WHITE PAPER

Ultracapacitor System Design; Optimizing Hybrid Electric Vehicles with Fuel Cell Power

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Introduction

The automotive industry's recent push towards developing electric and hybrid electric vehicles (EV and HEVs) is a direct response to the growing global pressure to improve the environment and has resulted in a search for significantly cleaner and more efficient vehicles. So far, the outcome of this search has not been entirely promising, as the success of these new, environmentally friendly vehicle architectures depends on the development of advanced energy storage technologies. Among the many options explored, fuel cells have been identified as having a good potential for use as the primary source of power train energy. But since internal combustion engines and fuel cells have significantly different characteristics, few current automotive designs can immediately replace conventional power trains with fuel cells alone.

However, the promise of fuel cell technology has had a recent resurgence due to new advancement - not in fuel cells, but in another power technology: the ultracapacitor. Indeed, high power energy storage is required in all types of fuel cell applications and ultracapacitors are ideally suited to provide it. Moreover, ultracapacitor technology and cost reductions have advanced significantly in the last few years, driven by the need to develop components for the consumer electronics industry as well as the new EV and HEV markets. These improvements, as well as the unique characteristics of ultracapacitors, open up opportunities for the development of new power train and subsystem architectures - utilizing both ultracapacitors and fuel cells - which can improve performance, efficiency, and cleanliness in EV and HEV technology.

System Design with Ultracapacitors

Hybrid applications with ultracapacitors and fuel cells use two different power sources to solve two different power requirements. The fuel cell, which acts as the primary power source, is sized for the continuous load requirement. The ultracapacitor, which acts as the secondary power source, is sized for the peak load requirement. In some cases, the peak load is satisfied by only the second source, and in other cases, both the primary and secondary sources are required. But because of the wide variety of driving profiles, the selection of the power ratio between primary and secondary power sources is a matter of judgement. Nevertheless, system architectures that optimize the balance of power and energy between fuel cells and ultracapacitors will be significantly cheaper and more responsive than fuel cells alone since fuel cell power trains are well suited to take advantage of the ultracapacitor's unique characteristics.

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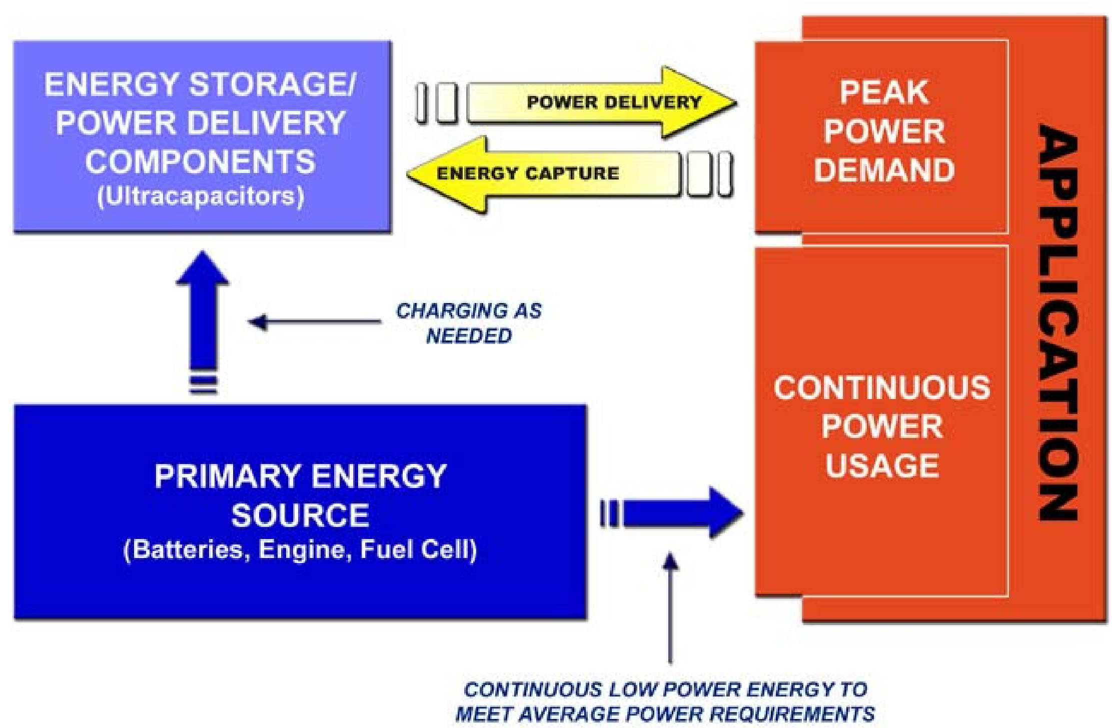
Indeed, as mentioned above, hybrid configurations rely on fuel cells as a primary power source for continuous power and ultracapacitors as a secondary power source for short duration load leveling events such as fuel starting, acceleration and braking. These short duration events are experienced many thousands of times throughout the life of the vehicle and require relatively little energy but substantial power. The low energy requirement and the high number of power cycles makes these designs well suited for ultracapacitors. Moreover, integration of ultracapacitors into hybrid vehicles allows for a slower transient response from the prime generator - and thus, less costly fuel cells - and for the capture (rather than dissipation) of regenerative braking energy for greater efficiency.

The duration and magnitude of typical acceleration and braking events determines the size of the ultracapacitor bank. The fuel cell, which only handles continuous loads, can therefore be smaller, lighter and lower in cost. Added benefits to this design approach are the long life of ultracapacitors as well as their low volume and weight, both of which reduce the life cycle cost of the system. Furthermore, ultracapacitors can be a lifetime subsystem, withstand wide temperature ranges, require little maintenance, and be placed more optimally for vehicle ergonomics.



The diagram above is a pictorial view of the system where the energy storage system is the fuel cell, the electric drive and subsystems are the application load, and the ultracapacitor is the secondary energy and power buffer.

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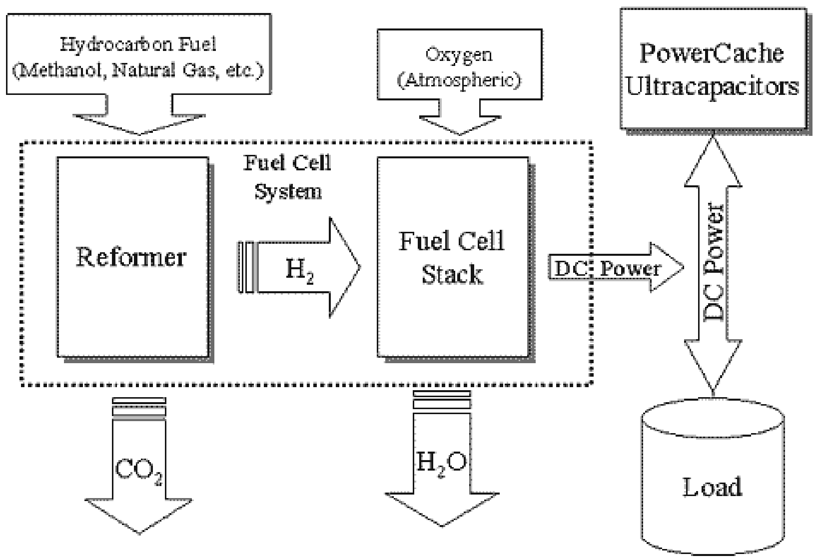
Specific Fuel Cell Hybrids Types

There are several types of fuel cells appropriate for automobiles. The most common type is the hydrogen-oxygen fuel cell made by Ballard Power Systems. The key advantages of this type of fuel cell is that it uses hydrogen for fuel and oxygen from the atmosphere to create electricity and its waste output is water.

These fuel cells are efficient and dynamic enough for automobile use but they do have a few drawbacks. For example, there is no existing infrastructure for hydrogen delivery, hydrogen is not easy to handle safely, and the tanks are rather large in volume and must be strong enough to withstand the very high pressures of storage and potential accidents. And even though the fuel cell is dynamic enough to handle

Ultracapacitors can also eliminate harnesses across hinges by allowing designers to place energy storage systems near specific loads in a door or visor - thereby creating federated power. Locks, lights, and windows can be powered by ultracapacitors embedded in doors and trickle-charged through point-to-point contacts when they are closed. When opened, point-to-point contact is broken and the ultracapacitor provides any required power. This can also be used for luxury items such as vanity lights in visors.

Finally, the short high current requirement of engine starting, especially in cold weather, is an excellent application for ultracapacitors. Even when a battery is very cold, or very depleted, it retains enough power to trickle-charge the ultracapacitor. In turn, the ultracapacitor can provide a starting current. This may allow for the use of smaller batteries optimized for energy and life, instead of cold cranking amps. As such, these subsystems will not replace batteries entirely, but will perform in tandem with them to improve design.



Towards the Future

As more electrical components are integrated into vehicles - from global positioning systems and telephones to navigation and wireless networks - overall automobile power requirements will increase. Indeed, ultracapacitors are now used as memory backup in many of these devices, and will continue to be a key component to assure adequate power.

And yet, the potential uses for ultracapacitors in the automotive industry are increasing rapidly because transportation markets demand not only raw performance, but long operating life, wide temperature ranges, and low cost. This is especially true in systems requiring high power. Ultracapacitors offer a long cycle life and excellent cold temperature performance, and the basic materials used in their construction pose no significant barriers to affordable cost in quantities typical of the automotive market. The introduction of ultracapacitors into subsystems and "stepping-stone" power trains will accelerate the adoption of the technology into the automotive market, and will drive up volumes, and therefore drive down costs. This volume-driven cost reduction will continue to make ultracapacitor technology an excellent solution for current and future fuel cell power trains, local power nodes, and electrically driven subsystems.

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