an investor, my money is in ultracap firms. Not ethanol or hydrogen. IMHO, both of these technologies are going to be a technological blip on the radar. Just barely.

20 years from now, if you see a fuel-powered vehicle on the road once a day, I'd be quite surprised. Why? Because once those fueling stations are no longer profitable to operate, fuel-dependent vehicles will go from scarce to gone overnight. How will you get enthanol, or gasoline for that matter, when there are no fueling stations and no tankers carrying fuel? And if you can't get fuel easily, why would there be any cars that used fuel, other than antiques?

1.3.3 - Why hydrogen can't compete

Hydrogen has a number of problems. First of all, the molecule is so small that it is very hard to store and transport, and is almost impossible to put into a pipeline. It can literally leak through metal. Secondly, creating hydrogen is a process that costs more energy than we can get back, and I'm not talking about just a few percent — it is *very* inefficient. Third, the energy density in hydrogen that we can recover chemically (meaning, in a non-nuclear manner) is very low compared to power we can create for ultracaps via, for instance, a nuclear power station. Fourth, to get energy densities that are high enough to get your car to go the usual cruise distance (about 300 miles), the hydrogen has to be compressed so hard that only very specialized equipment can compress, store and otherwise handle it. We're not talking about a light gas anymore, we're talking about a liquid compressed to a degree that is difficult to imagine. Lastly, there is no transport infrastructure and no fueling infrastructure.

Since all of these problems are inherent, and can only be solved by the application of large numbers of expensive technologies, it appears to me that hydrogen as a fuel is "right out."

Since everything — and I mean *everything* — is already in place that is required to support a nation of electric cars, barring the cars themselves, clearly the path of least resistance (hah!) is to go pure electric using ultracaps.

1.3.4 - Letters

I have just completed a comprehensive study of the EEStor technology. If it works (and there are the usualy sceptics)it will open up another set of problems.

First of all it will not charge in 6 minutes on household current. It would take 4-6 hours. And 3500 Volt!! Wow. If your tried to do it with solar it would take an array the size of a football field.

Not directly, no, but that's not how proposed high speed home charging stations work, so it really isn't relevant. First, they charge at a reasonable rate from the house service; this charge is accumulated in local storage in the charging system, and when the car needs juice, the charge transfer is local to car, not grid to car. Once this charge has been made, the house unit won't be prepared for another full charge for about a day, until it has had time to recharge from the grid (while still allowing for normal household electrical demands.)

In order to charge these in 5 minutes it would take 220 Volt wiring. I don't think it's feasible to re-wire every home and apartment bldg. The charge stations proposed would still not solve the basic problem of "Where to do get the electricity to charge these massive puppies? Still more infrastructure impact.

It takes a lot more than 220v wiring; it would take moving up from a 12 kw service to about a 150 kw service. That's why fast charge units store locally, rather than pulling directly from the grid. The infrastructure impact is minimal; most demand would be of a load balancing nature, delivered when the generation capacity is largely unused, meaning at night in most venues. Slow-charge units can be built right into the cars; there's nothing to them by comparison.

If he answer is the grid that won't fly either. The grid is and will be primarily dependent on fossil fuels, clean or dirty. So you are just transferring the problem. It would take 10-20 years to build up the infrastucture to accomodate this technology.

No again. The grid burns fossil fuels much more efficiently than does an individual vehicle. Combustion engines run at 25% or so; grid-level generators work at closer to 60%. This more than doubles the useful energy retrieved from fossil fuels, and that in turn extends the time we can use them and keeps the price from rising as fast. In the meantime, solar, wind, geothermal, and eventually nuclear sources can be brought online.

The EEStor technology is not a true ulatracapacitor (which take seconds to fully charge and

discharge). The testing data show that it takes twice as long to discharge as it does to charge (0.5 seconds charge and 1 second, discharge) on a 9 cell prototype. It will take 6 minutes to charge the full 31,000 cell EESU, so you could assume it would take 12 minutes to fully discharge. This is decidedly and NON-capacitor like aspect. THIS THING IS A VERY LARGE BATTERY, NOT AN ULTRACAP.

Where did you get this idea? A capacitor is not defined by the time it takes to charge and discharge, nor by a balance between charge and discharge times. It is defined by the mechanism used to store energy, which is via an electric field, rather than chemical means (which by the way is what defines a battery.)

Now let's look at a true ultracap. It has massive storage cacacity due to the makeup of the electrodes, which are usually some form of activated carbon or nonowires. These devices only require 1 to 5 volts to charge, a far cry from the EEStor technolgy.

I think you'll see how misplaced this argument is when you compare a high voltage RF capacitor to an audio-rate electrolytic. Just about every specification you can name varies widely between the two; charge capacity, rate of charge, breakdown voltage, impedance, etc... yet they are both clearly capacitors.

True ultracaps can be charge from renewable energy sources such as solar, wind and REGENERATIVE BRAKING IN CARS. Now let's look at these in cars. They are being used to assist hybrid vehicles all over the world because they increase thelife and reduce the size of LiOn batteries, as an example . If an ultracap is used to capture the regenerative power and then trickle charges the batter, now you have something.

At this time, ultracaps don't have the capacity to provide primary power sources, so yes, this is an appropriate role. The EEStor product, if and when it arrives, is expected to have sufficient capacity to serve in both roles.

Since true ultracaps charge easily with renreable energy, there would be little problem installing solar/wind driven rechargin system in homes and apartments. Renewable energy driven charging stations would now be feasible. A well designed car system like mentioned above would make it less likely that the battery would have to be charged on a daily basis anyway.

Certainly.

There are improvements coming soon in ultracaps which will improve them several orders of magnitude over what is presently being sold.

We hear about developments constantly; what we're missing - so far - is actual manufacturing and the support electronics that make high voltage ultracaps usable in consumer applications. The problem with energy storage in an ultracap is that the only known mechanism is $E = (V*V)*C$ where E is energy, V*V is voltage squared, and C is capacitance in Farads. Because the voltage is squared, the most important factor, by *far*, is the working voltage. Thus far, everything I've heard *except* from EEStor has been about increases in C, which bring linear improvement; increases in voltage being improvements at a nonlinear rate, much to be desired. Regardless of what I've heard, all I *want* is for batteries to go away and ultracaps to take their place. If I never buy another battery, it can't happen soon enough to satisfy me.

Thank you letting me share this with you. You are doing a great job in advancing science knowledge

Jack M.

Thanks to you in turn for writing.

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