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Metamodel-based Methodology for Design of Wireless Power Transfer Systems

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Abstract—This paper presents a comparison of metamodeling techniques to analyze the variability of the performances of an inductive power transfer (IPT) system, considering the sources of uncertainty (misalignment between the coils, the variation in air gap, and the rotation on the receiver). One of the key issues is the transmission efficiency of the system, which is greatly influenced by many sources of uncertainty. So, it is meaningful to find a metamodeling technique to quickly evaluate the system's performances. According to the comparison of Support Vector Regression, Multigene Genetic Programming Algorithm, and sparse Polynomial Chaos Expansions (PCE), sparse PCE is recommended due to the tradeoff between the computational time and the accuracy.

I. INTRODUCTION

Using a resonant IPT system seems an effective technology for the growth of electric vehicles (EVs). In a real scenario involving IPT systems, various positions of the receiver may happen during the park (static IPT) or driving (dynamic IPT). A careful design process of IPT systems requires considering multiple parameters (misalignment, relative rotation of the receiver, air gap, etc.). So, when using simulation tools, multiple 3D numerical computations are needed to assess the performances of the system when these situations happen. Nevertheless, using complex simulation tools (such as finite element method) leads to high computational costs in the case of wide parametric analysis.

To solve this problem, “metamodeling techniques” for the parametric and statistical analysis can be developed. These approaches reduce the computational cost by substituting an expensive computational model with a so-called metamodel, an analytical approximation of the original model that is much faster to evaluate [1]. Metamodels are constructed by learning the approximation from input parameters and their corresponding model responses, generated for example from running 3D FEM computations. A metamodel allows more sophisticated analyses, such as fast sensitivity analysis. In recent literature, several metamodeling techniques have been developed, such as Support Vector Regression (SVR) [1], Multigene Genetic Programming Algorithm (MGPA) [2], Polynomial Chaos Expansions (PCE) [3]. However, there is no clear conclusion in the literature about the relative performances of these tools.

This paper aims to compare three well known metamodeling techniques for analyzing the mutual inductance of a practical IPT system with rectangular coils and ferrite plates, considering the usual sources of uncertainty in such problem. Numerical predictions related to the electrical parameters and stray magnetic field are validated against experimental measurements.

II. METHODOLOGY AND RESULTS

The sources of uncertainty considered in the work are: The misalignment due to imperfect parking position and the air gap due to loading and unloading the vehicle. Fig. 1 shows the rotation angle along the Z axis α , the misalignment along the X axis Δx , the misalignment along the Y axis Δy , and the air gap between two coils Δz . A Gaussian probability distribution is chosen for the factors, which conforms to a realistic case. All metamodels are trained from the same training dataset distributed according to the Latin hypercube sampling (LHS) method. The work shows that the sparse PCE metamodel give the least computational time and the better accuracy with the standard (training and test) errors.

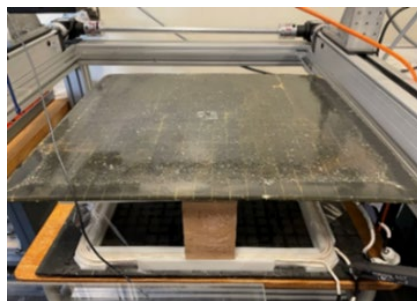


Fig. 1. Square coupler in GeePs

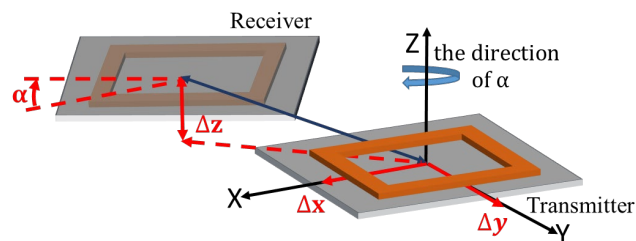


Fig. 2. Influencing factors for the square couplers

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