

Application of Wireless Transmission Technology in Power System

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Abstract. In order to study the theoretical research of electromagnetic coupling resonance wireless transmission technology, the model was established by coupling theory and circuit theory respectively. By studying the transmission characteristics of power and efficiency, the parameters of the system, the relative position of the coil, and the transmission medium, the power transmission was achieved by electromagnetic coupling resonant transmission technology efficiently and stably. Through model analysis and MATLAB and PSpice simulation analysis, the effects of coil natural frequency, mutual inductance and coupling coefficient, transmission distance, load and coil parameters on the transmission characteristics of the system were studied. The phenomenon of frequency division and its causes were discussed. The optimal power natural frequency f_p , the best power mutual inductance M_p , the best power load R_p , the best efficiency load R_η , and the optimum power distance d_p were obtained. It provided the basis for system optimization design. The corresponding scheme was proposed for the optimization design of electromagnetic resonance coupled wireless transmission system with different requirements. The hardware design of the system was introduced in detail. The experiment device was made by the hardware circuit design. Through a series of experimental data analysis, the factors affecting the transmission characteristics of magnetically coupled resonant wireless transmission technology were analyzed. The results show that as the transmission distance increased, the system's optimal output power and optimal transmission efficiency were reduced. The distance between the best power load and the best efficiency load was decreasing. Therefore, this method can obtain a high frequency power supply that satisfies the resonance frequency.

1. Introduction

Since the second industrial revolution, as a kind of cleaning, electric energy is easy to transport and easy to convert into other forms of energy. It is applied to all aspects of people's lives. The development of society has been accelerated and people's quality of life has been greatly improved. With the development of the times, the load is changing with each passing day. However, the generation and transmission of electrical energy are always the same. The emergence of various types of loads makes contact power supply cannot meet the needs of the load for electrical energy [1]. The traditional contact power supply includes wire transmission, and most of the power supply for the load uses this power supply mode. This power supply wire limits the movement of the load. Although the relative sliding transmission method can make the load move on the specified line, it is not perfect. In recent years, the popularity of consumer electronics has led to contact-based power supplies that have constrained people's lives. Is there any kind of power supply technology that can solve these problems perfectly? Obviously, the radio energy transmission technology can exactly meet the power demand of these special occasions. Electromagnetically coupled resonant radio energy transmission technology has the advantages of flexibility, convenience, safety, reliability, non-contact power supply, easy control and less external influence. It has received much attention in recent years [2].

2. State of the Art

Japan has made major breakthroughs in the optimal operating frequency of electromagnetically coupled resonant wireless transmission technology. Tokyo University combines circuit model theory, electromagnetic wave theory, and antenna theory to establish mathematical models for multiple system transmissions based on different power frequencies. Through model analysis and simulation verification, the optimal power frequency of the system was determined [3]. The Korea Academy of Science and Technology studied the multi-coil relay effect of magnetically coupled resonant wireless transmission technology and achieved a major breakthrough. The experimental results show that the magnetic coupling resonant wireless transmission system increases greatly in transmission distance when relay coils are added. This technology is used to charge wirelessly-powered electric vehicles. 30W of power is transmitted to a 17cm charger with an efficiency of 70% [4].

Prof. Chen Qingquan and his team of Harbin Institute of Technology have systematically studied electromagnetically coupled resonant wireless transmission technology based on circuit theory models. The magnetically coupled resonant wireless transmission system was optimized. 50w of electrical energy is transmitted 1m, and the efficiency is 60%. Different types of loads and multiple loads are studied in depth. Taking the actual scene of wireless power supply for home appliances as the research object, a large number of basic researches have been done on the frequency conversion power control of the electromagnetic resonance-resonant wireless power transmission technology. It provides the basis for the era of "tailless appliances" [5]. At the 2010 International Consumer Electronics Show, Haier launched the so-called "tailless TV" using electromagnetically coupled resonant wireless transmission technology, which is highly sought after by electronics enthusiasts around the world [6].

3. Design of Electromagnetically Coupled Resonant Wireless Transmission System

The electromagnetically coupled resonant wireless transmission system is composed of a transmitting part and a receiving part. The transmission circuit includes a high frequency power supply and a transmission coil. The receiving part mainly includes the receiving coil and the load. In order to obtain a high frequency power supply that satisfies the resonant frequency, it is necessary to rectify and invert the commercial power supply. The basic block diagram of the system is shown in Figure 1.

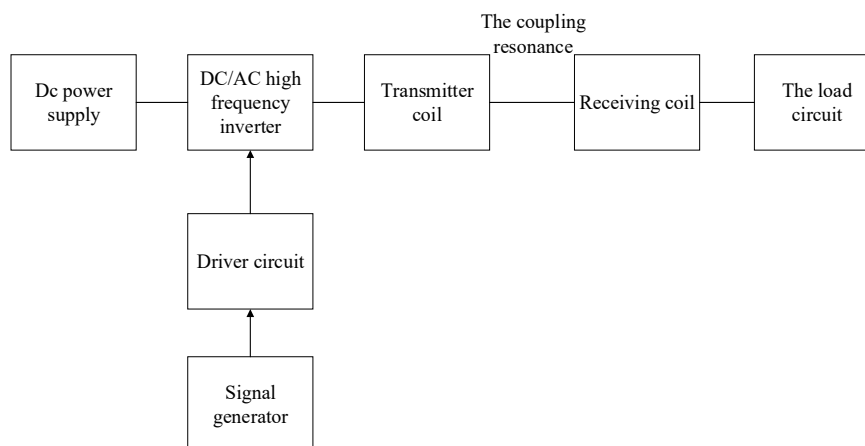


Figure 1. The Basic Block Diagram of the System

3.1 Design of High Frequency Inverter Circuit

This system needs to design a high frequency inverter circuit of about 1MHz. At present, the most widely used high-frequency inverter topology circuit is used, namely E-type resonant inverter circuit. The system design choice is IRF840MOS tube. The main parameters are shown in Table 1. The IRF840 MOS transistor has an operating frequency that can meet design requirements, a high withstand voltage value, and a small parasitic capacitance. It is conducive to the development of the circuit design.

Table 1. IRF840MOS Basic Parameters

Basic parameters	Value
Maximum working voltage	500V
Maximum driving voltage	20V
Maximum drain current	8A (25°C)
Maximum operating current	32A
On resistance	0.85Ω
Input capacitance	200PF
Output capacitance	1225PF

The choke inductor L_o has a steady flow effect. In order to obtain a stable current value, the inductance L_o of the choke inductor should be large enough. The auxiliary capacitor C_o makes the switch VG work in the best state [7].

$$L_o \geq \frac{10}{\omega^2 C_o} \quad (1)$$

$$C_o = \frac{0.1836}{\omega R} \left(1 + \frac{0.81 Q_L}{Q_L^2 + 4} \right) \quad (2)$$

Taking into account the difference between the actual design and the ideal situation, this experiment needs to test different factors that affect the transmission characteristics of the system. In order to meet the needs of the actual situation, in the system design, these parameters are fine-tuned to obtain: $L_o=1.5\text{mH}$, $C_o=1.5\text{nF}$.

3.2 Design of Driving Circuit

The IR2110 chip is an integrated circuit designed to drive high-power MOSFETs and IGBTs. The circuit chip has high integration and fast response and can generate a 3 MHz driving signal. The cost is low. It is easy to debug and has a small number of driving power supplies, which simplifies the design of the drive circuit. It can achieve a drive voltage of 10~20V output. The circuit diagram is shown in Figure 2.

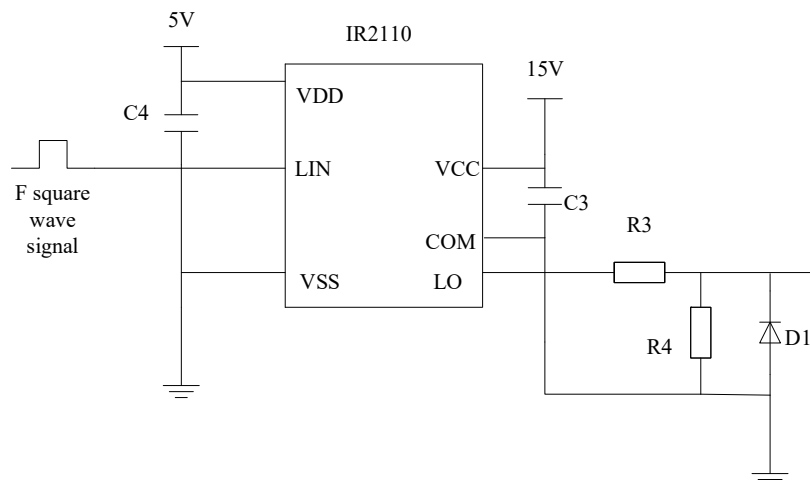


Figure 2. Driver Chip and Peripheral Circuit

4. Experiment and Result Analysis of Wireless Transmission

4.1 Experiment and Result Analysis of Power Frequency

In this experiment, the DC source is 20V, the two coils are coaxial and 6CM apart, and the load resistance is 200Ω. The signal generator's signal frequency is adjusted to change the system's power frequency. The output power is calculated by measuring the voltage of the load resistor. The input power of the system can be obtained by reading the source of the regulated voltage.

Using MATLAB software, experimental data was collated. The experimental curve of the system's power frequency effect on transmission characteristics is shown in Figure 3. When the frequency of

the power supply is near the resonant frequency, both the output power and transmission efficiency of the system reach a maximum value. At a resonant frequency of ± 0.02 MHz, the system's output power and transmission efficiency have dropped by more than 50%.

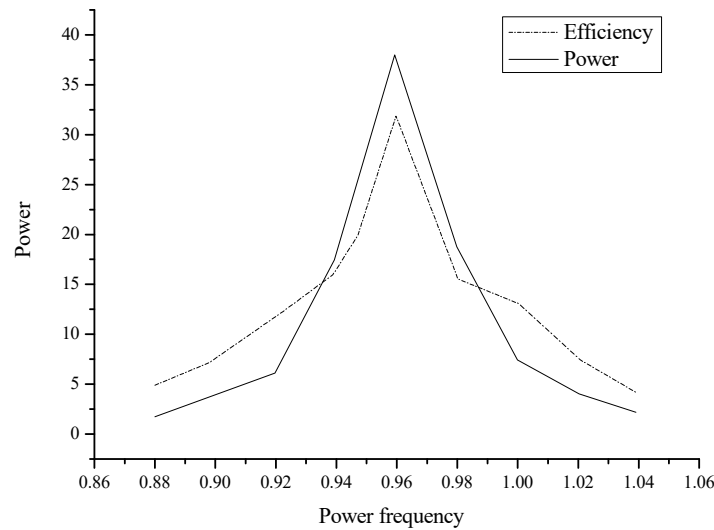


Figure 3. The Influence of Power Frequency on the Transmission Characteristics of the System

4.2 Experimental and Result Analysis of Natural Frequency

In this experiment, the DC source was 20V and the coil was coaxial. By increasing the compensation capacitance and adjusting the signal frequency of the signal generator, the experiment of the transmission characteristics of the natural frequency to the system is performed. Two sets of experiments were performed: the coil distance was 6CM, the load resistance was $R_{load}=25\Omega$, and $R_{load}=30\Omega$.

Using MATLAB software, experimental data was processed. The curves of the effect of the natural frequency of the coil on the transmission characteristics of the three groups of experiments are shown in Figure 4 and Figure 5. It can be seen from the figure that the transmission efficiency of the system increases as the natural frequency of the coil increases. However, when the natural frequency of the coil reaches a certain value, the transmission efficiency of the system does not increase. The output power of the system increases first as the natural frequency of the coil continues to increase. When the natural frequency of the coil reaches a certain value, the output power of the system decreases. A comparison of Figure 4 and Figure 5 shows that in a system with the same transmission distance, the greater the load resistance, the greater the natural frequency of the optimal power of the system. The best power natural frequencies of the three groups of experiments were calculated to be 0.797 MHz and 0.962 MHz, respectively, which are close to the experimental results.

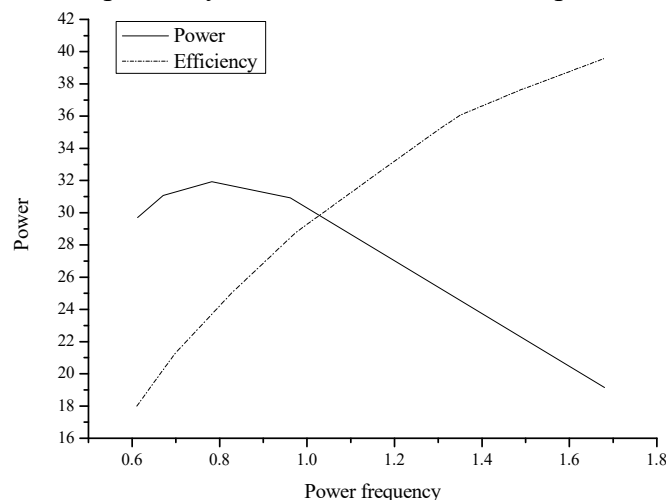


Figure 4. The Curve of System Transmission Characteristics with the Natural Frequency of the Line when $R=25\Omega$

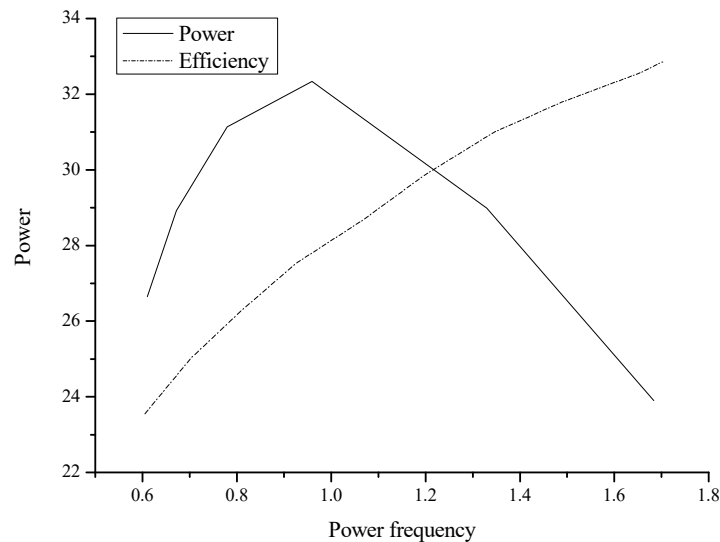


Figure 5. The Curve of the System Transmission Characteristics with the Natural Frequency of the Line when $R = 30\Omega$

4.3 Experimental Results and Analysis of Load

When the power supply voltage is 15V, the signal frequency output from the adjustment signal generator is the resonance frequency. Under the condition that the transmitting coil is coaxial with the receiving coil, experiments are performed on the transmission characteristics of the system with different loads for systems with 6CM and 8CM coil spacing. During the experiment, the resistance of the load was continuously changed, and the output power and transmission efficiency of the system were measured and calculated.

Using MATLAB software, experimental data was collated. When the transmission distance is $D=6\text{CM}$, $D=8\text{CM}$, the experimental curves of the system's load resistance on the transmission characteristics are shown in Figure 6 and Figure 7. Through analysis, it can be seen that both the output power and the transmission efficiency of the system increase with the increase of the load resistance, and then decrease. The system first appears the best power, and then the best efficiency occurs. The best power load is always greater than the best efficiency load. By comparing Figure 6 with Figure 7, it can be seen that as the transmission distance increases, the optimal output power and the best transmission efficiency of the system are reduced. In addition, the distance between the best power load and the best efficiency load is decreasing. This is because as the distance increases, the mutual inductance of the system decreases and the $k^2Q_1Q_2$ value of the system decreases.

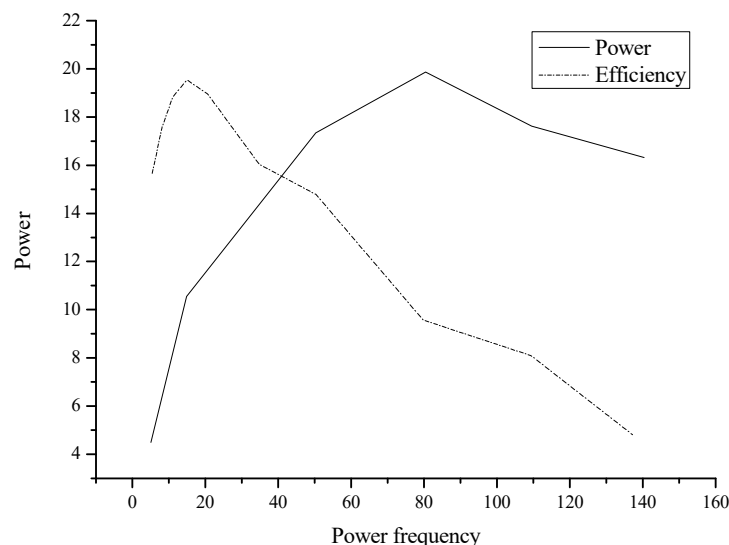


Figure 6. The Effect of Load Resistance on the Transmission Characteristics of the System

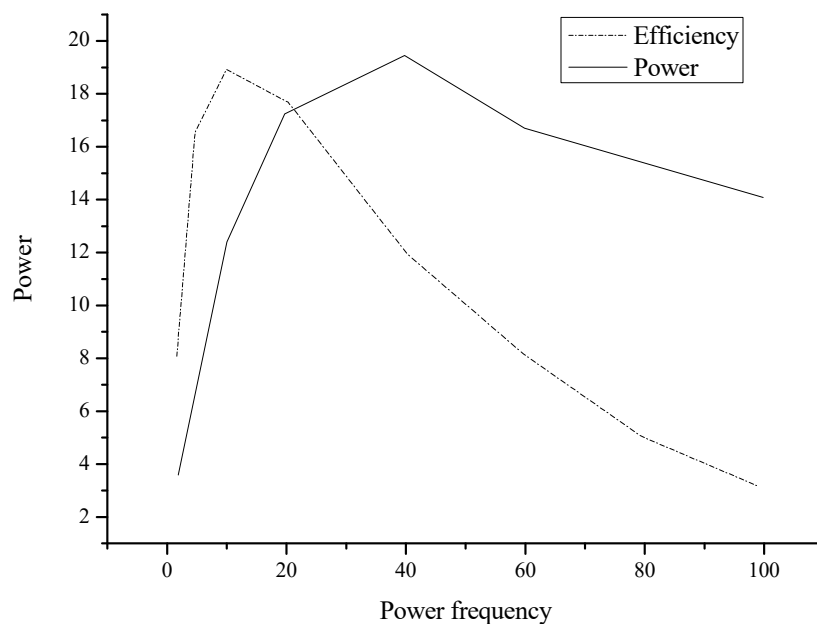


Figure 7. The Effect of Load Resistance on the Transmission Characteristics of the System

5. Conclusion

Through the theoretical research on the electromagnetic coupling resonance wireless transmission technology, the coupling theory and the circuit theory are used to establish the model. Through the model analysis, the transmission mechanism of the system is further understood. Through theoretical analysis and MATLAB software, PSpice software simulation analysis and experimental verification, various factors that affect the transmission characteristics of the system are studied. It provides a certain theoretical support for the optimal design of the system. In the case of system resonance, MATLAB software and PSpice software are used to study theoretically the influence of factors such as coil natural frequency, mutual inductance and coupling coefficient, transmission distance and load resistance on the transmission characteristics of the system. The corresponding conclusion is drawn. The parameters such as optimal power natural frequency, optimal power mutual inductance, optimum power load, best efficiency load, and optimal power distance are obtained, which provides the basis for system optimization design. In order to meet the different needs of the electromagnetic resonance coupled wireless transmission system, the design scheme is optimized and the corresponding scheme is proposed. The experimental platform of the system is set up, and the theoretical verification test is carried out. The design of the high frequency inverter circuit, the driving circuit and the selection of the circuit device are introduced. The design of the resonant coil is carried out. The experimental study on the factors that affect the transmission characteristics of the system is carried out. The correctness of the theoretical analysis and the feasibility of the system design are verified.

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