# Multi-Physical Model for Sizing Optimization of Electrical Machines

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***Abstract*— this abstract outlines a multi-physical modeling approach, which has been developed and incorporated in an optimization process. This approach allows the conceptual design of an electrical motor for electric hybrid vehicle. It is elaborated to be malleable and to satisfy different precision levels in order to address various sizing problems.**

***Index Terms*— Multi-physical model, optimal sizing, automotive applications, model coupling, electrical machines.**

## I. Introduction

The design of an electric machine is a complex and often needs iterative process. Designing requires the use of various physics and expertises. (Semi-)analytical models are wildly used for designing and they can be linked to finite-element analysis during the parameter adjustment and validation stages [1]. A model is always built for a purpose. A design model should take into consideration different physical aspects and be sufficiently fast for using in an optimization process. The designer should be able to manage multiple models via a fast and malleable design model.

The presented study describes a multi-physical model dedicated to the optimization scaling of a radial-flux interior permanent-magnet synchronous machine for automotive traction use.

## II. Model Coupling for Sizing

The multi-physical machine design model has been established by coupling a generalized nonlinear adaptive magnetic equivalent circuit (MEC) [2], the Loss Surface (LS) hysteresis model [2], and an aero-thermal model (SAME) [3]. These models are complex and represent just a part of the whole process needed to meet the design requirements of a traction motor in terms of the modeling of efficiency and heating. The multi-physical model proposed herein is malleable with many physical layers and many accuracy levels (viz., Coarse, Medium, and High) that the designer could adjust for each specific problem.

A flowchart of the developed tool is described in Fig. 1. According to the need, it allows to execute separately different layers. For example, if the optimization problem does not include the temperature effects, there is no need to execute the SAME layer (see.Fig.1) and it is sufficient to execute the two first ones i.e., the coupling (MEC-LS). Furthermore, each layer accuracy can be different from the others. Thus, in a design process, it is possible to reach the solution using coarse but fast model followed by a more accurate model to reach the optimal solution. This homotopic technic considerably saves calculation time and allows good accuracy. In addition, this coupling provides global data using the local ones (spatial and temporal). For instance, it is possible to study the geometric discretization influence of the MEC on the iron loss distribution in the machine magnetic circuit and thus, its impact on the global value in order to adapt the model to the need.

Three variable types are implemented: geometric variables $G_i$ linked to the dimensions, command variables $C_i$ related to the electrical machine operating point torque/speed and the temperature variables linked to the initial temperature $T_{0i}$ of the electrical machine studied part.

The model outputs are obtained as function of the rotor position and/or the electrical period. The multi-physical design model is incorporated in an optimization process. Examples including to temperature, control, geometry modifications and to the driving cycle will be studied in the extended paper.

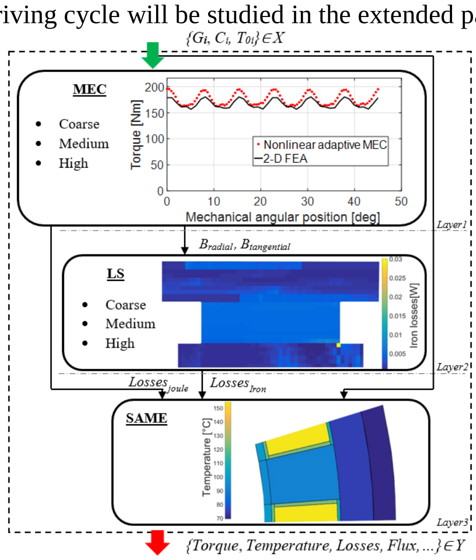


Fig. 1. A sizing model decomposed into different layers representing the physical phenomena and with different discretizations allowing a compromise between accuracy and computation time.

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