



**INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS**

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**SHORT ABSTRACT**

Wireless power transfer (WPT) technology offers better operational flexibility, safety, and durability in comparison to plug-in power transfer. Therefore, many applications, such as domestic appliances, rotating systems, mobile robots, and wearable devices, use WPT technology. In recent years, WPT systems are also used for charging the electric vehicle (EV) batteries. In the WPT system, power is transferred from source to load without any physical connection. Therefore, mutual inductance is an essential parameter in designing of WPT system. Generally, for calculating mutual inductance between the coils for the WPT system, the 3-D finite element analysis (FEA) is used because of its high accuracy. However, high mesh-density in the 3-D FEA model requires intensive computational power. The coil system with magnetic shields requires more numbers of mesh elements and results in substantial calculation time. The significant computational burden makes the design and optimization of the coil system a tedious process. Moreover, the designing of the WPT system involves numerous geometrical modifications in the 3-D FEA model. An analytical model is another approach to design the coil system, and this thesis deals with this issue.

This thesis begins with a review of various possible modelling technique for the coil system without the magnetic shield of the WPT system. A 3-D analytical model based on the harmonic modelling technique is developed to calculate air gap magnetic field distribution as well as mutual inductance between the coils. For the modelling, 3-D magnetic vector potential and magnetic scalar potential definitions in the Cartesian coordinate system is used. The current density distribution in the coil is modelled by four overlapping bars. Moreover, using the proposed analytical model, two new expressions are derived for faster calculation of the mutual inductance between the coils of the WPT system. The proposed analytical model takes into account the variation of mutual inductance due to different misalignments for the air core transmitter and receiver coil system. All possible misalignments that can occur during the

charging of EV are considered. The magnetic flux density distribution and mutual inductances are calculated with the analytical, and they are validated with finite element analysis and experimental results.

The harmonic model is further modified to include a magnetic shield below the primary coil. This model has the flexibility to change the width and permeability of shielding material. The magnetic flux density distribution and mutual inductance between the coils, obtained from the analytical model, FEM, and experiment results, which are in close agreement. The proposed analytical model considers the length of the magnetic shield is infinite, which is impractical. In practice, the magnetic shielding of finite permeability and finite dimensions is used with the primary and secondary coils. In this context, a 3-D analytical model that considers the magnetic shields of finite permeability and finite dimension is developed. This 3-D model is developed by the superposition of two 2-D analytical models. These 2-D models are developed based on the subdomain technique. Since 2-D models are invariant in their third direction (i.e., in the  $y$ -direction for  $xz$ -plane and the  $x$ -direction for  $yz$ -plane), a correction factor is introduced for 2-D subdomain models to make it variant in their third directions. The results obtained from the subdomain model are compared with FEM and experimental results, which are found in good agreement.

The change in the mutual inductance impacts the power transfer capability and the efficiency of the entire system. A steady-state model of series-parallel (SP) compensated WPT system is developed to analyse the impact of change in the electrical parameter due to misalignments. Effect of harmonics is considered in the steady-state model to get an accurate result. Magnetic model is coupled with the steady-state model to calculate the variation in electrical parameters during misalignments. The coupled model gives a comprehensive mathematical model for a WPT system for the charging of EV batteries. The mutual inductance calculated from the analytical model for different coil systems is used as direct input for the steady-state model. The proposed model can be used for analysing the component stress of the SP compensated WPT system for different misalignments, which helps in the initial design process of such a WPT system.

Overall, this thesis presents a comprehensive analytical model for research and design of the wireless power transfer system.