A Proposal of Criterion of Inductive Coupling and Magnetic Resonance Coupling in Wireless Power Transfer System

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I. Introduction

In Wireless power transfer system, the Inductive coupling(IC) techniques operate at distance less than a wavelength of the transmitted signal. In the case of Magnetic Resonance Coupling(MRC), the resonant peak of the input impedance is divided into several peaks due to increased mutual inductance between coupled coils. However these two terms are used indiscriminately. In this paper, we extend prior theoretical analysis of WPTS to define the two terms; IC and MRC using the key term, critical coupling coefficient. This term is verified through simulation. We took consideration into Power source.

II. WPTS USING POWER SOURCE

The structure of the proposed WPTS is illustrated in Fig. 1. Fig. 2 shows equivalent circuit model of Fig. 1. From Fig.2, the currents of each loop can be obtained using Kirchoff's voltage law and the power transfer efficiency at operating frequency is defined by

$$\left|\frac{P_{Load}}{P_{avs}}\right| = 4\beta_1\beta_2\frac{k_{12}^2 Q_1 Q_2}{\left\{(1+\beta_1)(1+\beta_2)+k_{12}^2 Q_1 Q_2\right\}^2} \quad (1)$$

where β_1=R_{Source}/R_{Tx}, β_2=R_{Load}/R_{Rx}, and Q_1, Q_2 are quality factors of each loop. In order to find $k_{critical}$ which represents the maximum efficiency that is achievable at the furthest possible operation point the derivative of (1) is taken with k_{12} [1]. Then the critical coupling point of power source $k_{critical\_power}$ is defined by

$$k_{critical\_power} = \sqrt{\frac{(1+\beta_1)(1+\beta_2)}{Q_1 Q_2}} \quad (2)$$

By varying the distance between two loops, we could experimentally find the distance (d=0.41 m) that magnitude of S21 has peak value which have maximum power transfer efficiency. The simulation is conducted using FEKO suite 6.0. As Table I, the critical coupling coefficient that we predict by theory is agreed with simulation result.

TABLE I. The $k_{critical\_power}$ of the theory and simulation

Theory	Simulation	ERROR
0.059	0.058	1.695 %

Using (2), we conclude that when the value of the critical coupling coefficient is between 0 and 1, the WPTS is using magnetic resonance coupling. If not, we define the inductive coupling is applied to WPTS.

IV. CONCLUSION

IC and MRC can be clarified analytically using the proposed definition of critical coupling coefficient. The theoretical critical coupling coefficient satisfies with the simulation result. In the case of power source, two couplings can be separated whether the value of critical coupling coefficient is between 0 and 1 or not. When all the WPTS parameter values are given, we can effectively clarify which coupling method is used.

Acknowledgement

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References

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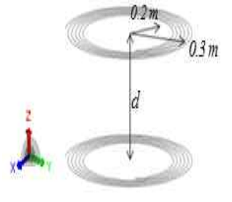

Figure 1. Structure of the proposed WPTS

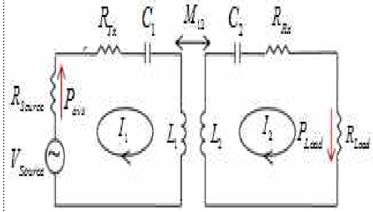

Figure 2. Equivalent circuit of Fig 1.