Hybrid Car Power Simulation

By Philip Joosten

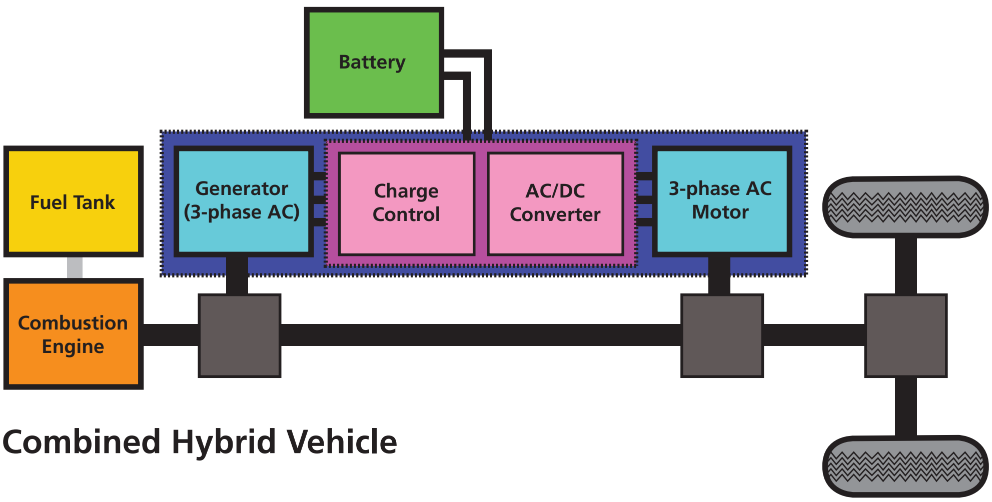
Back to the roots
More then 100 years ago, in the early days of car development, the technical advances between electric motor powered vehicles and combustion engine power vehicles was a neck on neck race. In fact, it was an electrical motor driven car that past for the first time a speed of over 100 km per hour. The problem was storing enough electrical energy to give an electrical powered car sufficient practical driving radius. And that is where the combustion engine was wining the race. Gasoline is so much easier to store and bring along, giving a car a large driving radius.

Today, over 100 years later, with a lot more new technology and not to forget, rising fuel prices, hybrid cars are a very realistic alternative to the conventional combustion engine only car. And again energy storage is one of the main challenges requiring very sophisticated modules managing and storing the required electrical energy. Interesting is that safety aspects for both the conventional gasoline tank and the new sophisticated high-voltage batteries as are important. Overheating such a specialized battery through overcharging can cause significant damage to the total vehicle. Therefore a lot of testing and power simulation is required during the development phase, long-term environmental testing and burn-in during production test.

Types of Hybrid cars
Hybrid vehicles are also not a new technology. For instance diesel electric locomotives are from the **Series Hybrid** type. **Parallel hybrid** systems, which are most commonly produced at present, have both an internal combustion engine and an electric motor connected to a mechanical transmission. Most designs combine a large electrical generator and a motor into one unit, often located between the combustion engine and the transmission, replacing both the conventional starter motor and the alternator. To store power, a hybrid uses a large battery pack with a higher voltage (up to 440VDC) than the normal automotive 12 volts. Accessories such as power steering and air conditioning are powered by electric motors instead of being attached to the combustion engine. This allows efficiency gains as the accessories can run at a constant speed, regardless of how fast the combustion engine is running. The starter motor function is now integrated between the engine and the transmission, allows for the car to start instantaneously. This means that every time the car is idling in neutral mode, the engine shots down and is restarted as soon as the car is put in its first gear.

Combined hybrid systems have features of both series and parallel hybrids. They incorporate power-split devices allowing for power paths from the engine to the wheels that can be either mechanical or electrical. The main principle behind this system is the decoupling of the power supplied by the engine (or other primary source) from the power demanded by the driver. In a conventional vehicle, a larger engine is used to provide acceleration from standstill than one needed for steady speed cruising. This is because a combustion engine's torque is minimal at lower RPMs, as the engine is its own air pump. On the other hand, an electric motor exhibits maximum torque at stall and is well suited to complement the engine's torque deficiency at low RPMs. In a combined hybrid, a smaller, less flexible, and highly efficient engine can be used.

A hybrid car has many operation modes. On the highway, when the car is running on a constant speed, a combustion engine becomes relative fuel efficient. At the same time the car is driving at relative high speed. In that case the car operates solely on its combustion engine and is charging the main battery. Next is stop & go traffic in the city. In that case the car with its combustion engine is very uneconomical. This is the ideal scenario to run



Combined Hybrid Vehicle

on the electro motors and therefore discharge the main battery. At fast acceleration, the electro motor can assist the combustion engine with the instantaneous power demands. Or vise versa, when breaking, the induction power of the electro motor can assist with breaking power and re-generate electrical energy back into the main battery. All these operation modes are managed by the charge controller, combined with the power converter applying power from the battery to the electro motor.

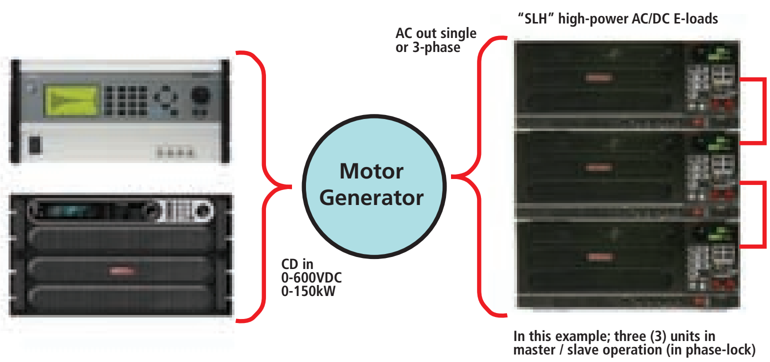
What these scenarios show is that the main battery is constantly changing from charge to discharge mode, all managed by a charge controller / power converter module. And on the other side, the electro motors, running at a moderate constant speed, either driving the car or generating electrical power to charge the battery or that same electro motor is in high acceleration mode, to start the car or slowdown the car.

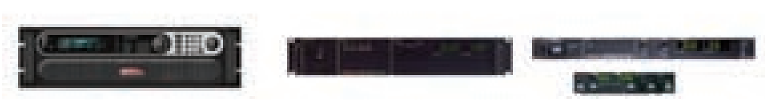
To test this charge controller / power converter module we need on one side a battery simulator and on the other side an electro motor simulator. The range of these high-voltage batteries varies from 280 to 440 VDC. Therefore a high power programmable DC power supply is required up to 100 Amps at 450VDC or more. The AMETEK model SGI provides a unique sequence programming that allows different declining voltage slopes over time at a declining state of charge based on a fixed DC current demand in battery discharge mode dynamic simulation. The electronic load simulates the battery charge mode. Also in this case dynamic simulation can be performed through sequence programming of the simulated charge input current. By changing constantly from charge to discharge mode, when at the same time the charge controller module is in some kind of a HALT chamber, simulating shock & vibration and high & low ambient temperatures, will ensure a real-life environmental test as if your hybrid car was used in the north of Sweden at winter time or in the Nevada desert at summer time.

On the other side of the charge control module / power converter module is the electro motor. With most of the hybrid car manufacturers I have encountered the use of 3-phase AC electro motors up to 380VAC. To simulate the charge process, we need a 3-phase AC programmable power supply. This AC power supply must be capable of fast fluctuating output AC voltage and variable frequency. Sequence programming can simulate both the breaking energy re-generation as well as the more steady-state high-speed charge mode. During these simulation scenarios it is important to measure parameters like, peak-current, phase imbalance, etc. Therefore a build-in power analyzer makes such a test setup easy to realize.

To test the electric drive train, the same AC or DC programmable power supplies can be used. But often more power is required. For this reason I would select an AC or DC power supply that is easy to parallel on the fly to provide that extra flexibility of additional power.

I have come across hybrid car designs were the main and only battery is the high-voltage battery. To create the standard low-voltage 12VDC power-bus, High current DC/DC-converters are used. Or in addition DC/DC-converters to create a 42VDC power-bus, to drive high power components like electronic breaks. Actuators used in electronic breaks that would run at 12VDC need to much drive current, causing the electrical wiring to thick, being thicker then the hydraulics it replaces. The introduction of these DC/DC-converters requires a lot of additional testing. On the input side is a programmable DC power supply connected to perform any margin testing and at the output is a DC electronic load connected. The advance sequencing capability in such an electronic load can simulate fast and high current demand change, like activating actuators, etc. Important is that the electronic load provides enough bandwidth to support a fast dI/dT. To support these applications, the AMETEK electronic loads are capable of 20kHz bandwidth, with a current slew-rate of 4000 A/ms.





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Lastly is battery testing. Environmental testing of batteries is crucial, because the battery performance depends greatly on its ambient temperature. This testing is very time consuming. Many daurtests at many temperature ranges. Again a combination of a DC programmable power supply and electronic load is required to simulate the charge and discharge process, but this time at relative lower DC power. The charge currents are limited to protect the battery from overheating. A nice feature AMETEK offers in this case is constant power mode, where the charge current decreases automatically when the DC voltage increases.

In all my visits to many customers I do not encounter so often that so many different power simulation and test equipment is required. Hybrid car testing is one of the few application examples where we need AC and DC power as well as AC and DC loads, in both low-voltage and high-voltage ranges. Perhaps it is good to look at a power test equipment manufacturer that can provide all needed equipment from its standard available product portfolio.