

MIDDLE EAST TECHNICAL UNIVERSITY

Electrical and Electronics Engineering Department

EE568 Selected Topics on Electrical Machines

PROJECT 4

DESIGN AN INDUCTIVE POWER TRANSFER INDUCTANCE AND ANALYSIS of MISALIGNMENT

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# Introduction

Inductive power transfer (IPT) has become more popular in recent years. It is used in range area from low power applications to high power applications. Cordless design and spatial flexibility of IPTs led them to be used in some applications such as portable chargers, biomedical implements, etc. Also, providing electrical safety and galvanic isolation make them the future of the electric car chargers and energy harvesting systems, etc.

In many applications (Electric vehicle, portable chargers), IPT system is used for multiple loads. For these applications, the position of transmitter and receivers are variable. Thus, the loosely coupled IPT’s have a variable mutual inductance between transmitter and receiver. The different mutual inductance affects the output power, output voltage and the efficiency of the system. In general, the small changes on mutual inductance can be tolerated by using frequency or phase shift control. However, small position changes on loosely coupled systems led the mutual inductance change drastically. Thus, transmitter and receiver coils should be designed to be misalignment tolerant. In literature, misalignment tolerant IPT systems are investigated in the papers The misalignments can be also changed with respect to coil shape and there are different misalignment conditions such as vertical, planar and angular.

In this work, the misalignment analysis and mutual inductance calculations will be conducted. Firstly, the mutual inductance calculation and misalignment analysis in literature will be examined. Secondly, a coupled coil is designed and the mutual inductance between coils are calculated analytically. Thirdly, the design is simulated by FEA. Finally, the analytical and FEA model are compared and the design will be optimized.

# Literature Review

In literature, misalignment analysis is well investigated. Misalignment tolerant system design is expected to provide stable output voltage and power for different position of receivers. The misalignment tolerant system come into view in two points. One of them is that the misalignment tolerant system is done with control methods. Other one is that the misalignment tolerant system is done with designing misaligned tolerant coils. Second method is investigated in the literature in these papers. The coil structures depend on application of the IPT and it is imported to design misaligned tolerant coils. There are some

# Analytical Calculation and Sizing

In this part, we chose inductor shape which are suitable to our applications [reference ver]. Our application is a contactless slip rings and it requires a planar misalignment tolerant in shown figure X. Thus, circular shape coil is chosen to provide planar symmetry. The value of self-inductances and mutual inductance were calculated by using the paper. In this section, we calculate the self-inductances and mutual inductance between transmitter and receiver coil analytically by using vector potential approach.

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| **Inductances** | **Values** |
| Transmitter Inductance |  |
| Receiver Inductance |  |
| Mutual Inductance |  |

## Self-Inductance Calculations

The inductance of a loop of wires shown at figure X can be calculated by using the formula.

By using the formula, we can calculate the transmitter and receiver inductances. In this part, we want to design a coil with angular misalignment tolerant. Thus, the radius of receiver is chosen smaller than transmitter to provide it.

## Mutual Inductance Calculations

Mutual inductance between two circular coils as shown figure X. are calculated by using vector potential approach. The mutual inductance formula as known Neumann’s formula is shown below.

Where the are defined as:

Then, two arbitrary points of coils, we define R as:

By using the definitions, we can calculate the mutual inductances as:

For misaligned coils shown at figure X, we can change the coordinate systems. Lateral and angular misalignment can be represented as translation and rotation of coordinate system. Thus, we can show that the position of receiver coil as:

or

Then, we can calculate the mutual inductance by considering the misalignment.

## Parameter Determination

Firstly, the parameters are calculated for misaligned condition. Then, the parameters are optimized to provide angular misalignment tolerant coil. However, the optimization will be made at section 4 after FEA analysis.

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