# Optimal design of a permanent-magnet excited synchronous machine for electrical vehicles

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***Abstract*—The paper deals with the optimal design of a new synchronous motor particularly suitable for electric vehicles. The main advantage of this motor is its possibility to realize field weakening at high speeds, which is the most important demand for such drives. The main design goal is to identify the dimensions of certain crucial geometrical dimensions of the machine to avoid saturation of the iron in order to minimize the mass to volume ratio, while simultaneously maximizing torque. The originality of the contribution is manifold: formulating the design problem in multi-objective terms, solving it by means of evolutionary computing, solving the associated direct problem based on a 3D-FEA field model, considering a reduced set of design variables by means of response surface method, referring to a real-life problem.**

***Index Terms* — Design optimization, electric vehicles, finite element method, genetic algorithms, permanent magnet motors.**

## I. Introduction

High-speed permanent-magnet motors with a brushless direct-current control scheme have found wide applications in the past few decades, because of their advantages such as high efficiency, high power density, and high drive performance. For automotive applications, other than the obvious goal of efficiency, the reduction of weight at a constant power and torque has also become a strategic target for the design of these machines. Additionally an optimal drive for electro-mobiles should offer a wide field weakening capability [1].

## II. Optimization of the Machine

This paper describes the performance of a modified ECPSM (Electric Controlled Permanent Magnet Excited Synchronous Machine) structure with single-tooth windings, where the field weakening can be achieved by an additional stator fixed DC-coil [1]. To control the magnetic field ranging from zero up to its maximal values (wide speed variations), this coil has to be fed by a simple DC-chopper. Figure 1 shows the fundamental structure of this machine.

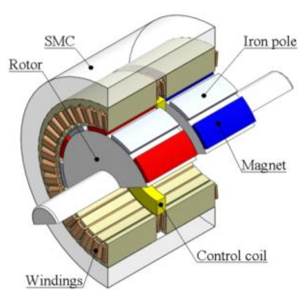


Fig. 1. ECPSM with the surface-mounted PM rotor.

The goal of this paper is to perform the design optimization of this machine which enables field weakening in a wide range subject to a prescribed torque: in practice, this will be implemented by means of some subsequent optimizations. The structure and all dimensions of the stator are set depending on application requirements. According to the problem formulation, a vector of design variables (main geometrical dimensions of the machine) has been defined. The identification of the optimal vector has been formulated in terms of a multi-objective optimal shape design problem [2]. In order to save computational resources it was possible to rely on approximation functions or response surface methods. Additionally, in order to determine the relative impact of design variables on the objective functions, the screening analyzer tool was used. This is obtained by building a response surface, which allows to determine the most influent parameters, and to reduce the number of variation parameters. The goal of the study was to optimize some crucial dimensions of the machine, while respecting all physical constraints. In order to carry out the optimization calculation, the genetic algorithm and other advanced optimization algorithms have been used [3,4]. The purpose of the next study is to find the optimal dimensions of the control coil in such a way that the total flux under the PM is equal to the total flux over the iron part. Therefore, it was possible to achieve better control properties of the ECPSM in the field weakening region. All above considerations made it possible to determine the optimal structure of the ECPSM (Fig. 2).

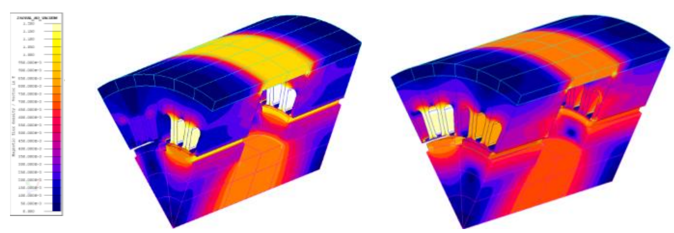

Fig. 2. Magnetic field distribution within the optimized model of the ECPSM in the case of strengthening (left) and weakening (right) of the magnetic field.

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## References

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