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Application of wireless energy delivery system in automobile charging

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Abstract. With the popularity of electric vehicles, wireless charging technology has become a key area to address the convenience of charging electric vehicles. The aim of this study is to explore the principles of wireless energy transfer technology and its application in the field of electric vehicles. We first provide a background introduction to the field of electric vehicles, emphasising the importance of wireless charging technology. Subsequently, we delve into the charging and discharging characteristics of power batteries to better understand the need for energy transfer. Then, we carefully selected wireless charging methods suitable for electric vehicles and developed a corresponding wireless charging system architecture. In this paper, we also provide theoretical analyses of two major wireless energy transfer technologies, including electromagnetic coupled wireless energy transfer and resonant wireless energy transfer, as well as exploring the principles of RF wireless energy transfer technology. Finally, we propose an architecture for a static wireless charging system including five modules: pre-processing, transmission, reception, charging control and battery load. The contribution of this study is to provide an in-depth research and a comprehensive theoretical foundation for wireless charging technology in the field of electric vehicles, which helps to improve the charging efficiency and convenience of electric vehicles.

Keywords: Electric vehicles, radio power transmission, charging systems

1. Introduction

Due to limitations in battery capacity, charging methods, efficiency, and battery life, electric vehicles face constraints on their range and experience long charging times, making them less suitable for medium and long-distance travel. These limitations hinder the widespread adoption of electric vehicles, and the development of efficient and practical charging technology is crucial to drive the growth and widespread use of the electric vehicle industry [1-5]. Presently, the predominant charging approach for electric vehicles relies on wired charging, necessitating specialized charging infrastructure and being subject to technological limitations. The extensive deployment of charging stations can strain the power grid, introducing numerous harmonics and potentially impacting the safe and stable operation of the traditional distribution network. Moreover, individual charging stations can only accommodate one or two electric vehicles, and their large physical footprint makes widespread deployment challenging. This limitation in the number of charging stations becomes particularly problematic when there is high demand for charging, such as in areas with a large number of electric vehicles [6-11].

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Utilizing the magnetic field as a medium, radio energy transmission technology enables power transfer without the need for physical cables. In contrast to plug-in charging methods, this approach eliminates the requirement for electrical contacts, offering benefits such as enhanced safety, user-friendliness, intelligence, and prevention of dust accumulation and contact losses. These advantages significantly reduce the need for regular maintenance and repairs, leading to substantial labor savings and increased cost-effectiveness [12-15]. Furthermore, the installation of wireless charging equipment in specific areas within large parking facilities enables the simultaneous charging of multiple vehicles, with the added benefit of simultaneous AC and DC conversion.

By dispersing charging stations connected to the power grid to electric vehicles without direct grid access and wireless power supply endpoints, a substantial number of electric vehicles can connect to the distribution network concurrently. This approach mitigates the introduction of harmonics into the power grid, which holds great importance for enhancing grid stability [16].

2. Electromagnetic Inductive Cordless Power Transfer (ICPT) technology

Electromagnetic induction is the phenomenon where a changing magnetic flux within a conductor generates an electromotive force. When the conductor is connected in a closed loop to form a primary circuit, this electromotive force drives the flow of electrons, resulting in the formation of an induced current. Although Francesco Zantedeschi’s work in 1829 may have foreshadowed it, electromagnetic induction is commonly credited to Michael Faraday’s discovery in 1831 [17-19].

The electromagnetic induction radio energy transmission system operates on the principles of electromagnetic induction, enabling the transmission of electric energy through the use of air as the medium. The energy transfer process can be divided into four key steps:

1. The input electric energy, originating from a 220V AC mains source, is first rectified by a power inverter.
2. Subsequently, the low-frequency AC current from the mains is transformed into high-frequency electric energy by a high-frequency inverter.
3. This high-frequency electric energy from the primary side coil is then transmitted through an intermediate coupler to the secondary side coil.
4. Finally, the energy is rectified and sent to power the DC load through a rectification device.

Figure 1 illustrates the structure of the ICPT (Inductive Coupling Power Transfer) device when operating under a DC load. The coupler plays a crucial role as a power transmission component. The part responsible for converting mains power into high-frequency AC power constitutes the primary energy conversion section, while the secondary coil serves as the energy-receiving component. After receiving the energy, it undergoes rectification and filtering through the processing circuit to provide power to the DC load [20]. Additionally, there is a control circuit that collects voltage and current information from the main circuit, feeds it to the primary energy conversion mechanism, and issues control signals to the high-frequency inverter to regulate its frequency.

In essence, the transmission mechanism within ICPT can be likened to a coupling transformer that utilizes air as its transmission medium. This model is often represented using concepts such as coupling mode, mutual inductance, leakage inductance, and other theoretical principles. In mathematical terms, it is realized by establishing a series of differential equations to derive the motion states of each independent unit. Subsequently, the system’s transmission characteristics are analyzed based on these equations.

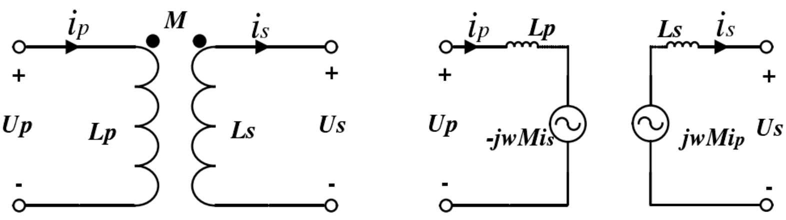

Figure 1. Magnetic coupled circuit topology and its equivalent model

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Here, L_p represents the self-inductance value of the primary coil, while L_s denotes the self-inductance value of the secondary coil, with M representing the mutual inductance value between the primary and secondary coils. When disregarding the internal resistance of the coil, we can derive the following transmission equation:

$$\begin{cases} U_p = L_p \dfrac{di_p}{dt} + M \dfrac{di_S}{dt} \\ U_s = M \dfrac{di_p}{dt} + L_s \dfrac{di_S}{dt} \end{cases}$$

Defined coupling coefficient

$$k = \frac{M}{\sqrt{L_p L_s}}$$

As shown in Figure 2 when the secondary side connected load needs to be further analyzed, rp and rs are the internal resistance of the primary and secondary coils respectively, and R_l is the load resistance. The equations are changed from time domain to algebraic equations, and the primary and secondary equations can be obtained:

$$\begin{cases} U_p = j\omega L_p i_p + r_p i_p - j\omega M i_S \\ j\omega M i_p = j\omega L_S i_S + r_S i_S + R_l i_s \end{cases}$$

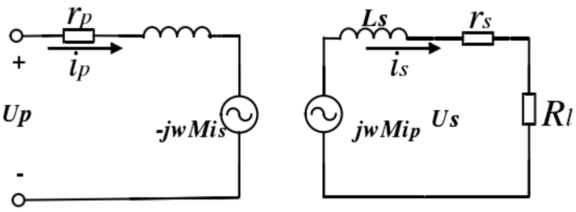

Figure 2. Equivalent model of mutual inductance coil with load

Assuming Zr is the equivalent circuit impedance from the primary side to the secondary side,

$$Z_S = \frac{-j\omega M i_S}{i_S} + j\omega M \frac{i_S}{i_p}$$

The total impedance in the secondary loop is

$$Z_S = \frac{j\omega M i_S}{i_S} = j\omega L_S + r_S + R_l$$

After simplification, we can get:

$$Z_r = \frac{(\omega M)^2}{Z_S}$$

The circuit on the secondary side can be equivalent to the circuit on the primary side for analysis and calculation by means of the reflected impedance, as shown in Figure 3:

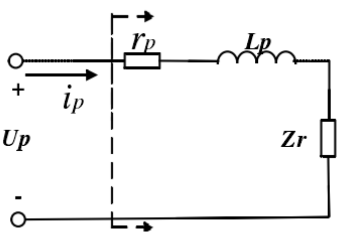

Figure 3. Primary equivalent circuit

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Then the equivalent input impedance is:

$$Z_{in} = r_p + j\omega L_p + Z_r = r + jX$$

Where $R -$ is the resistance part, representing the active part of the system transmission
$X -$ is the reactance part, representing the reactive part of the system transmission

From the above analysis, it can be seen that the impedance of the primary side equivalent circuit has a reactance part in addition to the pure resistive component, and the reactance part is mainly inductive component [21-23]. On the one hand, the existence of reactance affects the power factor of the system and increases the requirement of the power supply. On the other hand, the existence of a large amount of reactive power will also reduce the useful work of the system and greatly reduce the useful work efficiency.

In order to improve the useful work efficiency of the WPT system, the inductive reactance in the system circuit must be limited to a certain range. On the one hand, the presence of reactive power in the system increases the magnetic field strength of the magnetic coupling mechanism, resulting in an increase in the spatial transmission distance; on the other hand, the presence of a large amount of reactive power will also reduce the stability of the system and affect the input side of the power grid [24].

Generally, the inductive component in the circuit can be compensated by adding series or parallel capacitors at both ends of the inductor coil of the magnetic coupling mechanism. When the tolerance value and compensation topology are suitable, the LC network will reach a resonance state, that is, resonance compensation.

3. Magnetic resonance radio energy transmission technology

Magnetic coupling resonance radio energy transmission operates on the principle of “magnetic coupling resonance.” Within the induction field, magnetic field energy reciprocally circulates between the radiation source and its interior. Exploiting this phenomenon, electromagnetic resonance technology is employed to develop the system launcher, resulting in the accumulation of numerous non-radiating cross-magnetic fields in the vicinity of the launcher. Additionally, the system’s capacitance confines the electric field, preventing the generation of electromagnetic wave energy that radiates externally. Magnetic coupling resonance radio energy transmission technology utilizes high-frequency magnetic fields within the electromagnetic field for energy transmission without external radiation. The power transmission system topology comprises power supply, processing circuit, transmitting coil, receiving coil, and load components.

The basic topology of a magnetic field resonant power transmission system is formed by means of a pair of resonant coils, also known as the two-coil structure. However, the maximum distance that this two-coil structure can transmit is limited, and sometimes it cannot meet the needs of the load. In view of this phenomenon, some scholars have proposed a three-coil structure, that is, on the basis of the original two-coil structure, an intermediate induction coil is added as a trunk coil, which can increase the distance of power transmission. In addition, some scholars proposed to add two trunk coils in the middle of the receiving and transmitting coils to separate the power supply from the transmitting device, and the load from the receiving device.

In the research of wireless charging device, people pay more attention to the size of its transmission power. Therefore, the output power is taken as the research object when discussing resonant radio energy transmission. Taking the most basic two-coil model as an example, the three-coil and four-coil structures can be analyzed with reference to two-coil structures. Because resonance generates two modes of parallel resonance and series resonance, the resonant power transmission circuit topology has four different structures.

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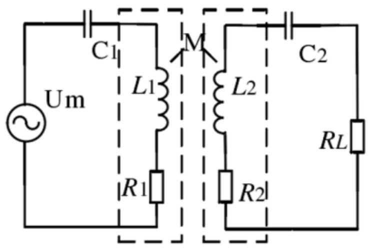

Figure 4. S-S resonance

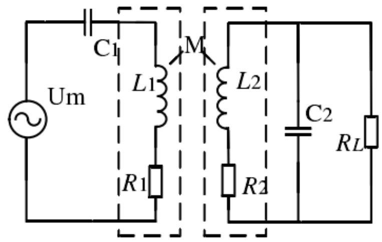

Figure 5. S-P resonance

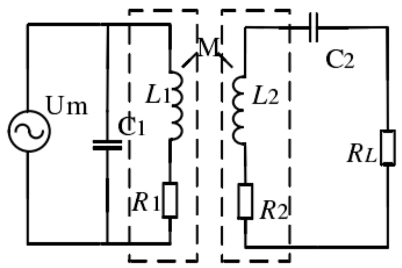

Figure 6. P-S resonance

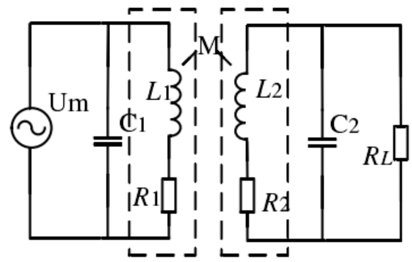

Figure 7. P-P resonance

Figures 4, 5, 6, and 7 depict four distinct resonance systems: double series, series parallel, parallel series, and double parallel configurations, respectively. Within each figure:

- Um represents the system's equivalent voltage source.
- C1 and C2 denote the capacitance at the transmitting and receiving ends, respectively.
- L1 and L2 represent the inductance at the transmitting and receiving ends, respectively.
- R1 and R2 are the equivalent series internal resistance values for the transmitting and receiving coils, respectively.
- RL signifies the load component.

The power loss of the electromagnetic resonance radio energy transmission system is mainly caused by the ohmic resistance loss, and the radiation loss of the system is much less than the ohmic loss, so it can be ignored. The ohmic loss is calculated as follows:

$$R_{ohm} = \frac{N_r}{a}\sqrt{\frac{\mu_0 \rho \omega}{2}}$$

Where, N is the number of turns of the coil; r is the radius; a is the radius of the wire; ρ is the constant, conductivity.

Four equivalent circuit output powers are described below:

(1) SS resonant system output power

The self-impedance of the primary equivalent circuit and the secondary equivalent circuit is Z11 respectively, and Z_{22} has:

$$\begin{cases} Z_{11} = R_1 + j\omega L_1 + \dfrac{1}{j\omega C_1} \\ Z_{22} = R_2 + R_L + j\omega L_2 + \dfrac{1}{j\omega C_2} \end{cases}$$

The system resonance angular frequency, coil self-inductance L, and mutual inductance M of the two coils are:

$$\begin{cases} \omega = \dfrac{1}{a\sqrt{L_i + C_i}}, i = 1{,}2 \\ L = N^2 r \mu_0 [1n(^{8r}/_{g}) - 2 \\ M = \dfrac{\pi\mu_0 (N_1 N_2)^{0.5} (r_1 r_2)^2}{2D^3} \end{cases}$$

Where D is the distance (m) between the two coils, assuming that the number of turns of the transmitting coil and the number of turns of the receiving coil is the same, and the radius of the transmitting coil and the receiving coil are the same.

According to circuit knowledge, the equivalent circuit of the secondary side coil is shown in Figure 8:

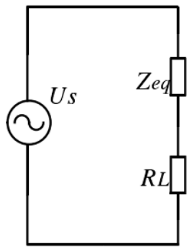

Figure 8. SS resonant system secondary side equivalent circuit

Where, Z_{eq} in the secondary equivalent circuit is the equivalent impedance, and U_S is the voltage source equivalent to the secondary side, then

$$\begin{cases} Z_{eq} = R_1 + j\omega L_2 + \dfrac{1}{j\omega C_2} + \dfrac{(\omega M)^2}{j\omega C_2} \\ U_S = \dfrac{j\omega M U_m}{Z_{11}} \end{cases}$$

From the above equivalent circuit, combined with the power calculation formula in the circuit, the output to the resistance R can be obtained

$$P_{ss} = \frac{(\omega M)^2 U_m^2 R_L}{\left| \left[\left(j\omega L_1 + R_1 + \frac{1}{j\omega C_1} \right) \left(R_L + R_2 + j\omega L_2 + \frac{1}{j\omega C_2} \right) + (\omega M)^2 \right]^2 \right|}$$

(2) SP, PS,SS resonant system output power calculation

Similar to the SS power calculation method, the output power calculation results of the other three circuits are as follows:

$$P_{sp} = \frac{(\omega M)^2 U_m^2 R_L}{\left| \left[\left(j\omega L_1 + R_1 + \frac{1}{j\omega C_1} \right) \left(R_2 + j\omega L_2 + \frac{R_L}{1 + j\omega C_2 R_L} \right) + (\omega M)^2 \right]^2 (j\omega C_2 R_L + 1)^2 \right|}$$

$$P_{ps} = \frac{(\omega M)^2 U_m^2 R_L}{\left| \left[(j\omega L_1 + R_1)(R_2 + j\omega L_2 + R_L + \frac{1}{1 + j\omega C_2}) + (\omega M)^2 \right]^2 \right|}$$

$$P_{pp} = \frac{(\omega M)^2 U_m^2 R_L}{\left| \left[(j\omega L_1 + R_1)(R_2 + j\omega L_2 + \frac{R_L}{1 + j\omega C_2 R_L}) + (\omega M)^2 \right]^2 (j\omega C_2 R_L + 1)^2 \right|}$$

Under identical conditions, the SS and SP resonant systems exhibit significantly higher output power compared to the PS and PP resonant systems. Specifically, the maximum output power of the PS and PP resonant systems is a mere 0.1 watt, whereas the SS and SP resonant systems achieve a maximum output power exceeding 18 watts. The output power characteristics of the SS and SP resonant systems share similarities, with the SP resonant system boasting the highest output power. Moreover, when the transmission distance exceeds that of the SS resonant system and the gap between the two coils is widened, the SP resonant system outperforms the SS resonant system in terms of output power. The power curve range of the SP resonant system is wider, while the SS resonant system's power curve range is narrower under the same conditions, further emphasizing the superiority of the SP resonant system's output power curve. Additionally, the number of turns and the coil's radius do have an impact on the system's maximum transmission distance. A decrease in the number of turns and an increase in the coil's radius result in an expanded maximum transmission distance for the system.

4. Research and application status

In 2012, Japanese car manufacturer Nissan Group announced the addition of wireless charging equipment in Leaf models, and changed the equipment to adopt electromagnetic induction wireless charging. There are two forms of charging, one is to install the device in the form of a charging pile on both sides of the parking lot, the other is to bury the device in the ground, as long as the vehicle enters the range of wireless charging equipment, you can charge yourself, while the car is also equipped with a control button, you can choose whether to charge, this device will not be affected by the weather [25-27]. In 2014, Toyota Motor Manufacturing Company pioneered the use of electric magnetic resonance technology for charging electric vehicles, deploying charging coils both beneath and atop parking lots during their experimentation phase. Subsequently, at the Formula E Electric Formula Championship on April 22, 2015, Qualcomm showcased its Halo unlimited charging technology, which achieved remarkable charging speeds of up to 30 MPH for electric vehicles. Last year, Volvo announced the outcomes of its collaborative research endeavors with other firms, focusing on a wireless charging project for electric vehicles. The primary goal of this project was to wirelessly charge electric cars equipped with a 24KWh battery pack and 120hp output. This project explored two distinct charging methodologies: a three-phase AC fast charging system and a DC slow charging system. The AC charging system boasted an impressive 20 kilowatts of charging power and a charging voltage of up to 380 volts, while the DC charging system, albeit more limited, still reached 3.8 kilowatts of charging power and a charging voltage of 240 volts. Notably, Volvo also adapted the AC fast charging approach for wireless charging applications in electric buses. Experimental findings affirmed the successful application of magnetic resonance-based wireless charging systems for electric vehicles, with the AC charging system proving particularly suitable for fast charging scenarios. Currently, major automotive manufacturers are fervently pursuing electric vehicle development while actively researching wireless charging technologies. Mercedes-Benz and BMW, for instance, have collaborated to advance wireless charging technology for electric vehicles, implementing it in Mercedes-Benz S-Class sedans and BMW HEVi8 models, achieving charging times of under two hours [28-29].

Beijing's electric car model E150 is equipped with wireless charging equipment. The device is composed of several subsystems, including a power supply system, a human-computer interaction system, a transmitting coil and a vehicle receiving coil system. The power supply system is 220V AC power supply, but this wireless charging system requires that the distance between the car and the launch system is 20cm, and the effective charging distance is within 50cm. The charging efficiency of this wireless charging system can reach more than 90%, which is similar to the charging efficiency of the commonly used cable charging system at this stage. In terms of charging speed, the device can fully charge the car in 30 minutes. However, because the distance has a greater limit on the charging power, in order to make the device have a higher charging efficiency, it must carry out position calibration operation, which brings great inconvenience to the user. In 2014, Yutong Bus released the overall solution for pure electric buses, and within this year, 20 12m electric buses will be put into operation on

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the BRT line in Zhengzhou, using wireless charging mode. In addition, BYD, Dongfeng Motor and other manufacturers are also actively studying wireless charging technology.

5. The Future Development Trend

The electric energy of electric vehicle to maintain its movement comes from the energy storage battery, because the electric vehicle itself consumes a lot of power, the power consumption is fast, and the existing battery capacity is limited, cannot support the car to travel too long distance, so it needs to be charged in time when the remaining battery power is insufficient. Now it is more commonly used to connect the car to the power grid through the charging pile. The charging pile inverts the alternating current of the power grid to charge the battery. Due to the direct introduction of the converter, it will cause a certain impact on the power grid and affect the stability of the power grid. And because of the charging speed, it takes quite a long time to fully charge such a large-capacity battery in an electric car. When the car travels a long distance, it must stop and charge every time it travels for a period of time, which greatly limits the promotion and further development of electric vehicles. Electric buses and taxis are required to charge the car without affecting operating hours. At the same time, it is also necessary to quickly complete the charging of the car during long-distance driving. Resonant wireless charging system can meet the needs of system charging. Wireless charging technology can complete the charging of the car without connecting the power grid through the cable and removing the battery, and can realize the charging of the car in any place equipped with wireless charging devices, and can charge the car while the electric vehicle is driving, greatly improving the driving range of the electric vehicle and improving the utilization rate of the car. At the same time, it can avoid the frequent disassembly and installation of the battery will bring additional damage to the car, minus the tedious charging operation, and avoid the occurrence of dangerous events such as electric shock during artificial charging [30].

The development and promotion of the great significance. Wireless charging technology can complete the charging without affecting the driving time of the car and meet the changing requirements of the car. Therefore, the development of wireless charging technology and the application of resonant wireless charging technology to electric vehicle charging will bring great economic and security value to the grid, users and automobile manufacturers.

6. Wireless charging system scheme principle

The charging equipment is divided into five modules, which are pre-processing module, transmitting module, receiving module, charging conversion module and electric vehicle self-contained battery module. The power preprocessing module mainly regulates the electric energy so that the frequency of the electric energy sent to the transmitter is the target frequency. The transmitter and receiver can adopt resonant coil structure; The main task of the charging control module is to invert the received electric energy and convert it into the DC piezoelectric flow required for battery charging.

(1) Energy preprocessing module

The power preprocessing module serves a multifaceted role, encompassing power factor correction, synchronization of input current phase with voltage phase, harmonics reduction, minimization of distribution system pollution, and enhancement of equipment safety and reliability. Power factor correction within this module focuses on mitigating current waveform distortion, a task primarily accomplished through a power factor correction circuit (PFC).

Among the commonly employed PFC circuit types, the active circuit stands out, offering variations such as boost, buck, lift, forward, and flyback. For the sake of this discussion, we exclude the forward and flyback circuits due to their intermittent input nature. Let's delve into the boosted PFC circuit, illustrated in Figure 9. When switch tube Q is in the "on" state, inductor L carries current IL. Prior to inductor saturation, current exhibits linear growth. Simultaneously, capacitor C discharges, delivering energy to the load. Upon Q's disconnection, self-induced electromotive force UL emerges across L's terminals, preserving the current's direction.

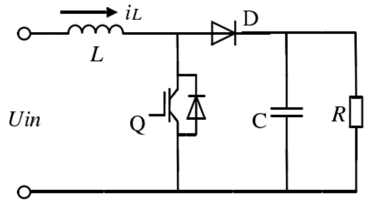

Figure 9. Boost type PFC circuit

It can be seen from its working principle that the inductance current is the circuit input, which is a continuous quantity and can be modulated throughout the sinusoidal cycle of the input voltage, so a high power factor can be obtained; The drive is simple, because the input current is continuous, the peak value of the switching tube is small, the input voltage transformation is strong adaptability, and the use of the grid voltage transformation is larger, but the main disadvantage is that the output voltage is high, and the switching tube cannot be used to achieve output short-circuit protection. The step-down PFC circuit, while subjecting the switching tube to lower stress, operates effectively only when the input voltage exceeds the output voltage. Consequently, during each sinusoidal cycle, there exists a portion where it cannot function optimally due to low input voltage. In contrast, the ups and downs circuit provide a wide output voltage selection range and allows for output short circuit protection via the switching tube. However, it exhibits a significant current peak, entails complex driving requirements, features an output voltage polarity opposite to the input voltage, and poses challenges in designing the post-stage inverter circuit. As a result, it sees limited use in practice. Hence, the preference lies in adopting the booster PFC circuit for power factor correction. To further enhance the PFC circuit's performance, this paper employs an interleaved PFC structure, comprising two booster PFC converters connected in parallel. Interleaved control is achieved by adjusting the drive signal's phase. Figure 10 illustrates the circuit structure.

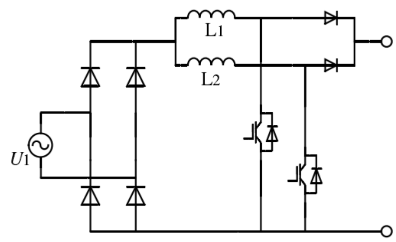

Figure 10. Interlaced PFC circuit

(2) Transmitting module

The resonant radio energy transmission scheme is used in the process of power transmission. The resonant radio energy transmission circuit is composed of four structures, SS, SP, PS and PP. Under the same conditions, the circuit with SP structure has better transmission performance, so this paper considers the use of SP resonant circuit to complete the power transmission. Due to the high output voltage of PFC circuit, it is necessary to transform the output voltage of PFC circuit to make the input voltage of S-coil meet the requirements. DC-DC uses buck circuit to reduce the output voltage of PFC circuit according to the output voltage of S-P structure, so as to control the resonant circuit and achieve the purpose of constant current control. Since the input voltage of the S-coil is required to be an AC voltage of a certain frequency, it is in advance.

After the line DC-DC conversion, it is also necessary to convert electrical energy into AC high frequency quantity, which requires the use of high frequency inverter circuit. The high-frequency inverter circuit can adopt the full-bridge topology, and its switching current is reduced by half compared with the half-bridge inverter, which is more suitable for high-power occasions, so the full-bridge inverter circuit is used in the process of wireless charging of electric vehicles. The structure of the launcher is shown in Figure 11.

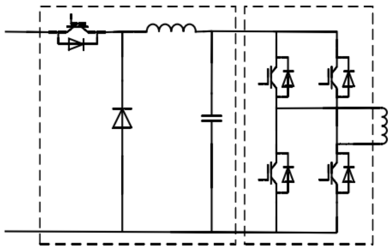

Figure 11. Radio energy transmission transmitter

(3) Receiving module and charging module

The coil of the receiving end circuit has a P structure. The coil rectifying the electric energy received from the transmitting end converts the high frequency AC into direct flow for battery power supply. The rectification process is realized through the AC-DC circuit. Also, due to the high power of the charging process, the AC-DC circuit adopts the full-bridge structure, and its circuit structure is shown in Figure 12. When the receiving end of the electrical energy after rectification processing, need to further through the voltage conversion circuit to meet the electric vehicle battery charging electricity, charging control part also uses DC-DC circuit.

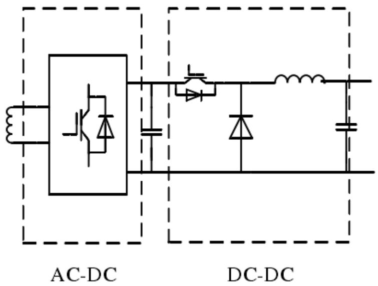

Figure 12. Radio energy transmission and receiving device

The circuit topology of the wireless charging system is shown in Fig. 13. The power pre-processing module and the transmitter module are installed in the charging station. The input to the PFC circuit is a 220V AC power source, which is power-corrected by the PFC circuit, and then the power is supplied to the primary coil with the rated frequency through the DC-DC and DC-AC circuits, and is transmitted through the transmitter coil. The receiver module and the charge control module are installed inside the vehicle. The receiver coil acquires power through the resonance principle and regulates it through the AC-DC and DC-DC circuits to supply power to the battery.

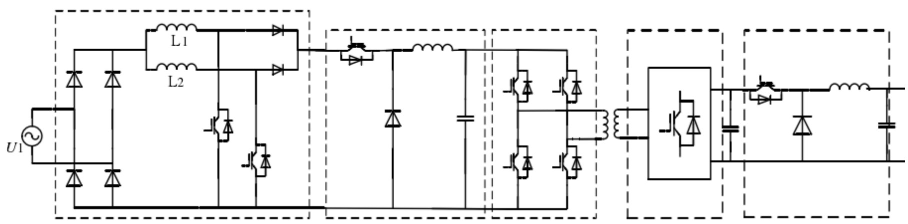

Figure 13. Wireless charging circuit topology

The power pre-processing module and the transmitter module are installed in the charging station. The input to the PFC circuit is 220V AC. The input to the PFC circuit is 220V AC, the power is corrected by the PFC circuit and then fed to the primary coil via the DC-DC and DC-AC circuits at the rated

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frequency and transmitted via the transmitter coil. After power correction by the PFC circuit, the power is supplied to the primary coil through the DC-DC and DC-AC circuits at the rated frequency and is emitted through the transmitter coil. The receiver module and the charge control module are installed in the vehicle. The receiving coil acquires power through the resonance principle and regulates it through AC-DC and DC-DC circuits to supply power to the battery. The receiving coils are resonated and regulated by AC-DC and DC-DC circuits to provide power to the battery.

7. Conclusion

Due to environmental pollution and the primary energy crisis, the development and application of new energy vehicles have gained significant attention. Electric vehicles, being the most mature and promising in this regard, have garnered increasing global interest. Many automotive manufacturers have already developed and implemented electric vehicles. However, the current limitations of electric vehicle charging are becoming increasingly apparent. Due to constraints in power electronic and battery technologies, electric vehicles currently suffer from extended charging times and limited driving ranges. The influx of a large number of electric vehicles into the grid will undoubtedly impose substantial challenges on the traditional distribution network. This, in turn, will have significant implications for the design and construction of new distribution networks in the future. These networks must not only ensure the reliable operation of traditional distribution functions but also meet the high demand for electric vehicle charging. To address the charging requirements of electric vehicles, this paper explores radio energy transmission technology and analyzes the charging and discharging characteristics of electric vehicles. It further delves into the principles of wireless charging systems and their topologies for electric vehicles.

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