Study on the Charging Technology Roadmap and Development Trend of Electric Vehicle

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Abstract—Electric vehicles (EV) are important to the successful achievement of carbon peaking and carbon neutrality goals, and the development of electric vehicles must accelerate the construction of charging and switching infrastructure and improve the level of charging infrastructure services. In this paper, the roadmap and development trend of electric vehicle charging technology are studied. The three charging technology roadmaps of EV conduction charging technology, wireless charging technology and power exchange technology are analyzed, and the future EV charging technology development trend is analyzed in terms of AC charging, DC charging, power exchange technology and wireless charging technology. This paper concludes that: in the future, AC charging is still the main energy replenishment technology in China, and the proportion of orderly charging will gradually increase; DC charging may be polarized, with high-power charging in the public sector and DC low-power slow charging in the private sector; power exchange technology is an important supplement for electric vehicle electric energy replenishment, and is expected to tend to standardization and shared development in the future; wireless charging technology is still in the exploration stage, and small-scale Commercial operation will take some time. This paper has certain reference value for the technical development planning of electric vehicle enterprises and the formulation of relevant government policies.

Keywords- Electric vehicle; Charging technology; Technology roadmap; Development trend

1 INTRODUCTION

Electric vehicles integrate electric power, new materials, and transformative technologies such as the Internet, big data and artificial intelligence, promoting the transformation of vehicles from simple transportation to mobile intelligent terminals, energy storage units, and digital space, driving the transformation and upgrading of energy, transportation and information, and communication infrastructures, promoting the optimization of energy consumption structure and the improvement of the intelligent level of the transportation system and urban operation, and being of great significance to the construction of a clean and beautiful world. In recent years, the world's major automotive countries have strengthened their strategic planning, and enhanced policy support, and multinational automotive enterprises have increased their R&D investment and improved their industrial layout [1].

The development of electric vehicles is the only way for China to move from a large automotive country to a strong automotive country and is a strategic initiative to cope with

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climate change and promote green development. In recent years, relevant government departments and electric vehicle enterprises have been accelerating the development of new technologies such as fast charging and wireless charging to improve the charging efficiency of electric vehicles, and actively promoting the construction and popularization of fast charging piles [2]. At the same time, the electric vehicle charging technology is also developing steadily, and the electric vehicle enterprises represented by BAIC and Azera are trying the mode of "tram separation" and exploring the development of electric vehicle charging technology [3]. Based on this, this paper examines the roadmap and development trend of electric vehicle hair charging technology development to provide a reference for the development planning of electric vehicle charging technology developers and relevant management departments.

2 ELECTRIC VEHICLE CHARGING TECHNOLOGY ROADMAP

At present, there are three main modes of charging electric vehicles: conduction charging technology, wireless charging technology, and power exchange technology [4].

2.1 Conductive charging technology

Conduction charging refers to a technical means of using wires to connect electric vehicles and charging facilities to form a conduction loop for charging. At present, almost all of the electric vehicles of each OEM use DC charging and AC charging for charging, and the technology becomes and is commonly applied; the future direction of the conduction charging technology field mainly focuses on high-power charging technology, and the promotion and development of this technology can significantly alleviate consumers' "car anxiety".

(1) DC charging technology

DC charging refers to the direct conversion of AC power from the grid to DC power through the charging set up to the vehicle's power battery. Most of the DC charging devices on the market are concentrated around 120 kW, and EVs can be charged more than 80% in 30 minutes. Because of this, DC charging is particularly suitable for scenarios requiring a fast recharge, such as city buses, sanitation, and logistics vehicles, cabs, etc. The disadvantage is the high cost of the product; due to the high output current when charging the EV, the charging process will be accompanied by a rise in battery temperature, which may lead to a reduction in the rated capacity of the power battery and irreversible damage to the battery. The flow of DC charging is shown in Figure 1. The charging pile and EVP are connected, the charging control unit is activated by identifying the communication protocol, the vehicle starts charging, and the EV sends an interrupt signal to end the charging process after the charging is completed.

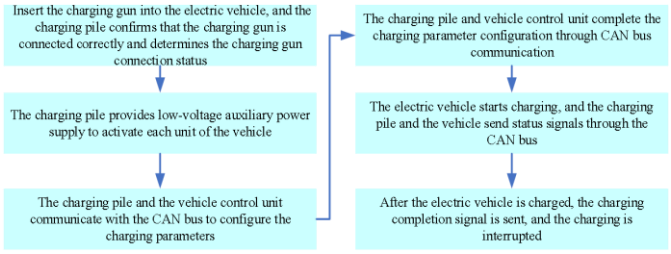

Figure 1. DC charging flow chart

(2) AC charging technology

The power battery of a new energy vehicle can only receive DC charging itself. When the external access to the electric vehicle is AC, it needs to go through the process of AC to DC conversion by the vehicle charger before charging the power battery. AC charging facilities occupy a small volume, are simple to operate, and easy to install, but their charging speed is slow, and it takes about 6-8 hours for an electric vehicle to be fully charged. The process of AC charging is shown in Figure 2. After the EV is connected to the charging facility, AC power is transmitted to the vehicle charger through the charging facility and charging connection device, which is converted into DC power for charging the power battery after rectification and filtering by the vehicle charger, and the EV sends out an interrupt signal to end the charging process after the charging is completed [5].

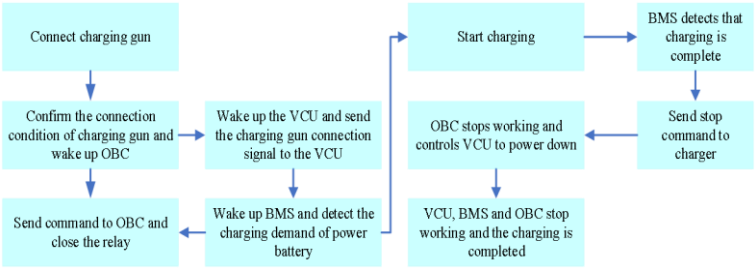

Figure 2. AC charging flow chart

(3) High power charging

As the range of electric vehicles increases, the battery capacity and charging time also increase. For electric vehicles, it is urgent to solve the charging time problem, and high-power charging technology has emerged. The industry defines charging power greater than 350 kW, voltage up to 1 000V, and currents up to 350A as high-power charging [6]. In recent years, many domestic and foreign car companies, and suppliers, such as Tesla, Star Charging, and Tesco, have been actively developing high-power charging technologies. Among them, the latest super-fast charging technology of North Energy Vehicle can achieve a maximum charging power of 280 kW and a range of 300 km in 10 min; the fast-charging system of Porsche Mission E can reach a maximum charging power of 350 kW and a range of 100 km in 4 min. On January 15, 2021, the "China Electric Vehicle 100 Conference" was held in Diaoyutai, Beijing, at which GAC officials said that the first AION V with graphene batteries has a maximum power of 600 kW. high-power charging technology needs to focus on safety and durability, and fast charging will

lead to a sharp drop in the potential of the negative electrode of the battery, which will not only bring problems to battery life but also safety.

2.2 Wireless Charging Technology

Wireless charging technology for automobiles mainly realizes contactless transmission of electricity through electromagnetic induction, magnetic field resonance, radio waves, and other principles. Based on the principle of electromagnetic induction, a coil is installed at the end of the wireless charging device and one at the end of the electric vehicle, and when a certain frequency of the alternating current is applied to the primary coil, a changing magnetic field is generated. The conversion efficiency is high, but the charging can only be done at a single point, and the distance of power transfer is short [7]. The magnetic field resonance wireless charging device consists of an energy transmitting/receiving device, which can complete the charging action when the charging device and the electric vehicle have the same resonance frequency; its electric energy transmission distance is long, which can realize one-to-many way charging and does not require precise alignment, but its energy loss in transmission is large.

Wireless charging mode is to bury the transmitting coil into the ground, which does not occupy the above-ground space and has no exposed interface and has the characteristics of safe operation, convenience, and flexibility. Wireless charging technology mainly has three methods: electromagnetic induction, magnetic field resonance, and microwave wireless. The working principle of the electromagnetic induction charging method is to charge the electric vehicle by generating alternating current through electromagnetic induction. The electromagnetic induction charging method requires a high level of electric vehicle placement, so how to ensure that the deviation of the electric vehicle in both horizontal and vertical directions is controlled within 200mm~300mm is the major difficulty of the wireless charging technology. Compared with electromagnetic induction, magnetic field resonance can be used for medium and long-distance transmission in practical applications. The charging method of magnetic field resonance does not require high accuracy of coil position, which is beneficial to the establishment of charging equipment [8]. Microwave wireless charging technology transmission distance up to 1000mm, this method is generally used for long-distance directional transmission, the disadvantage is that the output power is very low, the transmission speed is slow, and its efficiency is much lower than the electromagnetic induction type and magnetic field resonance type charging efficiency, so far microwave charging technology has not been widely used in the field of wireless charging.

The wireless charging system equivalent circuit is shown in Figure 3, and the equivalent circuits and Kirchhoff's voltage law are shown in Equation (1) [9].

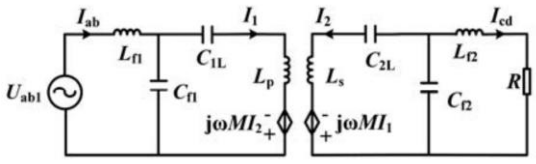

Figure 3. Wireless charging system equivalent circuit

$$\begin{bmatrix} a & b & 0 & 0 \\ b & c & d & 0 \\ 0 & d & e & f \\ 0 & 0 & f & g \end{bmatrix} \begin{bmatrix} I_{ab} \\ I_1 \\ I_2 \\ I_{cd} \end{bmatrix} = \begin{bmatrix} U_{ab1} \\ 0 \\ 0 \\ 0 \end{bmatrix} \tag{1}$$

The resonant frequency of wireless charging system should meet the requirements of Equation (2), namely

$$\omega = \sqrt{\frac{1}{L_{f1}C_{f1}} + \frac{1}{L_{V1}C_{f1}}} = \sqrt{\frac{1}{L_M(C_{V1} + C_{V2})}} \tag{2}$$

Where ω is the resonant frequency, L_{V1} is equivalent inductance, C_{V1} and C_{V2} are capacitance.

Through experiments, the relationship between output current and operating frequency under different load conditions is shown in Figure 4. It can be seen that the constant current output can be achieved for different frequency, but the output current will be large for some frequencies.

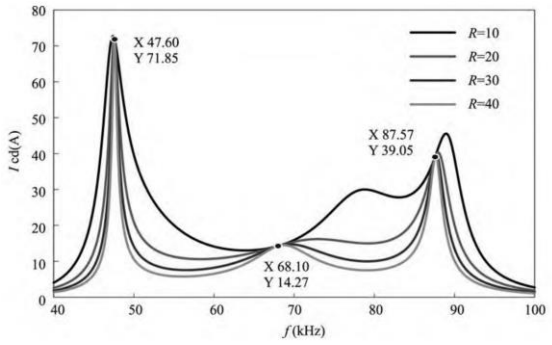

Figure 4. The relationship between output current and operating frequency

2.3 Power Exchange Technology

In the process of using new energy vehicles, a series of problems may be encountered including battery capacity decay, shortage of charging piles, etc., and power exchange technology comes into being. This technology refers to the centralized storage, centralized charging, and unified distribution of a large number of batteries through a centralized charging station, and battery replacement service for electric vehicles in the battery distribution station or a combination of battery charging, logistics deployment, and battery replacement service, which can theoretically realize uninterrupted operation of electric vehicles. To a certain extent, the service life of the power battery can be extended, and safety hazards can be eliminated at any time. However, unlike public charging piles, this method implies high construction and operation costs.2020 From August 12 to 13, 2020, the EVSC Electric Vehicle Sub-Committee held the 2020

Standards Review Meeting in Shenzhen, in which the GB/T "Safety Requirements for Electric Vehicle Battery Exchange", a recommended national standard drafted by BAIC New Energy, Azure, and CAC, passed the review. The development of the standard will provide guidance for the healthy and safe development of the power exchange electric vehicle industry. Figure 3 shows the Azera car exchange station, which takes only 3 to 5 minutes to replace a fully charged power battery.

Figure 5. Azera Vehicle Exchange Station

There still seem to be more technical bottlenecks in electric vehicle charging technology.

(1) Compared with traditional cars, the charging time and range of electric vehicles are problems that need to be solved, and there is no mature technical solution for high-power charging either at the end of the grid or at the end of electric vehicles.

(2) The huge gap in infrastructure such as the number and scale of gas stations with conventional cars is a bottleneck that electric cars must overcome, and charging facilities need to be built reasonably and effectively to overcome the mileage anxiety about electric cars.

(3) The charging technology for electric vehicles should be a symbiotic ecology, with conventional charging, fast charging and wireless charging forming an energy internet.

3 ELECTRIC VEHICLE CHARGING TECHNOLOGY DEVELOPMENT TREND

3.1 For a period of time in the future, AC charging is still the main energy replenishment technology in China, and the proportion of orderly charging will gradually increase.

By the end of 2021, about 56.2% of private charging piles in China's charging infrastructure are AC charging piles, and about 43.8% of public charging piles, of which about 25.9% are AC public piles. Overall, the proportion of AC charging piles in China's charging infrastructure is about 82%. Due to the low charging current of AC charging piles, the damage to the power battery is small and the safety is high, it will still be the main force in China's charging infrastructure to support the replenishment of electric vehicles in the future, especially in the private sector.

3.2 DC charging will be polarized

As the range of new energy vehicles increases, the power battery is generally larger, the problem of "slow charging" of electric vehicles is more prominent, and the user's demand for fast energy replenishment is increasing, so high power charging has become an inevitable choice for high range models. There are two technical routes for high power charging: the high current route, typically represented by Tesla; and the high voltage route, typically represented by Porsche's 800V high voltage technology. Under the high-current technology route, more heat will be released when charging, and the high temperature will lead to a sudden reduction in power battery capacity and permanent damage to the battery core, which will affect charging efficiency and may even cause safety risks. In addition, high current has high requirements for charging pile hardware equipment and cables, and thick cables will reduce the convenience of charging. The high voltage route can alleviate the above problems, but there is the disadvantage of high cost of components. Nevertheless, domestic and foreign car companies generally choose the high-voltage route. Since 2021, several car companies have released production models and super-fast charging solutions based on the 800V high-voltage platform, such as Porsche, Hyundai, Mercedes-Benz, BYD, etc. On the other hand, with the active exploration of charging infrastructure operators and equipment manufacturers, there is a trend of "DC" for low-power charging. Operators believe that low-power DC charging piles have lower output power and higher safety; compared with AC slow charging, they do not need to be converted by on-board chargers, and the power output can be dispatched, which is more suitable for V2G technology; if low-power DC charging is promoted, the on-board charger device can be eliminated, reducing the cost of the whole vehicle and saving space. A charging operator has carried out pilot work of low-power DC charging in Qingdao, Nanjing, Chengdu and other ground-oriented residential areas and industrial parks, and said that in the future, it will no longer build AC charging piles in residential areas and will switch to building low-power DC intelligent charging networks.

3.3 Power exchange technology is an important supplement to electric vehicle electric energy replenishment and is expected to be standardized and shared in the future.

From the perspective of the development trend of electric energy replenishment, charging is still the mainstream way of electric vehicle energy replenishment. However, as one of the routes of electric energy replenishment for electric vehicles, power exchange has its special advantages. First, the state encourages diversified energy replenishment methods, and the competent government departments will promote the development of charging and power exchange industry for a long time. 2020, the National Development and Reform Commission, the Ministry of Industry and Information Technology, the Energy Bureau and other competent departments have issued policy documents, focusing on promoting the formation of unified power exchange standards for major application areas, improving the safety, reliability, and economy of power exchange mode, and accelerating the promotion and application of power exchange mode. Secondly, as the development of the charging and replenishment method still has some problems to be solved, such as the shortage of land resources, the impact of centralized charging on the power grid, the future high-power charging tariff increases, the existence of these problems may help the further development of the power exchange mode. Third, the power exchange mode has the advantage of unified management of power batteries,

which can make the battery used in the best operating conditions, thus reducing the number of battery investment, extending the service time, and increasing the return on assets.

The charging-based, power-exchange supplemented replenishment route will not change in the short term. In the short term, the application of power exchange in specific areas, such as the promotion of power exchange heavy trucks in short-haul high-frequency use scenarios such as port outbound barges, logistics parks and steel mill short barges. In the long run, the shared power exchange is the future development trend, and the country will certainly actively promote the unification of power exchange technology at the standard level.

3.4 Wireless charging technology is still in the exploration stage

Wireless charging technology for electric vehicles involves the communication between the ground end equipment, vehicle end equipment, ground end and vehicle end, as well as the interaction between the wireless charging system and electric vehicles and the power grid. At present, China has taken the lead in completing the preparation of standards for wireless charging technology, which sets requirements for the functions and performance of wireless charging system for electric vehicles in terms of system design, equipment topology, communication protocol, operating frequency, electromagnetic environment, etc. Wireless charging has the advantages of safety and reliability, high convenience and simple operation compared with wired charging, and has a stronger interaction with the power grid. However, there are also some shortcomings. They are mainly reflected in a series of problems such as lower energy conversion efficiency compared with wired charging methods, higher initial investment costs, and electromagnetic radiation generated by some charging methods affecting human safety.

4 CONCLUSIONS

The massive use of automobiles has caused a series of environmental pollution and greenhouse effect problems, which are not conducive to the healthy and sustainable development of the ecological environment. Under this background, new energy electric vehicles have emerged to play an important role in promoting the continuous development of the transportation industry in the direction of greening and environmental protection. This paper analyzes three charging technology roadmaps, namely, EV conduction charging technology, wireless charging technology, and power exchange technology, and analyzes the future EV charging technology development trend from AC charging, DC charging, power exchange technology, and wireless charging technology. In the actual development, automobile enterprises should pay attention to the application of new energy electric vehicle charging technology and continuously improve the operational performance of new energy electric vehicle. This can improve social and economic benefits and stand invincible in the fierce market competition. In the future research, these three charging technologies of electric vehicle can be comprehensively evaluated and compared by conducting the experiments.

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