

Looking at Cars 100 Years in the Future

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Abstract- One hundred years from now, vehicles will be powered by a combination of motor, capacitor, and wireless technologies. Electric-motor-driven vehicles (EVs) will be widely used and will be linked to the electric power system infrastructure. The vehicles will operate through frequent electric charging, as is the case with electric trains. Long-life super-capacitors will play an important role in the future for charging of EVs.

Wireless power transfer based on magnetic resonance is an extremely important technique. In a laboratory experiment, this technique enabled a power transfer with more than 95% efficiency at a distance of 1 m. One hundred years from now, this technique will be greatly improved; e.g., it could be possible to have a 10 kW power transfer over a distance as long as 10 m. This level of improvement will drastically change how cars are powered.

In addition, to improve the energy efficiency and safety of future EVs, the implementation of novel motion control techniques is crucial. These techniques would be based on the excellent controllability of electric motor.

The combination of electric motors, super-capacitors, and wireless power transfer eliminates the requirement for engines, high-performance Li-ion batteries, and large, quick charging stations. This approach is also achievable and suitable for large-scale development of future vehicles.

I. INTRODUCTION

The technology in gasoline engine cars is approximately 100 years old, and is now being replaced in the transition to electric vehicles (EVs).

It is a common misconception that EVs require “refueling” (i.e., recharging) stops that deliver a large amount of energy in a short time, similar to a gasoline-powered vehicle, despite the fact that the two energy forms are completely different. This mindset of focusing on the similarities also makes it difficult to visualize the electric equivalent of a technology in which gasoline is atomized in an urban area, and cars “breathe” the vapor in before running. However, an electric analogy of this type is substantially possible for EVs.

It is generally accepted that the current driving range of EVs is insufficient and that short-distance usage must be accepted. In addition, quick-charging, high-performance lithium (Li)-ion batteries are thought to be the key technology. However, an even better technology is available that has only a few of the disadvantages of a Li-ion battery-powered system.

II. MOTOR/CAPACITOR/WIRELESS TECHNOLOGY

The motor/capacitor/wireless technology operates very differently from one based on a Li-ion battery. The new technology would receive energy directly from the electric power infrastructure, like trains do. In this context, the disadvantage of the limited range of one battery charge will be minimized. Under this scenario, the future car society would be totally different from one in which cars have a large operating battery. Cars would not carry a large amount of stored energy with them, but instead would receive energy slowly and occasionally from the infrastructure.

To achieve such a scenario, it will be important to incorporate charging using wireless power transfer across a distance of several meters.

A careful analysis reveals that how to supply energy to a car and how to use that energy are completely different matters. However, as long as batteries are used, the two are strongly linked, and the performance of the battery is the deciding factor in the car’s range. It is important to look beyond the use of the battery as soon as possible.

If future cars are instead connected to the electric power infrastructure, the current situation of the range of a car always being limited by a single battery charge will instead shift to a focus on the distance that can be traveled when away from the infrastructure. Cars that can run based on frequent wireless charges, similar to trains, will become quite common. The shift from a battery-powered technology to one with a capacitor and wireless power transfer will be accomplished, freeing EV owners from the responsibility of frequent charging.

In conjunction with the above technology, advanced motion control using the superior control characteristics of electric motors can be realized.

These superior characteristics are as follows:

A. Motor: True advantage of electric vehicle

The advantages of EVs are similar to those of electric motors. ICVs cannot realize the following three essential aspects of electric motors: (1) quick torque response, (2) distributed motor installation, and (3) tractable motor torque.

Through application of adhesion control quickly to reduce motor torque against micro scale tire slip, tire slippage is less likely to occur. If the same performance as previously is sufficient, adhesion control allows the possible mileage driven to become several times longer owing to the use of low-loss tires with a narrow width.

In other words, the energy used by an electric car decreases drastically with the use of motion control to utilize the very quick torque response of the electric motor. This reduces the need to carry a large battery. In fact, such motion control is the biggest advantage of EVs, because the motion control increases safety and ride comfort. Attitude control such as active suspension, yaw, roll, and pitch motion control using in-wheel motors will be the common technique 50 years from now.

B. Capacitor: Frequent charge

The necessity of having a 500-km high-performance battery for a car has not been proven. Rather than use the same concept as conventional gasoline cars (i.e., to accumulate many expensive batteries), the best way to use electricity is to use it as soon as generated. It is not smart to save it for later use, as evidenced by the fact that electricity is sent long distances of several hundred kilometers to its point of use using high voltage power transmission lines.

Although electric cars could be run similarly to electric trains, they do not have identical requirements. Cars require enough energy storage to run, e.g., 10 km, but do not need to be able to run 500 km.



Fig. 1. C-COMS driven only by super-capacitors.

For such an application, instead of using short-life batteries, physical battery “capacitors” will be used that can tolerate millions of charge-discharge cycles for transferring electricity in and out frequently. As an example, the small electric vehicle C-COMS of our laboratory demonstrates the high performance of a capacitor, in which an approximately 30-s charge allows the operation of the vehicle for more than 20 min.

C. Wireless: A promising technology

There are 100–200 V electricity outlets with 10–15 A of current in many locations in Japan, and frequent charging is already possible at any time. Intensive research and development of a wireless power supply has been carried out, and such a supply will reach the commercial market in several years. The present technical level for transmission of electricity by wireless mode is around 95% efficiency between the transmission and the reception coils at a distance of 50 cm – 1 m. This distance can be extended to several meters using simple repeating coils, which enable power to be fed to cars for operation.

The desired target is to send 10 kW of power across a distance of 10 m when the system is installed under roads. The present technical level is not enough to achieve this, but the technique is brand new. It will progress greatly over the next 100 years and will have a drastic impact on the car world.

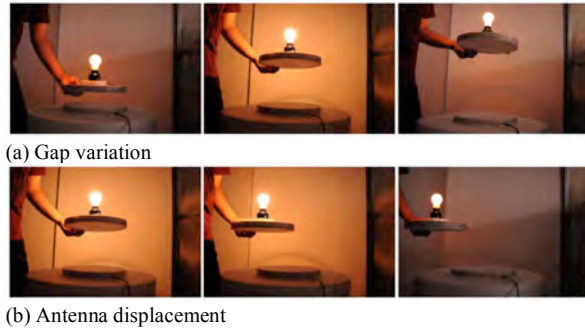


Fig. 2. Robustness of wireless power transfer system against gap variation and antenna displacement.



Fig. 3. Transfer distance extension using repeating antennas.

It is likely that the cost to society to provide a widely available wireless power supply infrastructure will be much smaller than that for an infrastructure based on large-capacity batteries. In addition, the political risk caused by the difficult resource problem of lithium supply can be avoided.

Development of a wireless power supply infrastructure needs careful examination, including establishment of

standards and human body protection. The entity who wins the race to implement wireless power supply technology will control the car society in the future.

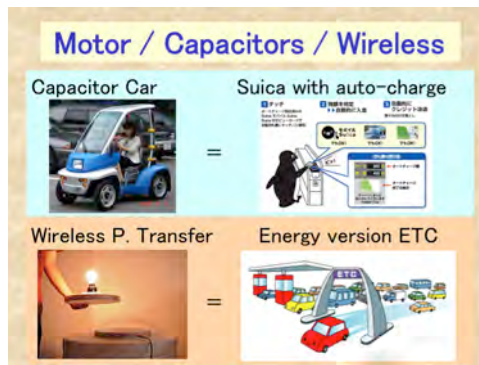


Fig. 4. Concept of motor/capacitor/wireless technology.

One hundred years from now, the Li-ion battery electric cars that now disturb the world will be obsolete. Along with gasoline cars and fuel-cell-powered vehicles, they will be seen only in museums.

III. WHY COMMON WISDOM IS SOMETIMES WRONG

The concept of a capacitor EV is similar to that of the “automatic-charge Suica,” and the wireless-feeding “ETC for energy.” In the old days, the Suica payment card for railway system in Tokyo area could be charged only at large rail stations, but gradually things changed to allow it to be charged anywhere. In addition, the system evolved to allow customers to reload the card with several different amounts of money. One can say the same thing for capacitor vehicles. Even if not all infrastructures are established at the start, as was the case for Suica, it is possible to start small and proceed from there.

Cars today are completely information-oriented, and there are many people who cannot drive cars without an electronic navigation system connected wirelessly to the infrastructure. There is no good reason why energy should not also be independently located relative to its infrastructure. Like the Li-ion battery electric car, there are some other technologies that are popular, but have their shortcomings:

A. Fuel cell vehicle

The current popularity of the Li-ion battery-powered car may prove elusive in actuality. At one time, a fuel-cell-powered vehicle was thought to be the ultimate car, and it was said that those who won the competition to develop it would control the car society. However, the development of a catalyst to replace platinum and the establishment of a hydrogen-fueling infrastructure have proven difficult, and the spread of fuel-cell-powered vehicles has not advanced as expected. It may become a model for a highly praised technology that did not go so well. A drastic switch to a

short-distance compact car appears to be necessary; thus, the fire of fuel-cell-powered vehicles must not be extinguished.

B. Permanent magnet motor

The permanent magnet is promising in many ways, but presents other issues. It drastically improved motor performance and contributed to today's wealth of electric and hybrid vehicles. However, it requires the use of dysprosium, which is available only from China. The continued use of dysprosium in addition to neodymium for high-temperature applications therefore depends heavily on the status of trade relations with China.

The development of motors that do not use permanent magnets (dysprosium in particular) is important for the future. Fortunately, several projects supported by NEDO in Japan for rare-earth-free or rare-earth-saving motors have been successfully completed and have attracted much attention.

C. Vehicle-to-grid system

Vehicle-to-grid (V2G) systems are based on the concept that EVs with Li-ion batteries can be charged at night and return some of the stored power to the power system during the day when there is peak demand for electricity and they are parked. V2G has been widely praised as a part of the smart grid, but battery life immediately becomes an issue when it is recharged so frequently. In addition, some car owners may refuse such a use of their car batteries unless they are compensated for the power that is provided.

The government has realized the benefits of implementing a V2G system and is currently examining the possibility of using 10% of the charged energy. If this limited approach is taken, one cannot expect a great contribution of V2G power to the power system. To create a society in which cars do not depend on battery usage is the first thing that must be done. This can be promoted by removing batteries from cars, which will make the price of cars much lower.

IV. ENERGY AVAILABILITY 100 YEARS FROM NOW

Electricity is likely to be used for decades to come as a medium of application for a wide variety of energy sources, because it can be controlled with high precision and efficiency.

However, too much reliance on photovoltaic power generation and wind-generated electricity threatens the overall stability of the electric power system. It is an illusion that the necessary power can be averaged if a large amount of it is generated from these sources. There are many times that it is dark on the scale of, e.g., the entire Kanto district including Tokyo, and the wind starts and stops many times a day.

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Wind power generation in particular is a problem. The wings of a 5-MW station are several-fold larger than the size of a jumbo jet airplane. The ability to generate power takes 10% of the facility's capacity or approximately 500 kW. In addition, a huge battery bank is necessary, and there is also the problem of battery life.

If the goal is to replace a generator of 1,000 MW, then it is necessary to construct 2,000 wind power stations. If this were done over the course of a year, 40 such stations would need to be built in a week. If the goal is to replace 20% of Tokyo Electric Power Company's power usage with wind sources, then 500 wind generation stations per week would need to be constructed.

The problem merely of finding locations and materials for such an effort is impossibly difficult. Regarding solar power, the mega solar station's power production ability is only 1/10 that of wind power. Installing photovoltaic batteries on home roofs and relying on wind-generated electricity are acceptable in remote islands, but these sources are not sufficient to replace large-scale thermal or atomic energy. It may take 20–30 years before those who focus only on wind and solar energy realize this fact.

It is unclear what the next 100 years hold for energy generation; perhaps new sources such as magma or volcanic power generation will be added to the mix. Such sources will need to be obtained from depths of greater than 10 km to avoid competition with hot springs.

It would be wise to pay more attention to the infinite energy available beneath the earth's crust, rather than watching only the sky. Unsolved technology dilemmas for using magma or volcanic power as a stable source of power generation include the development of new materials that can tolerate elevated temperature and pressure. However, the significance of the current challenge is to provide energy in 2030, as compared to thinking about energy sources in 2100. The hope is that 100 years from now, humans have secured an infinite energy source.

V. CONCLUSIONS

There have been many times that the commonly held wisdom was incorrect, but people did not question it. It is better to think carefully and calmly to avoid getting caught up in popular thinking. The promoters of wind-generated electricity must provide more information to reduce misunderstandings about its true potential. Even if the potential for wind energy is large, it is a difficult energy source from an engineering point of view. There must be no hesitation in correcting course again if errors are noticed in popular thinking.

APPENDIX CAPACITOR BUS IN SHANGHAI

The concept of "capacitor car" has already been employed in city buses in Shanghai; these buses provide a stable operation, as shown in App. Figures 1 and 2. The city operated about 30 buses at the Shanghai Exposition in 2010. This system would be extremely suitable for bus transport in most big cities in the world.



App. Fig. 1. Capacitor bus (left) and battery bus (right) at Shanghai Expo.



App. Fig. 2. A large-scale battery exchange station. (Without this, battery buses cannot be operated.)



App. Fig. 3. Illustration of charging an EV at a bus stop.
(Charging duration: less than 30 s)

Electricity development consents have become ubiquitous in recent times. Further, there exists an accessible charge infrastructure. Train-like EVs based on frequent recharge can be presently accomplished; however, their full potential is hindered by the large battery requirement. In a capacitor vehicle scenario, the range can be redefined as the distance from the infrastructure at which car owners do not feel any significant difference in their comfort level.

In contrast to capacitor buses, battery buses need a huge-scale battery exchange station as is shown in App. Figure 3, because it takes a long time to recharge battery buses. Battery buses are not a realistic solution for a metropolitan area.



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