Journal of Electronic Research and Application, 2026, Volume 10, Issue 6
http://ojs.bbwpublisher.com/index.php/JERA
Online ISSN: 2208-3510
Print ISSN: 2208-3502

Design and Simulation of Wireless Charging Circuit for Electric Vehicles

Zijian Lu
College of Instrumentation and Electrical Engineering, Jilin University, Changchun 130012, Jilin, China

Abstract: In the 21st century, wireless charging technology has developed rapidly, and realizing wireless charging for electric vehicles is a key focus of future charging work. Building upon previous research, this paper studies and designs a wireless charging circuit based on the principle of electromagnetic induction, which includes a transmitter and receiver, a bridge rectifier, and an RLC series resonant circuit. A set of feasible key parameters was analyzed, and some optimization schemes were proposed. The feasibility and safety of the circuit were verified through simulation software testing. The circuit was found to be relatively stable and applicable to charging most practical electric vehicles. This could provide a new solution for wireless charging of electric vehicles. It also has the potential to contribute to the efficient and convenient development of electric vehicle charging and is worthy of further research.

Keywords: Electric vehicles (EVs); Wireless charging; Electromagnetic induction; High efficiency and convenience

Online publication: Jul 23, 2026

1. Introduction

1.1. Research background

Technological advancements have brought cars into every household. While cars help people travel, environmental protection has become a focal point of discussion. Electric vehicles can significantly reduce vehicle exhaust emissions, which is very effective in energy conservation and emission reduction. Therefore, electric vehicles have been widely used in recent years. How to charge electric vehicles efficiently and conveniently is one of the urgent problems that the automotive industry needs to solve. Compared to traditional wired charging, wireless charging technology is renowned for its superior safety, efficiency, and stability. It has a broader prospect in the field of charging.

1.2. Previous research and limitations

In recent years, numerous advances and achievements have been made in the development and research of wireless charging circuits for automobiles. Oak Ridge National Laboratory in the United States has a long history of research in the field of high-performance Technology and has been able to increase the performance of wireless charging methods to over 120 kW after years of testing. The transmission efficiency is over 97 %, thus forming the basis for fast charging [1]. The Korea Advanced Institute of Science and Technology in South Korea developed an electric vehicle that uses electromagnetic induction and wireless charging and was put into operation in Seoul in 2011 [2]. In 2023, in Detroit, Michigan, North America's first dynamic Wireless charging track opened. The 400-meter-long track reached a charging power of 19 kW during a demonstration drive. The Israeli company Electron Wireless installed a dynamic Wireless charging system on a main road southwest of Paris [3]. Thanks to this research, Wireless charging technology has made great progress and is now gradually entering practical application. Energy transmission efficiency and range are generally sufficient to meet the basic charging needs of electric vehicles today. However, there is still room for improvement in terms of performance, heat generation, and stability, and the transmission efficiency and range are not optimal and need further optimization.

1.3. Research content and significance

This study utilizes Faraday's principle of electromagnetic induction. After carefully studying the working principle of wireless charging, we designed a dual-port charging circuit equipped with a transformer. By utilizing the resonance of inductors and capacitors, it can significantly reduce energy loss during the charging process. A bridge rectifier circuit was added to the output of the circuit. It can convert AC power to DC power. This provides the load with a relatively stable charging voltage. We analyzed whether this circuit is safe and feasible, and proposed methods for improvement. The goal of this research is to make wireless charging both safe and practical. It also enables fast, convenient, and efficient charging. This also offers new ideas and approaches for the wireless charging of electric vehicles.

2. Scheme principle and design

2.1. General design principle and logic

Electromagnetic induction wireless charging occurs when the coils of the transmitting end and the receiving end are close; the transmitting end generates an alternating magnetic field through the alternating current, which then induces a current in the receiving coil to realize the transmission of energy. This method is simple and direct, and can complete energy transmission at a short distance. It has relatively mature technology, nd the cost is relatively controllable [4]. When the araetes ω_0, L,C in a ciruit satisfy $\omega_0 L=\frac{1}{\omega_0 C}$, which implis $f_0 \frac{1}{2\pi\sqrt{LC}}$, the circuit state in which the port voltage and current of a one-port network happen to be in phase is called a resonant state. An *RLC* series circuit has the minimum impedance and the maximum current at resonance. It can achieve relatively high energy transmission efficiency. The transmitter design in this scheme includes a resonant network comprising an alternating power supply, resistors, capacitors, and inductors. Alternating current is transmitted to the receiving end through a transformer. At the receiving end, an *RLC* series resonant circuit is still used to play a crucial "frequency selection filtering" role. In the wireless charging system, by locking the resonant point, the influence of input voltage fluctuations can be offset, and the load voltage can be more stable. A bridge rectifier circuit is added between the resonant circuit and the load, and the alternating current becomes a one-way pulsating direct current, which is more in line with the needs of wireless charging.

The design of wireless charging circuits cannot be separated from the design of inductive devices. Modern inductive devices can be divided into two categories: air-core inductors (including solenoid inductors, ring inductors, flat inductors, etc.) and magnetic core inductors (including ferrite magnetic ring filter inductors, electrically controlled adjustable inductors, etc.). A magnetic core inductor is an inductor with a magnetic core, which uses magnetic cores (usually iron, ferrite, or other magnetic materials) to enhance the inductance effect. The magnetic core can improve the self-inductance value of the inductor, enhance the response of the inductor to the external magnetic field, and reduce the magnetic coupling noise. Compared with air-core inductors, magnetic core inductors are more widely used in high-power, medium-low-frequency, or some high-frequency occasions that require energy storage and filtering. The magnetic core can store more magnetic energy and generate a higher induced voltage. In the field of wireless charging of electric vehicles, it is suitable for inductors with magnetic cores. It can significantly improve transmission efficiency and reduce energy waste. It realizes large inductance and large current in a smaller volume to meet the needs of electric vehicles better. How to place the ferrite magnetic core will also affect the focusing effect of the magnetic field. Different core shapes such as U-shaped, E-shaped, and zig-shaped have their own uses [5].

Based on the principles discussed above, the key parameters for the circuit are established as shown in **Table 1**.

Table 1. Key parameter settings

Operating frequency	50Hz
Resonant capacitance	$100\mu F$
Resonant inductance	$100mH$
Transformer turns ratio	1:1.2
Target RMS output voltage	$263V$
Load resistance	50Ω
Rated output power	$1.38338kW$

Verification of resonance conditions: $f_0=\frac{1}{2\pi\sqrt{LC}}=\frac{1}{2\pi\sqrt{0.1\times1\times10^{-4}}}\approx 50.3Hz$, which is close to the operating frequency and satisfies the resonance condition. The transformer turns ratio. $n=\frac{N_2}{N_1}=1.2$, therefore the effective value of the transformer secondary no-load voltage is: $U_1=n\times U_0=1.2\times220=264V$ (where U_0 is the total input voltage of the power supply), and the forward voltage drop of the 1N4007 diode is $U_D\approx 0.7V$. Therefore, the effective value of the voltage across the load R_2 is $U_2=U_1-\frac{2U_D}{\sqrt{2}}=264-\frac{1.4}{1.414}\approx 263V$. The load output power $P=\frac{U_2^2}{R_2}=\frac{263^2}{50}=1.38338kW$. The quality factor of the transmitter is $Q=\frac{2\pi f_0 L}{R_1}=\frac{2\times3.1416\times50\times0.1}{1}\approx 31.42$, indicating that the loss of the transmitter circuit is relatively small.

2.2. Safety and feasibility analysis of the scheme

This solution does not use contact charging, which effectively avoids the risk of leakage and electric shock. Furthermore, the magnetic field is relatively concentrated, the external radiation is low, and it has certain overvoltage, overcurrent, and overtemperature protection. This set of schemes is simple in structure, universal in devices, and low in cost. It is suitable for static charging in the car and in the parking lot, and basically has the value of engineering promotion. *RLC* resonant charging technology allows the transmitting coil and receiving coil of the system to be at the same operating frequency. At a specific working frequency, the transmitting coil and the receiving coil will resonate. In this way, electricity can be transmitted efficiently

[6]. In practical applications, you can also add controllers, integrated sensors, communication modules, and so on. The wireless charging system can be remotely monitored, fault-diagnosed, and adaptively adjusted, and the user experience and intelligence level can also be improved [7].

2.3. Circuit structure design

This scheme uses a dual-port network between the transmitter and the receiver, plus the *RLC* oscillation circuit. Within the range allowed by the error, a relatively stable DC pulsation voltage can be obtained at both ends of the load. The circuit topology based on the principles mentioned above is shown in **Figure 1**.

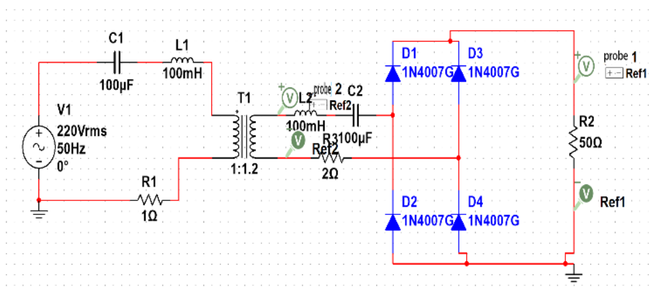

Figure 1. Circuit topology diagram.

3. Test results

Use a voltmeter probe to measure the total voltage at the receiving end and the output voltage across the load. The circuit structure was built using NI Multisim 14.3 simulation software, and the waveforms of the total output voltage and the voltage across the load were plotted, as shown in **Figure 2**.

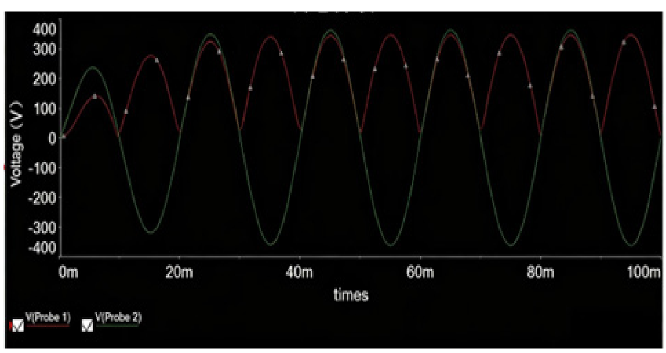

Figure 2. Waveforms of the total output voltage and the voltage across the load.

Analysis of the waveform in **Figure 2** shows that: Within the allowable error range, the total output voltage exhibits a basically stable sine wave, indicating that the *RLC* resonant system has achieved basic stable operation. Energy transfer via magnetic coupling is normal. The voltage across the load is a rippled DC voltage. The peak voltage is approximately 380–400V. This is the expected output waveform after rectification by the wireless charging system. It can directly charge the load of electric vehicles. It meets the basic requirements for wireless charging. The system detects indicators such as the state of resonance, operational stability, safety, and feasibility. The results show that the waveform is relatively smooth, and no drastic voltage changes have been observed. The entire charging system operates in a coordinated and stable manner, and its overall performance is good. Able to provide a basically stable pulsed DC power to the load. Its kilowatt-level power output gives it a long battery life. The temperature, voltage, and other properties of each component all meet safety standards.

4. Optimization research

4.1. Research limitations

The main shortcomings of this solution are as follows: The transmission distance is relatively short, and the efficiency will decrease significantly as the distance increases; When the system is working, the coil that is supplied with a high-frequency signal may generate significant heat, which accelerates the aging of the coil; If the coil deviates, the power will fluctuate, and the overall stability still needs to be improved. These shortcomings of wireless charging systems can be optimized in the following aspects to meet the charging needs of electric vehicles better.

4.2. Transmission distance optimization

The transmission distance will directly determine the upper limit and application areas of wireless charging. Optimizing transmission distance is a top priority for improving various wireless charging systems. Adjusting the magnetic field focusing effect is the most important part of increasing the transmission distance. Optimizing the distance for power transmission requires consideration of energy loss, transmission efficiency, and cost. The reference proposes a coil optimization design method for a high-efficiency mid-range magnetic resonance coupled wireless charging system for electric vehicles that adapts to demand-side management [8]. The structure of the charging coupling coil was designed, and the efficiency changes caused by the relative offset of the coil were optimized and analyzed. The optimal operating frequency of the system was determined, which improved the transmission distance of the system.

4.3. Coil heating optimization

According to Joule's law, current flowing through various circuit components will definitely produce thermal effects. Long-term heating will reduce the efficiency of the equipment and accelerate the aging of the components. If it is serious, it may also bring danger. The temperature rise of the wireless charging coil is also a key factor affecting the reliability and efficiency of the system. If the temperature is too high, it will accelerate the aging of the insulation and also increase the copper loss and magnetic core loss. Using the electromagnetic-thermal coupling model, coupled with the multi-objective Pareto optimization method. By optimizing the winding structure, the layout of ferrite, and the heat dissipation structure, it can effectively reduce the steady-state temperature of the coil. It can effectively reduce the steady-state temperature of the coil [9].

4.4. System efficiency optimization

Improving the energy conversion efficiency of the system can enhance the overall efficiency of the charging system, making charging tasks more convenient and faster. Reference suggests that high-frequency copper loss can be effectively reduced by setting the coil structure parameters reasonably (such as optimizing the wire diameter and number of strands, using Litz wire for winding, and optimizing the number of turns distribution) [10]. Choose magnetic core materials with high magnetic conductivity to reduce the loss of the magnetic core itself. Then make adaptive adjustments to the size and geometric shape of the magnetic core; this can reduce iron loss and enhance magnetic field coupling. Improving the design of the magnetic shielding structure and the spatial layout of the coil can suppress the phenomenon of magnetic leakage and improve the utilization rate of magnetic flux.

4.5. System stability optimization

The primary prerequisite for designing wireless charging circuits is a stable charging process. The stability of the system is mainly reflected through the dynamic balance of output power. To solve the power fluctuation problem caused by coil misalignment, researchers have introduced some feedback mechanisms. For example, closed-loop power control, power factor correction, and automatic power control are used. They are used to reduce or eliminate the impact of uncertainties. In this way, the output power and various voltage and current parameters can basically be stable. The overall stability of the system in the dynamic working state has also been improved.

5. Conclusion

This paper designs a wireless charging circuit based on the principles of electromagnetic induction and resonance. It is divided into two networks: the transmitting end and the receiving end. The transmitter uses AC power as the excitation source. The receiving end, in conjunction with a bridge rectifier circuit, provides pulsed DC voltage to the load. The circuit structure of this solution is relatively simple and has strong feasibility. It facilitates the detection of the source of the fault when a circuit malfunctions. The overall cost is low. Non-contact magnetic coupling charging is used, and the components are functioning well. Safety is guaranteed. The voltage across the load terminals exhibits a basically stable pulsed DC voltage. The power output reached the kilowatt level, and both the *RLC* series resonant and bridge rectifier systems operated normally. Good energy transfer effect. However, there is still room for improvement in transmission distance, heat generation, system efficiency, and stability. This research can now be applied to charging in fields such as wireless charging for household electric vehicles, automatic parking lot recharging, and on-board low-voltage auxiliary power supplies. In the future, this technology will continue to develop towards long-distance, high-efficiency charging. Further optimize heat generation and operational stability. To better adapt to the high power and dynamic wireless charging of electric vehicles, giving it a broader application prospect.

Disclosure statement

The author declares no conflict of interest.

References

[1] Chen P, Niu H, Ji S, 2025, Research on Magnetic Coupling Resonant Wireless Charging System for Electric Vehicles. Special Purpose Vehicle, 2025(06): 21–23.

[2] Yang F, 2023, Research on Electromagnetic Shielding Design and Safety of Wireless Charging Coupling Mechanism for Electric Vehicles, thesis, Chang'an University.

[3] Li X, 2024, Research on Power Stability Control Optimization of Dynamic Wireless Charging System for Electric Vehicles, thesis, Southeast University.
[4] Xing R, 2025, Efficiency Improvement and Electromagnetic Compatibility Analysis of Wireless Charging Technology for Electric Vehicles. Popular Science & Technology (Volkswagen Qiche), 2025(07): 43–45.
[5] Shi W, 2026, Research on Wireless Charging Technology for Power Batteries of New Energy Vehicles on Expressways. Internal Combustion Engine & Parts, 2026(06): 104–106.
[6] Zhang Q, 2021, Research on Static Resonant Wireless Charging System for Electric Vehicles, thesis, Anhui University of Science and Technology.
[7] Qin S, 2025, Design and Optimization of Wireless Charging System for Electric Vehicles. Auto Time, 2025(02): 124–126.
[8] Zheng G, 2017, Optimal Design of High-Efficiency Medium-Distance Magnetic Resonance Wireless Charging Coil for Electric Vehicles Adapting to Demand-Side Management. Transactions of China Electrotechnical Society, 32(S1): 209–216.
[9] Ma J, Li Z, Liu Y, et al., 2023, Thermal Analysis and Optimization of the Magnetic Coupler for Wireless Charging System. IEEE Transactions on Power Electronics, 38(12): 16269–16280.
[10] Zhong Y, 2025, Optimization Research of Magnetic Coupling Mechanism for Electric Vehicle Wireless Charging System. Popular Science & Technology (Volkswagen Qiche), 2025(11): 70–72.