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Characteristics of CHAdeMO Quick Charging System

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Abstract

In the transportation sector, electric vehicles (EV) are expected to play an instrumental role in reducing carbon dioxide emissions due to their eco-friendly and high-energy efficiency features. Further, in light of recent plans that have been announced globally to introduce the EV, it is believed that the spread of this new technology will be inevitable.

Although EVs were on track to become widespread many times in the past, they never did take off and the underlying reason(s) why must be investigated so as to not repeat the same mistakes that had prevented the past dissemination of this revolutionary new technology.

The major factor impeding the spread of EVs is the limited capacity of the lithium ion battery stored inside the vehicle. Although, there have been price and performance improvements allowing for widespread application to cell phones and computers etcetera, the exorbitant costs make substantial on-board battery enhancements prohibitive. Although the present infrastructure is unable to support electric vehicles, it is believed that with sufficient upgrades such facilities can be made useful and help pave the way for reduced battery capacity. In developing the design of the CHAdeMO standard quick charger, the following past infrastructure challenges were addressed.

Keywords: Quick charger, CHAdeMO, Infrastructure, DC charger

1. Necessary driving range for EV users

In order to satisfy EV users, exactly how long should the capacity of the on-board battery be?

This issue was explored via a questionnaire distributed to general automobile drivers. The answers received were 200 to 300km, which revealed that the expectations being held towards EVs were the same as those for gas-driven vehicles. About 40 to 50kWh would be needed for a battery to achieve this, and on average the current lithium ion battery price would go up to four to five million yen per unit making it difficult to achieve market penetration.

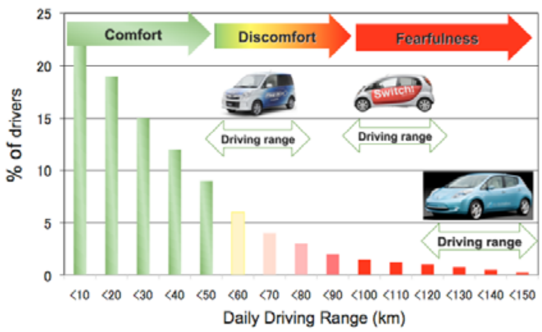

Figure 1: Typical distribution of daily driving range

Although common knowledge, a sample vehicle's daily driving distance has been provided in Figure 1. The average daily driving distance varies from region to region. Even in the United

States, where driving long distances is common, it is said that the average daily driving distance is below 50km. Theoretically, a capacity of 100km should be sufficient to meet the needs of most drivers. However, when we drive an EV and find that the remaining battery life is less than 50km, we become upset.

Tokyo Electric Power Company introduced a trial EV with a capacity of 80km in 2007. Figure 2 is the driving record of the EV which took place in Yokohama in October 2007. The area is compact and the gas vehicle's daily driving distance is around 40km allowing for the EV to easily cover the entire area. However, the driving distance covered in October did not reach 200km. Although the driver had been informed that the vehicles battery capacity was more than sufficient, due to worries that he would run out of power, he was unable to take advantage of this.

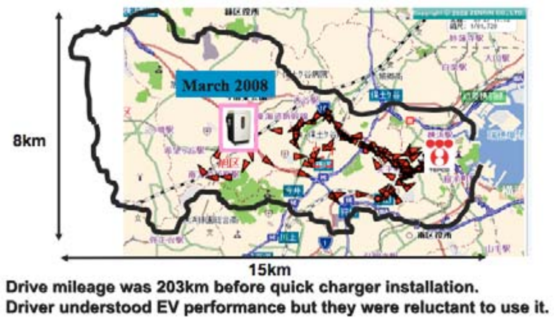

Figure 2: Driving record in October 2007

To relieve this anxiety, we installed a quick charger and then as shown in Figure 3, car usage dramatically increased with the monthly driving distance exceeding 1400km, which was more distance than normally covered by gas vehicles in the same area.

Of notable mention is that the driver hardly used the quick charger. If so, why did the driving distance suddenly increase to the extent that it did? It was all psychological. In other words, the driver, knowing that he could charge up the car's battery at any time gave him peace of mind resulting in longer (and probably more relaxed) drives.

Hence, we discovered that quick chargers contribute to both the charging efficiency and increasing driving distances. However, even if the chargers are actually not used, the nearby installation of quick chargers provides drivers with a feeling of comfort which induces users to maximize EV usage.

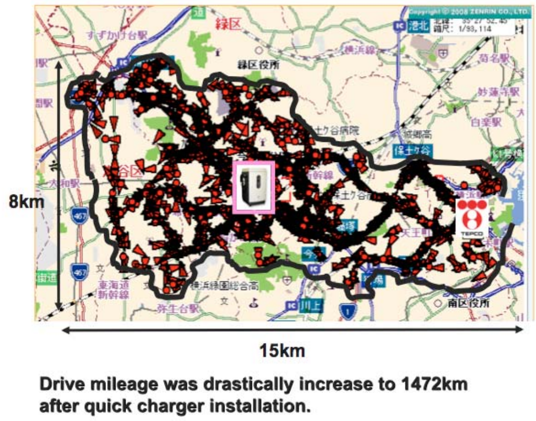

Figure 3: Driving record in July 2008

One negative opinion often raised is that the cost of quick chargers is too high. However, unless quick chargers are frequently used, it is not necessary to install many chargers. Moreover, fully leveraging the high performance capacity of the batteries will lead to reasonable cost benefits for all of society.

2. Optimal output for public charging infrastructure

In past EV trials, cases where quick chargers exceeded 40kW were rare.

In California, many charging infrastructures were made because of the ZEV mandate. This state has the most developed infrastructure and the largest number of EVs in the world. Even now, hundreds of public charger stations have been installed primarily in San Francisco and Los Angeles with an average individual output of around 5kW.

In 2000, in the Tokyo area, one problem was that there were only six charger stations with an individual output of only 2.5kW.

The problem with these kW chargers is that it takes over an hour to charge 50km worth of driving distance. Drivers cannot endure waiting for more than an hour. If EVs are charged at night, they have six to eight hours to charge. So, low-power chargers are not a problem, but quick chargers are needed to serve as auxiliary chargers while drivers are on the road during the day.

Since the cost of high-output chargers is high, the desired public charging infrastructure's output is determined by achieving a healthy balance between its charging rate and the costs shown in Figure 4. In order to be able to reach a 50 to 60km charging capacity within ten minutes, an output of

40 to 50kW is needed assuming that the average power consumption of EVs is around 7km/kWm.

On the other hand, basically, the cost of a charger increases in proportion to output. However, if the output of a charger increases, this may necessitate having to upgrade the electric power supply system. In actuality, given that enhancing the output would require redoing the design to make it safer, the charger cost would end up being higher than the output proportion. Although there is a direct correlation between enhanced output and minimized charging time, 50kW is the saturation point from where increasing the output to decrease the charging time would no longer be economical.

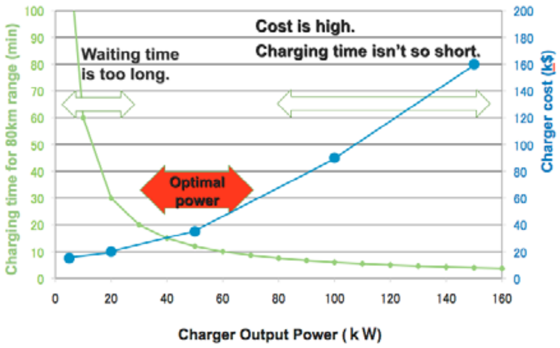

Figure 4: Optimal output for public charger

3. Charging method to prevent battery degradation

Another concern is that quick chargers contribute to battery deterioration (a capacity decrease) of which the dominant factors are over voltage and high temperature. Deterioration occurs when the battery's voltage level or temperature increases to the point where the decay of electrodes begins to accelerate.

In recent EVs, a battery management unit (BMU) always monitors each battery cells' voltage in addition to the lithium ion battery's entire system to prevent it from exceeding safe voltage levels.

The battery temperature is a key component of the quick charging process. When the flowing current is large, the battery temperature increases due to internal resistance. However, since the BMU also monitors the battery temperature, if the charger current is controlled in step with battery temperatures, battery deterioration can be avoided.

Since the charging speed can vary depending on battery characteristics and their circumstances, if the charging procedure is standardized, the charging current can be determined based on the lowest-performance battery and the worst environment conditions for usage. Under such a standard, the public quick chargers' original purpose cannot be achieved and the charging time cannot be shortened even if the battery performance is improved in the future.

As described in Figure 5, the CHAdeMO standard quick charger's control of the charging current receives instructions from an EV via the CAN bus, and the quick charger sets the current to meet the command value from an EV. This mechanism allows for optimal and speedy charging in accordance with battery performance and the conditions of the charging environment. What we are proposing for the CHAdeMO standard charger is a signal transaction mechanism between the EV and the charger to ensure safety. The interface shapes of the connecters also need to be standardized to accommodate all types of EVs as public chargers.

The originality and ingenuity of charger designers and manufacturers have not been incorporated into the standardization. In other words, minus the interface geometry, the AC/DC converters' circuit design and the connectors' hardware is all left up to the charger manufacturers' preferences.

As part of the business development of quick chargers, the certification of EVs and billing methods will be taken into consideration. However, since the required conditions of reliability of these services differ from the CHAdeMO standards of maintaining tight safety controls, it would be appropriate to have these systems developed independently.

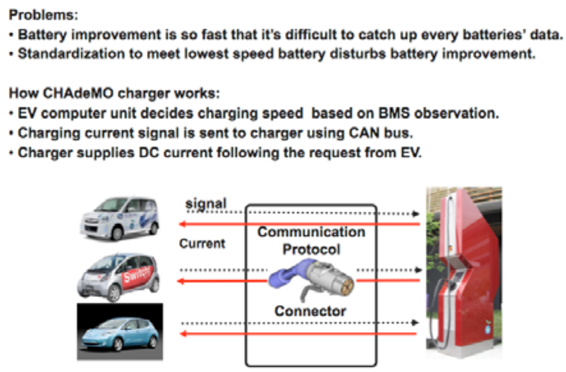

Figure 5: CHAdeMO quick charger

4. Impact on electric power grid

Many people are concerned about the impact to the electric power grid since the output of a quick charger is 50kW.

They are operating under the misconceived fear that the future proliferation of EVs would lead to peak load increases due to the simultaneous usage of quick chargers during the daytime. Further, they are afraid that if battery development leads to an increased number of on-board batteries, the usage frequency of high-output chargers will also increase resulting in having to invest huge amounts of cash towards distribution grid enhancements. This concern arises from the idea that EV usage is similar to gas vehicles.

The charging of EVs will be conducted mainly at night by utilizing a low-output charger. Therefore, as stated before, quick chargers are not used that often. So it is unlikely that the electric power grid will find itself in a situation where it will be unable to bear the burden due to simultaneous quick charger usage. Furthermore, when quick chargers are installed, the capacity of the distribution grid needs to be taken into consideration. As shown in Figure 6, when installing quick chargers, electricity supply facilities that are able to handle more than tens of thousands of ultra high voltage should be chosen. In such facilities, 50kw is only a small percentage of the entire receiving capacity and thus has little if any impact. Even in facilities being supplied with a few thousand volts of electricity, the installation of quick chargers is possible. One problem is the case where quick chargers are installed under low-voltage distribution grids such as residential areas. However, in the home, the need for quick charging is practically non-existent.

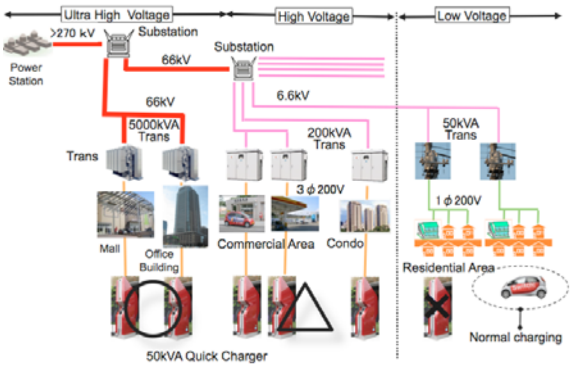

Figure 6: Install point of quick charger on power grid

Some people worry about the inconvenience that would ensue if the future development of the battery's capacity reached the point where it would take a low-output charger inside the garage over 10 hours to achieve a full charge during the nighttime and are not confident that distribution grid enhancements could solve this problem.

However, this is another misconception of the mechanisms that govern EV usage. Even if a gas vehicle can run more than 300km on one fuel charging, the average daily driving distance is still below 50km. Even if the EV's battery capacity were increased to 300km in the future, it would not significantly alter one's daily driving distance because the primary determining factors are one's daily habits and lifestyle not the size of the fuel tank or battery.

The amount of electricity needed to drive 50km is around 7kWh. Assuming that the EV is charged every night, they can be charged under less than four hours even if a low-capacity 2kW on-board charger is used. Some drivers may worry about the battery running out, but this shouldn't be a problem if a sufficient quantity of electricity is charged overnight for the next day. If a driver absolutely insists on having a full charge, he or she can always use the nearest quick charger.

It is in this way that the installation of a widespread quick charging infrastructure can curb the need and desire to increase the output of average chargers at home. In Figures 7 and 8, we estimated the impact to the low voltage distribution system when the percentage of EV users is 5% and 20%. If the output of an on-board charger can be maintained at around 2kW, there is no need to enhance the distribution grid even if EV's share reaches 20%.

On the other hand, if we increase the output of the onboard charger, even at a 20% dispersion rate, this will lead to distribution grid enhancements and ultimately to increased costs connected to EV usage.

When it comes to the public installation of quick charging infrastructures, a balanced approach can achieve remarkable results in curbing the need to increase the capacity of facilities for EV nighttime charging and the impact to the low-voltage grid for that time when EVs become ubiquitous.

Figure 7: Impact on distribution grid (5% dissemination)

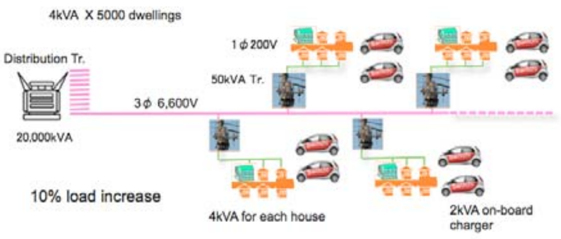

Figure 8: Impact on distribution grid (20% dissemination)

5. Conclusion

Although there were many times when EVs appeared to be gaining popular momentum, they never did fully take off.

Some of the reasons were their battery capacity which limited the distance one could drive on one charge and the existence of poor charging infrastructures to support this new technology.

Especially, there was a lack of consensus among automakers, utilities and governments to build a suitable public infrastructure. As a result, a small number of charger installations, slow charging speed and insufficient standardization caused trouble for EV users.

In the early stages, it is important to minimize the total cost of the charging infrastructures. In order to quickly achieve this objective, incorporating already existing normal AC outlets with public quick chargers is the most reasonable option.

As shown in Figure 9, the cheapest, low power electric equipment is most useful for the home and office charging. However, in the public arena, quick chargers will serve an excellent supplementary role in compensating for the slow charging infrastructures allowing for maximum efficiency.

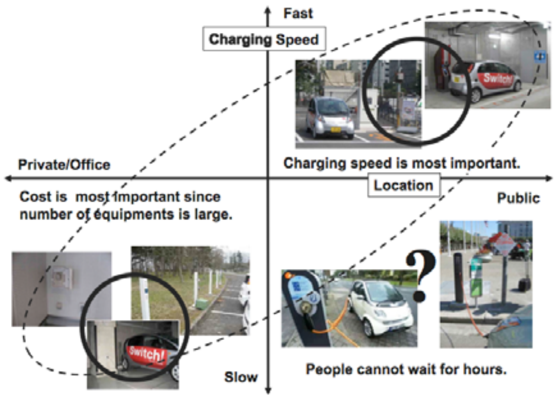

Figure 9: Impact on distribution grid (20% dissemination)

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