

Technology, Challenges, and the Future of Electric Drive

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Introduction

Electric vehicles of today have been largely limited to the garages of hobbyists and golf courses. After the glimmer of a mass market with the GM EV1 in 2000 it appears that electric drive is poised for resurgence. The Tesla Roadster has recently entered production, Toyota has announced plans to produce a plug-in version of its popular Prius, and GM has the highly touted Chevy Volt on the horizon supposedly in the next few years. In perhaps the biggest new yet, Israel is launching into a widespread electric vehicle program called "Project Better Place". The partnership between the Israeli government and carmaker Renault is likely to be duplicated in other areas. Other models and companies are popping up suggesting that this time we will get more than a bitter documentary to show for it.

There is a broad range of electric vehicle technologies that are being demonstrated in these upcoming projects. This begs the question, of what to expect next. Let's start by looking at the main ways that electric vehicles differ from the cars of today and then project what might be just around the bend for future EV technologies.

Challenges Facing EVs

The basics of how an EV works and the technology behind it are discussed in other information papers on the EVT website. Here the limitations are discussed in the following categories.

- Energy and power density
- Battery charging
- Lifetime performance
- System Costs

Existing internal combustion powertrains are remarkable in that they provide excellent performance in each of these categories. We can drive our cars for more than 300 miles, fill up anywhere in 5 minutes. When treated well, these vehicles can last a decade and travel hundreds of thousands of miles before they finally fall apart. This sets quite a high bar for the new EV market entrants.

Energy and Power Density

The total amount of energy that a battery pack contains translates to the vehicle range. The power is how quickly that energy can be removed, which translates to vehicle acceleration. For these two attributes there are constraints within the car of weight and volume. In the vehicle application small batteries increase range, and light batteries increase the power to weight ratio for better acceleration.

The entire vehicle is constrained by cost. More batteries are more expensive which is why EVs are typically smaller. The Tesla roadster is well placed as a high end car so a \$100k price tag is justified. As the price of batteries fall along with volume and weight per unit energy then larger electric vehicles will become economically viable.

Electric vehicles have a head start for quick acceleration due to the high torque characteristics of the electric motor. The discharge rate of batteries further enables high performance electric vehicles. New battery chemistry such as nano-phosphate cathodes is now allowing for these high discharge rates. While this opens the door for great vehicle performance range will continue to be an issue.

Battery Charging

The issue of range is one of the key limiting factors for electric vehicles. In most applications drivers cover fewer than 40 miles however the option to go further without waiting to recharge is one that drivers may be reluctant to relinquish. There are a number of different methods to address issues of range in electric propulsion systems.

The plug-in hybrid (PHEV) and extended range electric vehicle (EREV) can fall back on the existing liquid fuel infrastructure at the sacrifice of some efficiency and fuel costs. This strategy will likely dominate in the near term.

The discharge rate discussed earlier relates to acceleration, but the mirror metric of charge rate will determine how quickly batteries can be charged. The higher the rate the more energy is lost through heat. Other components such as capacitors can have very high charge and discharge rates with lower losses, but typically have low energy density. Future battery systems may combine ultra-capacitors with batteries if neither storage device has optimal qualities by itself.

Future charge systems may not even require a physical connection. Some designs for charging stations as part of Project Better Place will be able to charge wirelessly. Plans are also being developed to swap out a battery pack instead of re-charging it. The challenge for battery exchange systems is the standardization of the vehicle, battery pack dimensions and removal mechanism. If implemented, however this option offers much greater flexibility to the driver to cover greater distances without tailpipe emissions or lower efficiency.

Lifetime Performance

Every cycle of charging and discharging is a day in the life of a battery. Each battery chemistry has its own peculiarities of how different usage parameters affect its usable life. Advanced lithium ion chemistry exhibits small cycle degradation rates up to 1000 cycles with deep discharge capability. Current battery technology in automotive applications is likely to last up to 5 years. This is a step down from the current expectation for new cars.

The driving performance of electric vehicles diminishes over the lifetime of the vehicle. For example, a plug-in with 60 mile range at the showroom floor may only be 40 miles by the defined “end of life”. It is typical for any old car to show degraded performance as it ages, but the symptoms of age for an electric car may be more pronounced and take some time for customers to accept.

As with charging and performance the battery technology will be the key determining factor for lifetime. The battery management system can control the charge and discharge rates to help extend life. Careful thermal management can also reduce capacity degradation over time. High temperature in particular are more damaging for the batteries.

System Costs

While battery costs are high, and the lifetime is relatively shorter than traditional powertrains, there must be some more creative ways to address the burgeoning cost of the vehicle. Electric sports cars are a good early market, but to make dent in gasoline consumption there need to be many more electric vehicles on the road.

New innovations in the business plan for auto sales can already be seen in Project Better Place. Instead of the driver owning the entire car, the battery pack will be leased and swapped out interchangeably by a service provider. The driver will pay a monthly fee for this service instead of taking on the risk of battery system repair.

Conclusions

As new electric vehicles enter automotive markets in a big way, companies will learn much more about warranty costs, lifetime, vehicle performance over time, and user satisfaction. The growing market for electric drive will continue to spur innovation in battery technology and charging infrastructure. We can see where some of the challenges that have yet to be overcome. Perhaps the largest one will be non-technical. The biggest challenge that remains for the acceptance of electric vehicles is simply education of the driving public.