가정용 전자제품을 위한 이중 송신부 LCC-S 보상 WPT 시스템의 오차 허용에 관한 연구

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A Study on Misalignment Tolerance in Dual-Transmitter LCC-S Compensated WPT System for Household Appliances

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ABSTRACT

This study proposed a dual-transmitter wireless power transfer (WPT) system with good misalignment capability for 200mm home appliance applications. The main coils respectively adopt a pair of multi-E dipole structure coils, and an extended DD coil wrapped around the ferrite on the multi-E dipole structure coil. The transmission performance of the coupling structure in the misaligned state is enhanced through dual-path power transmission. Finally, a 300W simulated WPT prototype was built to verify the superiority of the proposed coupling structure.

1. Introduction

Wireless power transfer(WPT) is safe and flexible is used in various areas of life. Among them, the field of WPT for household appliances is actively advancing. Some small-power home appliances have achieved satisfactory performance in centimeter-level short-range power transmission. However, for high-power appliances with hundreds of watts, the energy consumption is high, and due to volume and distance limitations, the size of the magnetic coupling structure cannot be too big, resulting in less than ideal transmission performance. Therefore, enhancing the long-distance transmission performance of household appliances has become one of the current research priorities. In addition, since misalignment of electrical appliances often misaligned in daily life, being able to maintain good transmission performance under such circumstances is also a problem that needs to be solved.

To tackle the challenges of long-distance WPT and misalignment of household appliances, this study proposes a dual-transmitter magnetic coupling structure in a half-bridge LCC-S compensated WPT system. The transmitter side adopts two types of coils: the multi-E dipole structure coil and extended DD coil for long-distance transmission. while the receiver side employs multi-E dipole coil, establishing two magnetic field transmission paths to enhance transmission and misalignment performance.

2. Theoretical Analysis

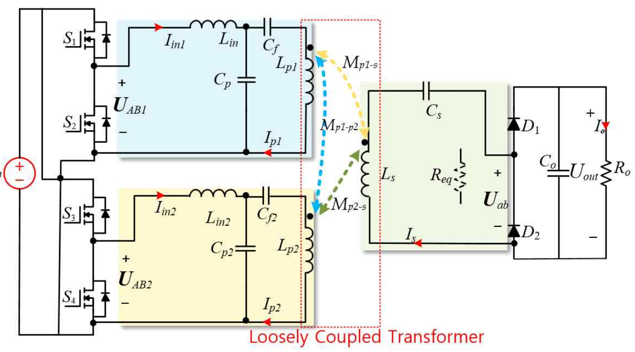

Fig. 1 Topology of dual-transmitter half-bridge WPT system

The proposed dual-transmitter half-bridge LCC-S topology is illustrated in Fig 1. Enhancing the transmission capability of the system is crucial for its application in long-distance WPT for household appliances. In this study, employing half-bridge mode inverter and rectifier can reduce switch losses, thereby contributing to efficiency improvement. And, proposed topology has three coils, so three mutual inductances are generated. However, only considers the mutual inductance of the opposite side circuit: M_{p1-s} and M_{p2-s} within the circuit and denotes the equivalent coupling coefficient of the dual-transmitter system as M_t:

$$M_t = M_{p1-s} + M_{p2-s} \quad (1)$$

The relationship between the transmitting side and receiving side currents is:

$$I_{p1} = \frac{U_{AB1}}{j\omega L_{in1}},\ I_{p2} = \frac{U_{AB2}}{j\omega L_{in2}},\ I_s = \frac{j\omega M_{p1-s}}{R_{eq}} I_{p1} + \frac{j\omega M_{p2-s}}{R_{eq}} I_{p2}. \quad (2)$$

According to [2], it is known that when both phases of the transmitter side are operated with a phase difference of 180°, under system alignment state, M_{p1-s} and M_{p2-s} are positive. This helps improve energy transfer within the magnetically coupled structure, enhancing performance both in alignment and misalignment states.

3. Design of Magnetic Coupled Structure

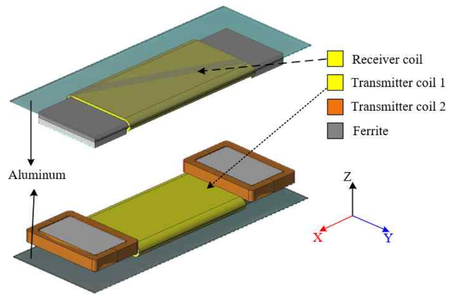

Fig. 2 3-D geometric structure of the designed magnetically coupled structure.

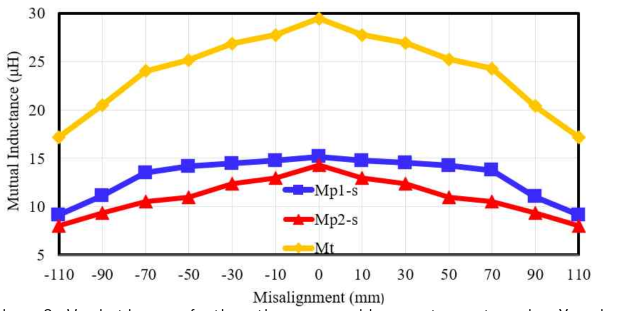

Fig. 3 Variations of the three couplings at system is X-axis misalignment state.

Fig 2 illustrates the schematic diagram of the magnetic structure for the dual-transmitter main coils. Transmitter coil 1 utilizes a multi-E dipole structure coil(L_{p1}), transmitter coil 2 adopts a extended DD structure coil wound separately on ferrites used to guide the magnetic field(L_{p2}). Receiver coil(L_s) used coil and ferrites similar to transmitter coil 1. Additionally, to ensure approximately equal power transmission on both paths, three coils with similar self-inductance values are selected as the coupled structure under certain coil turns conditions in this study. Due to the limited lateral misalignment capability of the bipolar coils, simulations were conducted using FEM tools to misalignment in the X-axis direction for the proposed magnetic coupling structure. In Fig 3, the coupling between the transmitter coils M_{p1-s} and M_{p2-s} gradually decreases with increasing misalignment distance. However, due to the dual-channel of the proposed magnetic coupling structure, Energy can be transmitted through two paths and can overlap, so the transmission efficiency is higher than a traditional single channel.

4. Simulation Verification

Fig 5 compares the output power of the single -transmitter and dual-transmitter system under misalignment along the X-axis. It can be observed that both systems achieve an output power of 300W when the aligned state. However, in the misaligned state, the dual-transmitter continuously transmit higher output power compared to the

Tab.1 System specifications

Parameter	Symbols	Value
Output Power	P_o	300 W
Input voltage	U_{in}	220 V
Output voltage	U_{out}	100 V
Resistance	R_o	33 Ω
Frequency	f	100 kHz

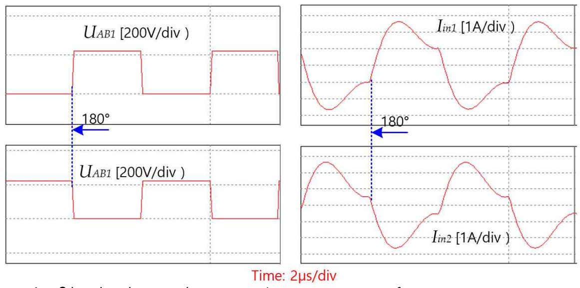

Fig. 4 Simulation voltage and current waveforms.

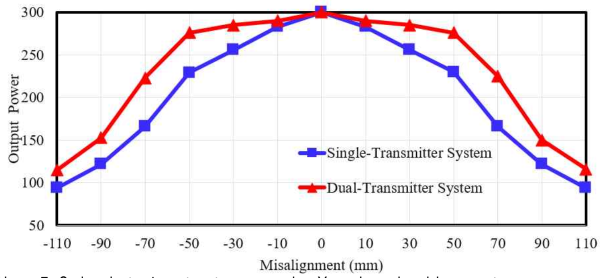

Fig. 5 Calculated output power in X-axis misalignment.

single-transmitter system. This indicates that the dual-transmitter system has better misalignment tolerance, thus confirming the analysis presented earlier.

5. Conclusion

This study proposes a half-bridge mode dual-transmission WPT system to improve misalignment performance. In the proposed dual-transmission side system, energy is superimposed and transmitted to the receiving side through two paths to increase the output power in the misaligned state. The output power is calculated using the PSIM simulation tool, which verifies the reliability of the proposed idea.

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