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Electricity storage

Ne plus ultra

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Illustration by David Simonds

A new version of an old idea is threatening the battery industry

PUT the pedal to the metal in the XH-150—a souped-up Saturn Vue—and watch the instruments. Sure enough, the speedometer shoots up in a satisfactory way. But an adjacent dial shows something else: the amount of charge in the car's capacitors is decreasing. Ease off the accelerator and as the speedo winds down the capacitors charge up again.

Such a capacitor gauge could become a common sight on the dashboards of the future. A capacitor can discharge and recharge far faster than a battery, making it ideal both for generating bursts of speed and for soaking up the energy collected by regenerative braking. AFS Trinity, a company based in Washington state, has turned that insight into a piece of equipment that it has fitted into an otherwise standard production model as an experiment. The result—the XH-150—was unveiled at this year's Detroit motor show.

In fact the XH-150 is a three-way hybrid, employing a petrol engine and conventional lithium-ion batteries as well as its special capacitors. An overnight charge gives it an all-electric range of 40 miles (60km), after which the petrol engine needs to come into play. AFS Trinity says the vehicle is capable of more than 80mph and returns the equivalent of 150 miles per gallon (more than 60km/litre) in normal use. Edward Furia, the firm's chief executive, reckons the extra kit would add around $8,700 to the price of a petrol-only vehicle were it put into mass production.

This, however, may be only the start. Eventually, the so-called ultracapacitors on which the XH-150 is based may supplant rather than merely supplement a car's batteries. And if that happens, a lot of other batteries may be for the chop, too. For it is possible that the long and expensive search for a better battery to power the brave, new, emission-free electrical world has been following the wrong trail.

Full capacity

A traditional capacitor stores electricity as static charges, positive and negative, on two electrodes that are separated by an insulator. This works best when the electrodes are parallel with each other, which means they need to have smooth surfaces. The amount of charge that can be stored depends on the surface area of the electrodes, the strength and composition of the insulation between them, and how close they are together. If the electrodes are then connected by a wire, a current will flow from one to the other. A battery, by contrast, stores what is known as an electrochemical potential. Its two electrodes are made of different chemicals—ones that will release energy when they react. But because the electrodes are physically separated from one another their chemical constituents can react only by remote control.

This is able to happen because the space between the electrodes is filled with a material called an electrolyte which allows ions (electrically charged atoms, or groups of atoms) to pass from one electrode to the other and thus combine with their chemical complements. To compensate for this movement of ions, electrons have to move in the opposite direction—and if the electrodes are connected by a conducting wire running through a useful circuit, that is the route they will take. Chemical electrodes of this sort can store a lot more energy than the static electricity of a capacitor. But the whole process of ion movement and chemical reaction is slower than the movement of electrons in a capacitor. Hence the different advantages of the two storage systems: capacitors give speed; batteries, endurance.

The reason ultracapacitors may be able to bridge the gap between speed and endurance is that, like batteries, they use ions and an electrolyte rather than simply relying on the static charges. In an ultracapacitor, positively charged ions gather on the surface of the negatively charged electrode and negative ions on the surface of the positive electrode. Since the ions do not actually combine with the atoms of the electrodes, no chemical reaction is involved. The ionic layers are also very close indeed to the surfaces of the electrodes, and obviously run parallel with them whatever their shape. This, in turn, means clever engineering can increase the surface area (and thus the storage capacity) without increasing the volume. And that gives endurance without sacrificing speed.

Existing ultracapacitors get their extra surface area by using electrodes coated with carbon and etched to produce holes, rather like a sponge. This gives about 5% of the storage capacity of a battery. But Joel Schindall and his colleagues at the Massachusetts Institute of Technology think they can do better than that using nanoengineering. Instead of digging holes in the electrodes, they are coating them with a forest of carbon nanotubes, each five nanometres (billionths of a metre) wide. This, they hope, will push capacitors to 50% of a battery's storage capacity.

A different approach has been taken by EEStor, a Texan firm that has developed a capacitor it claims can store “very high” levels of energy using a special insulator called barium titanate rather than an electrolyte. Its “Electrical Energy Storage Units” will go into production later this year. EEStor recently signed a deal to supply Lockheed Martin, a big defence contractor, which wants to use the storage units in rugged packs that will power a variety of military and security equipment.

EEStor also envisages employing its devices to build an “energy bank” to store off-peak power and release it when demand is high. One use of such a bank, the firm suggests, could be the rapid charging of electric cars—which would, of course, also be fitted with capacitors.

That would remove a big obstacle to the adoption of electric vehicles in general—that it takes so long to refuel them. If a driver could pull into an electrical filling station and top up his capacitors as rapidly as he can now replenish his petrol tank it would both increase the effective range of all-electric vehicles and decrease resistance to buying them in the first place.

At least one firm is backing the logic of this argument in its showrooms rather than just in prototypes. Ian Clifford, the chief executive of the Zenn Motor Company in Toronto, has done a deal with EEStor to replace the lead-acid batteries in the small, low-speed electric cars that his firm sells for urban use. Mr Clifford reckons that ultracapacitors will transform his vehicles and enable them to be used on motorways as well as city streets.

Whether ultracapacitors really will take over the market now dominated by batteries, rather than merely supplementing them in it, remains to be seen—for batteries themselves are also getting better. They do have a chance, though, of being one of the 21st century's disruptive technologies. And even if they do not replace batteries entirely, the world will surely be seeing more of them in applications which need that little bit of extra oomph from time to time. After all, as Dr Schindall points out, animals use two types of muscle fibre: one for endurance and one for rapid movements. So it could make sense for machines to do the same.

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