Analysis and Design of Wireless Charging System based on SSC

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Keywords: Resonance, wireless charging, coupling coil, chopper frequency.

Abstract: Based on the series resonance compensation topology structure as the research foundation, taking charging electric cars as the object, using the simulation software to build a wireless charging system T model equivalent circuit, by dealing with choosing the right frequency sweep chopping frequency, using the method of regulating control, solves the problem of wireless power transmission efficiency is low and the rate of change, and finally the use of Ansoft electromagnetic simulation software Maxwell3D theory analyses the mutual inductance coil and the relationship between the transmission distance, to the study of wireless charging of electric cars, has very important significance.

1 INTRODUCTION

Comrade Xi Jinping pointed out in the report to the 19th national congress that "clear water and green mountains are golden mountains", adhering to the basic state policy of resource conservation and environmental protection, electric energy as a kind of clean energy is widely used in all walks of life, and electric vehicles as a new type of energy transportation is an inevitable development trend. As a safe, convenient and adaptable Power Charging technology, Wireless Power Transfer (WPT) is the key technology for the development of pure electric vehicles in the future. If we master this technology, we will have the right to speak in this field. Many companies have designed wireless charging systems with power up to 3kw (L. Chen, S. Liu, Y. C. Zhou and T. J. Cui, 2011), but there are still some research points that need to be improved, such as: how to reduce the coil size to reduce the system cost when the same power is transmitted, how to make the system better adapt to the complex situation of different coil displacements, how to improve the transmission efficiency while reducing the loss, etc., are hot issues in current research. Based on previous studies, this paper adopts the transformer wireless charging control system to regulate the output power, and mainly analyzes the influence of the characteristics, frequency characteristics and coupling coefficient of the series-series resonant topological switch on the output power and transmission efficiency.

2 S-S RESONANT TOPOLOGY MODEL ANALYSIS

The main principle of wireless charging technology is that the transmitter coil and the receiver coil have the same resonant frequency. To achieve this purpose, an appropriate resonant compensation capacitor is usually added to the two coils. According to the transmitting terminaland receiving terminal network connection relationship, WPT system topology structure can be divided into series -series (S-S), series and parallel (S-P), parallel and series (P-S), parallel-parallel (P-P) of these four basic structure, the series-series(S-S) resonant topology is the best power wireless transmission resonant topology (Yongsheng Fu, Lei Shi, Kevin(hua) Bai, 2014). Figure 1 is transformer equivalent model of (S-S) resonant.

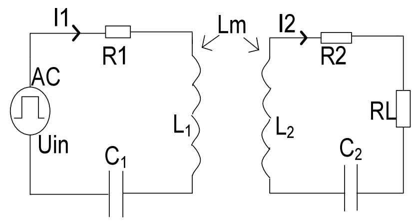

Figure 1. S-Stransformer equivalent model.

It is assumed from figure 1 that:

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$$Z_1 = R_1 + j * w * L_1 - \frac{j}{w * C_1} \tag{1}$$

$$Z_2 = R_2 + R_L + j * w * L_2 - \frac{j}{w * C_2} \tag{2}$$

$$X_m = w * L_m \tag{3}$$

$$Z_m = j * w * L_m \tag{4}$$

Where, R1 is the internal resistance of L1 of the primary coil, R2 is the internal resistance of L2 of the secondary coil, and RL is the load, C1 and C2 are the resonant capacitors of the primary side and the secondary side respectively. Lm is the mutual inductance of the primary and secondary coil. Therefore, it can be known from the transformer principle that:

$$\begin{cases} Z_1 * I_1 - Z_m * I_2 = U_{in} \\ I_1 * Z_m - I_2 * Z_2 = 0 \end{cases} \tag{5}$$

Equation 5 shows that:

$$\begin{cases} I_1 = \dfrac{U_{in} * Z_2}{Z_1 * Z_2 + (w * L_m)^2} \\ I_2 = \dfrac{j * w * L_m * U_{in}}{Z_1 * Z_2 + (w * L_m)^2} \end{cases} \tag{6}$$

Total power input of circuit:

$$P_{in} = \mathrm{Re}(U_{in} * I_1) = \frac{U_{in}^2 * |Z_2|}{|Z_1 * Z_2 + (w * L_m)^2|} * \cos\theta \tag{7}$$

Total power output of circuit:

$$P_{out} = |I_2^2| * R_L = \frac{U_{in}^2 * R_L * (w * L_m)^2}{|[Z_1 * Z_2 + (w * L_m)^2]^2|} \tag{8}$$

Total circuit efficiency:

$$\eta = \frac{P_{out}}{P_{in}} = \frac{(w * L_m)^2 * R_L}{|Z_2 * [Z_1 * Z_2 + (w * L_m)^2]| * \cos\theta} \tag{9}$$

Maximum transmission efficiency:

$$\eta = \frac{(w * L_m)^2 * R_L}{(R_2 + R_L)[R_1(R_2 + R_L) + (w * L_m)^2]} * 100\% \tag{10}$$

3 COIL MODEL AND CIRCUIT SIMULATION

3.1 Coil Model

By equation (10) with known as in resonance circuit and load coil of the case, the transmission efficiency of circuit is only related to the mutual inductance coil, the greater the mutual inductance transmission efficiency is higher. According to the principle of magnetic coupling, when the same wire is used to form a coil, the larger the coil area, the greater the mutual inductance value and mutual inductance coefficient will be. So the method to improve the transmission efficiency of system is within the allowed space set up the large area of the coil.

This design by using the finite element analysis software Ansys/Maxwell circuit parameters of the simulation to get the best parameters based on figure 2 inject 50 KHZ high frequency ac signal to the coil, the magnetic field lines toward the trend and magnetic field strength.

3.2 Principles of WPT

Principle of electric vehicle charging system: power frequency alternating current (ac) is obtained by rectifying filtering first stable direct current (A.K. RamRakhyani, S.Mirrabbasi, and C.Mu, 2018), then through high frequency inverter for high frequency square wave ac, repass transmitter resonant compensating network and launch coil to make work in resonant state, when transmitting circuit frequency and receiving coil and the receiver equals the compensating network frequency, magnetic field energy can be transmitted through magnetic resonance (NMR), receiving coil get electricity finally through the high frequency output rectifier to the electric car battery.

3.3 Circuit Simulation

For s - s resonant topology, switch frequency directly affects the system's output power to the total loss, so the simulation of the system do sweep with the equivalent circuit of transformer, zero point of resonance analysis impedance has two, as shown in figure 3 so this design choice than 50 KHZ and chopping frequency can be changed as a resonance point, make the output power under control.

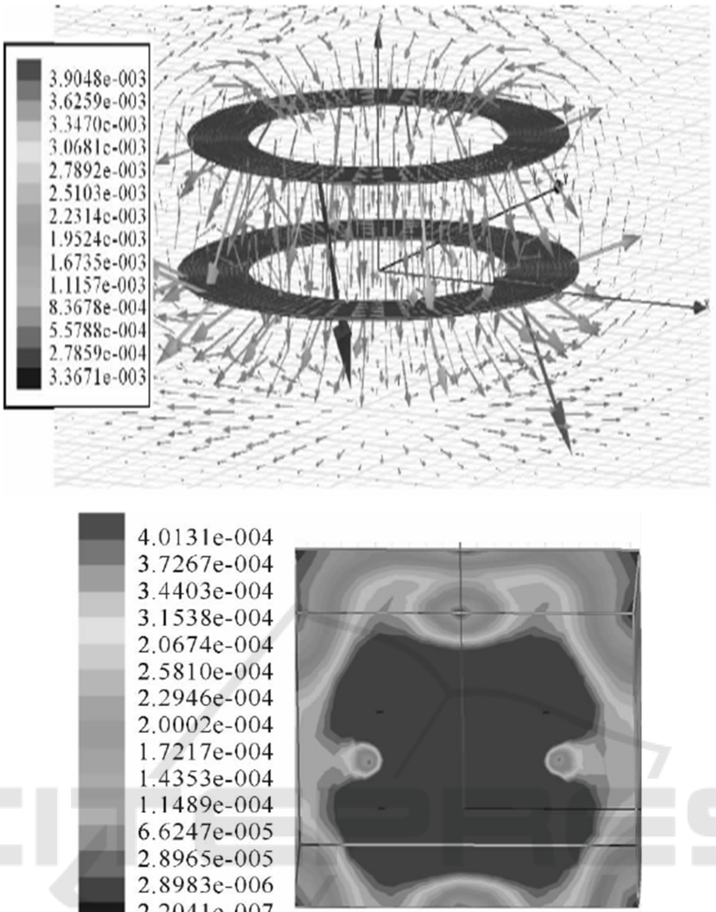


Figure 2. Lines of magnetic force coupling coil and the magnetic field intensity distribution.

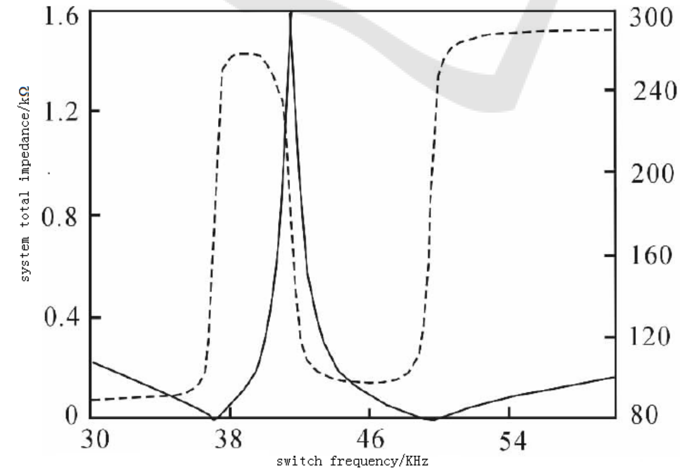


Figure 3. System total impedance and phase VS switch frequency.

According to the working principle of WPT and simulation of coil parameters, the system simulation waveform is shown in figure 4.

Simulation waveform shows by the figure 4 system of charging: when adjusting the input dc voltage of 220 v, the charging power of about 345 w, system about 60 ms into a stable state, the charging waveform smooth system safe and reliable operation.

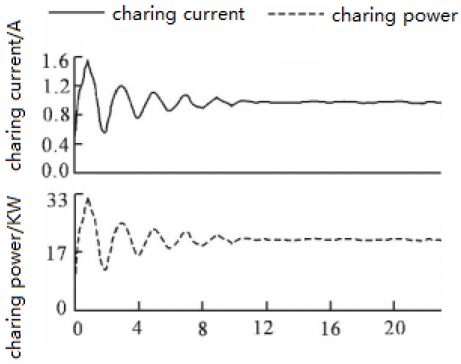
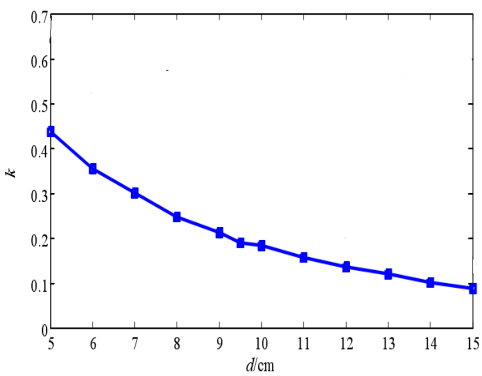


Figure 4. System simulation waveform.

4 COUPLING COEFFICIENT MEASUREMENT AND ANALYSIS

Coupling coefficient is the physical quantity that reflects the coupling degree of transmitting coil and receiving coil most directly. The coupling coefficient varies with the transmission distance of the system. The change of coupling coefficient directly affects the output power and transmission efficiency of the system.

Can be seen from the figure 5, the farther the transmission distance, the smaller the mutual inductance between the two coils M, the smaller the coupling coefficient k, and the smaller the coupling coefficient of output power and transmission efficiency is smaller, so, choose appropriate transmission distance is the factors affecting the output power and the transmission efficiency is very important.



5 CONCLUSION

Based on the s-s resonant topological structure, the design obtains the model parameters and chopper frequency of the wireless charging system through simulation analysis, and obtains the charging simulation waveform by simulating the T equivalent circuit diagram of the wireless charging system. It is pointed out that the system must detect the changes of coil mutual inductance and leakage inductance in real time according to the changes of relative displacements between coils in order to charge stable. The relationship between coil mutual inductance M and transmission distance d is analyzed theoretically.

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Figure 5. Relation curve between coupling coefficient and transmission distance.