Study and Design of Resonant Charging System for High Voltage Transmission Line Monitoring Equipment

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A wireless energy transfer system based on magnetic resonant technology for power transmission and 110kV high voltage transmission line monitoring equipment recharging is studied and designed. The relationship among coil size parameter, transmission distance, the maximum approachable efficiency and several key parameters of the system are analyzed. The system operating under a high voltage transmission line condition, its loss and heat dissipation should be considered. Therefore, the optimal resonance frequency is obtained considering the switching and radiation loss. The coupling coils is is fixed on one side of the insulators, thus amorphous alloy (FeCrMoCB) interlayer is added to constrain the magnetic field distribution of the coils. The characteristic of coupling coils with interlayer is analyzed and compared with normal coils. The amorphous alloy interlayer reduces the resonance frequency and increases the quality factor of the system. Voltage distribution of insulator string and shed with the resonant charging system is simulated and calculated. The application of the system will not affect the performance of insulators. Being used in the 110kV high voltage transmission line, the distance of charging system is about 1.5m length. And the efficiency of charging system designed in this paper is 26.4% with resonance frequency 451kHz.

Index Terms—**magnetic coupling, resonant wireless power transfer, high voltage transmission line, insulation**

I. INTRODUCTION

NOWDAYS, there are a few types of power supply methods for HVTL (high voltage transmission line) monitoring equipment by the utilization of solar power, wind power, etc. However, these power supply quality is significantly affected by weather conditions. As a new wireless power transfer technology, resonant power transmission is based on the concept of near-field strongly magnetic coupled resonance, which currently can achieve adequate power transfer over a few meters. This novel technology can make the power supply for equipment on the HVTL more reliable and convenient. No physical connection between the high and low voltage sides assures the complete electrical isolation and safety.

The paper mainly focuses on studying and designing of resonant charging system for 110kV HVTL monitoring equipment. The research not only creatively provides the scientific method for the design of resonant charging system of HVTL monitoring equipment but also analysis the electromagnetic characteristics of the system when it applied under the condition of HVTL.

II. THEORETICAL ANALYSIS OF RESONANT CHARGING SYSTEM

The relationship among efficiency η, coupling coefficient k and quality factor Q can be obtained from the equivalent mutual inductance coupling model of the two-coil resonant charging system. The equation is showed in (1).

$$\eta_{R_L\text{-opt}} = \frac{k^2Q^2}{4(1+k^2Q^2)^{1/2}+2k^2Q^2} \tag{1}$$

In order to facilitate the design of system, the physical parameters (η, Q) are converted to the geometric parameters (A, D) of the system. A is the coupling coil size parameter, D is the distance between two coils. The derived relational equation is showed in (2).

$$\eta_{opt} = \frac{\frac{A}{D^6}\sqrt{\frac{A}{D^6}+1}}{\left(\frac{A}{D^6}+1+\sqrt{\frac{A}{D^6}+1}\right)\left(\sqrt{\frac{A}{D^6}+1}+1\right)} \tag{2}$$

According to the equation (2), the relation graph among system efficiency η, coil size parameter A and the transmission distance D is computed and showed in the Fig. 1.

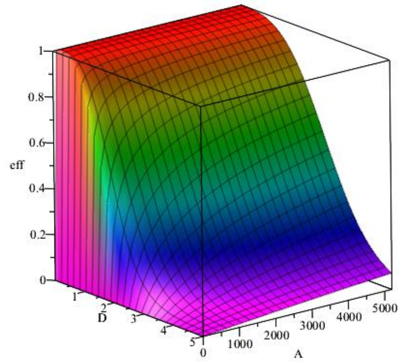


Fig. 1. Relationship among transmission efficiency η, coil size parameter A and the transmission distance D

III. DESIGN AND SIMULATION OF THE SYSTEM

A. Configuration of system

Fig. 2 demonstrates the configuration of two-coil resonant charging system for HVTL monitoring equipment. The whole system includes CT, inverter, transmitter, receiver, etc. The transmitter and receiver are designed to fix at the one side of the insulator string. This fixed mode can operate when the line is live. When the system tuned into a resonant state by the inverter, power exchanges between the transmitter and receiver through resonant electromagnetic coupling.

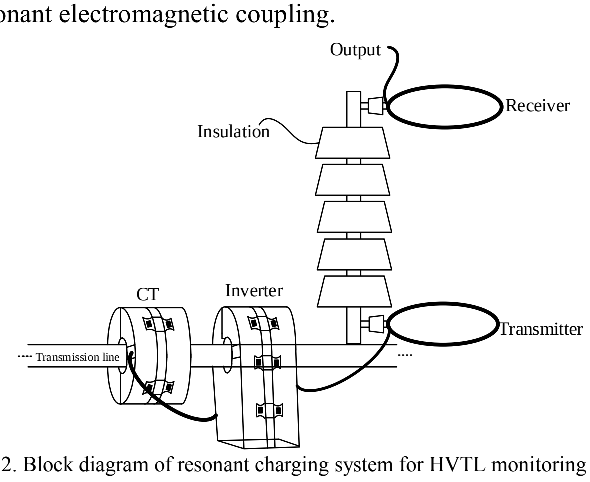


Fig. 2. Block diagram of resonant charging system for HVTL monitoring equipment.

B. Determination of optimal resonance frequency

The system operating under the HVTL condition, thus it can only use static heat dissipation. Reducing the resonance frequency is the most effective way to reduce heat generation. Therefore, the optimal resonance frequency is obtained considering the switching and radiation loss. The relationship between the resonance frequency and the overall system efficiency considering loss is showed in Fig. 3. It can be seen that when the resonance frequency of the system is greater than 510 kHz, the overall efficiency of system increases slowly.

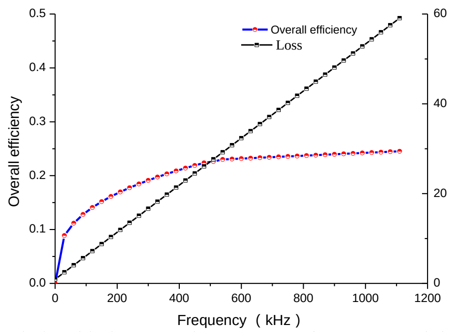


Fig. 3. The relationship between the resonance frequency and the overall system efficiency.

C. Design and optimization of coupling coils

With reference to the state standard, it can be found that for 110kV power transmission line, seven or eight suspension insulators are required between the transmission tower and power transmission line, covering an insulation distance of approximately 1.5 m. According to the section 2, coil parameters can be computed and designed. The coupling coils is is fixed on one side of the insulators, thus amorphous alloy (FeCrMoCB) interlayer is added to constrain the magnetic field distribution of the coils. The electromagnetic characteristic of coupling coils with interlayer can be analyzed and compared with normal coils. And Fig. 4 shows the efficiency of system with two different coupling coils. The interlayer reduces the resonance frequency and increases the quality factor.

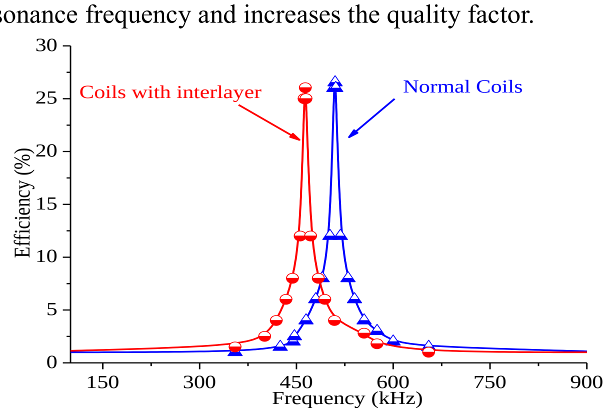
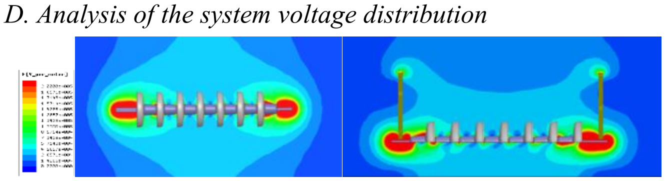


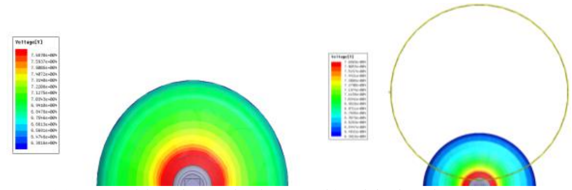
Fig. 4. System efficiency vs. frequency with a distance of 1.5 m

D. Analysis of the system voltage distribution



(a) normal insulator string (b) with the charging system

Fig. 5. Voltage distribution around insulator string



(a) normal insulator shed (b) with the charging system

Fig. 6. Voltage distribution of the insulator shed

Voltage distribution of insulator string and shed with the resonant charging system is simulated and showed in Fig. 5 and Fig. 6. By comparison, it can be concluded that the application of the system does not affect voltage distribution and the performance of insulators.

IV. Experiment

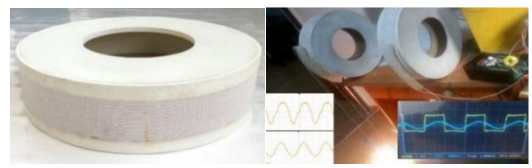


Fig. 7. Experimental platform of the resonant charging system.

According to the theory and simulation analysis, the resonant charging system used in 110kV high transmission line is designed and showed in Fig. 7, whose transmission distance is 1.5m length, transmission power is 27.1W, resonance frequency is 451 kHz and transmission efficiency is 26.4%.

V. Conclusion

A resonant charging system used in 110kV high transmission line is studied and designed. The relationship among coil size parameter, transmission distance, the maximum approachable efficiency of the system are analyzed. The optimal resonance frequency is obtained considering the switching and radiation loss. The optimal resonance frequency is about 510kHz with the specific MOSFET and 100W inverter power. The coupling coils is is fixed on one side of the insulators, thus amorphous alloy interlayer is added to constrain the magnetic field distribution of the coils. The electromagnetic characteristic of coils with interlayer can be analyzed and compared with normal coils. The interlayer reduces the resonance frequency and increases the quality factor. Voltage distribution of insulator string and shed with the resonant charging system is simulated. The application of the system will not affect the insulation performance. The result of simulation and experiment shows that the efficiency of the designed charging system is 26.4% with resonance frequency 451kHz, transmission distance 1.5m length.

References

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