Development and Application of Wireless Charging Technology in the Field of Electric Vehicles

Mofan Chen[1] and Rui Dai[2, *]

[1] School of Automotive Engineering, Wuhan University of Technology, Wuhan, 430070, China
[2] School of International Education, Guangdong University of Technology, Guangzhou, 510000, China
3122010108@mail2.gdut.edu.cn

Abstract. Due to the rapid development of the electric vehicle industry at home and abroad, the number of electric vehicles has increased dramatically, and the original charging method cannot meet the rapidly growing charging demand. This paper introduces two ways of wireless charging for electric vehicles, analyzes the working principles of these two charging methods. Their respective advantages and disadvantages through the comparison of their different technical routes then introduces three innovative solutions in this field. Mainly include dynamic charging technology. The BP neural network to realize automatic coil positioning technology, and grid-connected technology for EVs. Examples of relevant application cases are discussed. Finally, the development trend of EVs in the future. There are some possible changes are predicted, as well as the wireless charging technology. It will provide more possibilities for the solution of EV charging problems. There are some encouragements is given to technological research and the construction of charging facilities. The formulation of unified standards to promote its further development.

Keywords: Electric Vehicles, Wireless Charging, Electromagnetic Induction, Magnetic Resonance

1 Introduction

As the electric vehicle technology continues to mature, electric vehicles have gained widespread acceptance and promotion around the world, and the electric vehicle market is constantly expanding. However, the charging problem of electric vehicles has always been a barrier limiting their popularization and development. Traditional wired charging not only requires a long time, but also the popularity of charging piles is far from meeting the demand, thus limiting the flexibility and convenience of electric vehicle use. Currently, a safe, reliable, intelligent, small footprint, low maintenance cost, flexible and convenient charging method is needed. So, the wireless charging technology applied to electric vehicles emerges as the times require, and quickly becomes a hot topic of concern. As early as 2017, Duan et al, mentioned this scheme. In the article, they mentioned that "the wireless charging technology of electric vehicles overcomes the problems affected by external factors. Charging

Y. Yue (ed.), *Proceedings of the 2024 International Conference on Mechanics, Electronics Engineering and Automation (ICMEEA 2024)*, Advances in Engineering Research 240,
https://doi.org/10.2991/978-94-6463-518-8_52

without direct contact avoids the need for unified interface standards, which are convenient and safe to use[1]. This also shows that wireless charging technology has more obvious convenience and irreversibility in the field of electric vehicles and will provide more opportunities for the development of electric vehicles. Wei et al. also suggested that 'after 2035, the intelligent automobile industry and wireless charging technology will gradually mature, and wireless charging technology for electric vehicles has a huge development prospect. This technology is of great significance in achieving a carbon peak by 2030 and carbon neutrality by 2060 and can help alleviate environmental pollution and cope with the energy crisis [2]. This article presents an overview of the fundamental principles and categories of wireless charging technology. It examines the advantages and challenges of wireless charging in the context of electric vehicles, proposes innovative solutions, and finally, offers a prospective analysis of the development of wireless charging for electric vehicles. It is anticipated that wireless charging will become faster, more convenient, and more efficient in the future, and will represent a significant advancement in the field of electric vehicles.

2 Principles of Wireless Charging for Electric Vehicles

2.1 Wireless Transmitter Winding

Electromagnetic Induction Wireless Charging Technology. Firstly, the transmitter obtains power from the grid after rectification and inversion. The high-frequency alternating current signal is injected into the primary side coil through the compensation circuit, which under the regulation of the control circuit generates high-frequency alternating flux signals in the neighboring space; the coil of the receiving end is close to the transmitter that obtains the induced electromotive force by inductively coupling the high-frequency alternating flux. At the same time, the rectifier, filtering. The power conditioning is realized for the on-board battery under the control of the control circuit [3]. The energy flow is shown in the figure1. Charging of the vehicle battery is realized through rectifier filtering and power regulation under the control circuit [2].

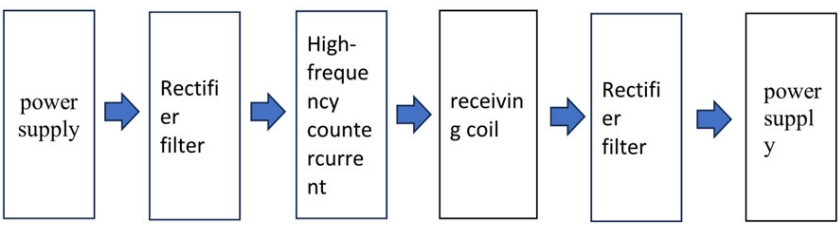

Fig. 1. Electromagnetic induction circuit diagram.

（Photo/Picture credit: Original ）

Magnetic Coupling Wireless Charging Technology. Magnetically coupled resonant technology is one of many wireless energy transmission technologies, which includes magnetically coupled inductive wireless energy transmission, magnetically coupled resonant wireless energy transmission, and magnetically coupled dual-mode wireless energy transmission[4]. In order to achieve high transmission efficiency, compensation capacitors are connected at the transmitter and receiver ends [4]. In order to achieve high transmission efficiency, compensation capacitors are connected at both the transmitter and receiver sides.

This method utilizes the coil on the power supply side to generate an alternating magnetic field, which is coupled to the coil on the load side, thus transferring electrical energy to the load [5]. The compensation capacitor enables the converter to operate in a resonant state, realizing resonant soft switching of the switching devices and reducing the switching losses, thus improving the transmission efficiency.

2.2 Receiving End of Electric Vehicles

The principle of the receiver end of the electric vehicle wireless charging technology is mainly based on electromagnetic induction and magnetic resonance. It is mainly composed of a receiving coil, electronic circuit, and energy storage system. The receiving coil is an important part of the receiver end of the electric vehicle wireless charging technology. It applies a specific structure and uses copper wire as a specific material to improve charging efficiency and transmission effect. It is generally wound under the ground of the receiving end and used to receive the alternating magnetic field formed by the high-frequency current supplied by the external power supply through the transmitting coil of the transmitting end. The receiving coil receives the alternating magnetic field through electromagnetic induction and converts it into an alternating current signal to be transmitted to the electronic circuit for processing. The electronic circuit is the control center of the receiver end, which is used to process the alternating current signal sensed by the receiving coil. The LC compensation circuit in the electronic circuit receives the alternating current signal and converts it into direct current power to charge the energy storage system of the electric vehicle. At the same time, the electronic circuit also includes a rectifier circuit, a control circuit, and other cooperating uses that can control and regulate reactive power, improve the power factor of the power system, and improve system stability and efficiency. The energy storage system refers to the battery pack of the electric vehicle. Its main function is to receive and store the electric energy charged from the transmitting end through wireless charging technology, and supply it to the vehicle's drive system. This system functions similarly to a battery, but is more advanced and efficient. It is a high-capacity, high-voltage power system formed by connecting multiple battery cells. Most of the battery cells adopt lithium-ion batteries because lithium-ion batteries have high energy density, long cycle life, and are suitable for high-capacity motor applications. The battery pack provides driving energy for electric vehicles and accepts external power charging during parking to recharge the electric energy.

3 Innovative Programs

3.1 Dynamic Charging Technology

As Fang Lei said, innovative dynamic charging technology is proposed, which involves laying energy-transmitting devices on the road and transferring power to the receiving end of electric vehicles in a high-frequency alternating manner [6]. This technology enables wireless charging of vehicles when driving on specific road sections, thus expanding the range and flexibility of electric vehicles. By allowing wireless charging while driving on specific road sections, the range of electric vehicles is no longer limited by the location of charging piles, making the use of electric vehicles more flexible and convenient. This significantly enhances the convenience and ease of use of electric vehicles. In addition, compared to traditional charging methods that require the installation of a large number of charging piles and stations, dynamic wireless charging technology can reduce or eliminate the need for these facilities, saving valuable space.

However, there are also some drawbacks to this scheme. It requires high-power transmission, which may lead to energy losses and a decrease in transmission efficiency, making it difficult to achieve high-frequency power transmission. Furthermore, compared to traditional charging methods, the implementation of dynamic wireless charging technology requires a significant amount of equipment investment and technical support, increasing the costs of construction and maintenance. To solve the problem of high energy loss in dynamic wireless charging, Zhang et al. proposed a segmented dynamic wireless charging system in "Research on Segmented Dynamic Wireless Charging System", which is the use of technologies such as segmented construction, equipment sharing, solar power generation and energy storage, which can effectively alleviate the existing problems such as high energy loss [7].

3.2 BP Neural Networks for Automatic Coil Positioning

In order to make the charging efficiency more efficient and the energy loss less, Pan Zhixin et al. pointed out in "Research on coil localization technique based on BP neural network" that because the electromagnetic transmission of magnetic coupling resonance requires that the transmitting coil and the receiving coil work in alignment, so that it can operate efficiently and stably.

However, it is impractical for the driver to accurately manoeuvre the electric vehicle to align the transmitting coil, so this paper proposes a BP neural network-based coil positioning technology, which is a technology that uses the BP neural network to learn the induced voltage and complete the prediction of the docking coil to achieve coil positioning [8]. This technology greatly improves the charging efficiency of electric vehicle wireless charging by increasing the coupling coefficient of the coil, and the operation is more stable, and reduces the core heat loss and magnetoresistance caused by magnetic leakage phenomenon. This technology is

implemented by artificial intelligence algorithm, which reduces a lot of human workloads.

However, the BP neural network requires a large number of training samples and iterative calculations to obtain accurate prediction results, which may take a considerable amount of time and computational resources. And in practical applications, the interference factors in the environment around the transmitting and receiving coils can affect the accurate measurement of the induced voltage and the accuracy of the coil positioning. Therefore, this technique needs to be further refined.

3.3 Evs Grid-connected Technology

With the rapid growth in the number of electric vehicles, the surge in charging loads is a serious test for the power grid, easily triggering load tension in the distribution network and even causing grid stability problems. EVs grid-connected technology can realize two-way wireless energy flow between the grid and EVs, and electricity can flow from the grid to EVs and from EVs to the grid.

Vehicle to Grid (V2G) utilizes the energy of on-board power batteries to participate in the "peak shaving and valley filling" scheduling operation of the power grid, i.e., when the load of the power grid is too high, the energy stored in EVs feeds into the power grid to alleviate the pressure on the supply of power to the power grid, and when the load of the power grid is too low, the excess power in the power grid supplies power to the EVs, thus avoiding the waste of energy. The most fundamental requirement of V2G technology is to realize the bidirectional flow of energy between the two sides of the vehicle and the network. The grid delivers power to the EV battery when it works in the positive resistance state. The EV battery delivers energy to the grid when it works in the negative resistance state. At that time, the converter has to satisfy the requirements of realizing the rectification as well as inversion processes at the same time [9]. Electric vehicles and the grid are connected in a variety of ways. Within a corresponding connection system platform, electric energy can be effectively converted to the grid partly by thermal power generation, like wind power generation and other renewable new energy sources, promoting the effective flow and utilization of energy between the two [10].

3.4 Volvo XC40

March 4, 2023 - Volvo Cars is participating in the "Green City of Gothenburg" strategic plan, which Volvo says will enable it to test new technologies in a real-world environment. Charging vehicles simply park at wireless charging units embedded in the road, automatically activating the charging function without the driver having to get out of the car. The 360° panoramic image, which allows the car to be easily aligned with the wireless charging unit, is used in the electric version of the Volvo XC40, which employs magnetically coupled wireless charging technology. This wireless charging power can exceed 40kW, and charging speeds can be comparable to that of a 50kW DC fast-charging post, and up to four times as fast as that of a traditional 11kW AC charging post.

3.5 SAIC ZhiJi Automobile L7

On April 1, 2022, ZhiJi L7 was officially launched, the world's first mass-produced vehicle equipped with high-power wireless charging, the maximum power of wireless charging reaches 11kW, which is equipped with intelligent driving and intelligent parking functions, which can maximize the efficiency of wireless charging. In March 15, 2023, the wisdom of the car launched the first mass production of 11kW high-power vehicle intelligent wireless charging pile, charging efficiency reaches the same power wired charging efficiency of about 95%, and at the same time has a collaborative position detection function. In terms of safety, the wireless charging plate protection level up to IP67, IP6K9K, using a high-strength design, support for metal and live foreign body detection, in the future, the wireless charging program will also be integrated with the WLC exclusive high-precision parking technology, parking can be charged, without the need to operate the charging gun.

4 Conclusion

Overall, wireless charging technology has a very promising future in the electric vehicle sector. It solves many of the problems associated with charging electric vehicles, such as difficult charger connections, queuing for charging and long charging times, by eliminating the need for a physical connection. It increases the convenience, safety and reliability of electric vehicle use and improves the efficiency of charging. With the development and maturity of wireless charging technology, it is expected that it will provide more opportunities for solving electric vehicle charging problems. In order to further promote the development of wireless charging technology in the field of electric vehicles, it is essential to strengthen technical research and development to improve the efficiency and stability of wireless charging technology and reduce the cost of its use. The next step is to popularise the construction of charging facilities and build wireless charging facilities in cities and key locations to solve the problem of insufficient existing charging facilities. Strengthening the development of standards is also necessary to develop a unified wireless charging standard, and improve the interoperability of charging equipment. So that the use of electric vehicles wireless charging users more convenient charging. With the development and maturity of wireless charging technology, we can foresee the improvement of charging efficiency, the realisation of intelligent applications, and the construction of a wireless charging network. Charging efficiency will be more efficient and charging time will be shortened, improving user experience and vehicle availability. Wireless charging devices will be remotely controlled and monitored to provide users with intelligent charging services. At the same time, wireless charging devices will be connected to a network to form an intelligent charging network.

Authors Contribution

All the authors contributed equally and their names were listed in alphabetical order.

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