Multilevel Design and Optimization of a FSPMM Drive System by Using Sequential Subspace Optimization Method

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Abstract—In our previous work, a new axial structure flux-switching permanent magnetic machine (FSPMM) was presented for the application in hybrid electric vehicles. To obtain the best performance of the whole drive system, a multilevel design optimization method is presented for this kind of machine and a field oriented control system. The proposed multilevel optimization method is called as sequential subspace optimization method. In the implementation, three subspaces are adopted to get the optimal design scheme. Manufacturing condition and cost are included in the design and optimization models. Finally, from the design analysis, it can be found that the proposed method can provide design scheme with better performance while the needed computation cost will be reduced greatly.

Index Terms—Design optimization, electrical drive system, electromagnetic fields, field oriented control, permanent magnet machines.

I. INTRODUCTION

To obtain the best performance of electrical drive systems, not only motors but also their control systems have to be designed and optimized synchronously at system level rather than component level. Although the importance of system level design optimization of drive systems is noted, not much work has been reported in the literature [1], [2]. Traditional design optimization methods are mostly on the component level of motors [3]-[6], and depend largely on experience in many situations. For the control systems, though a lot of control algorithms have been developed, such as field oriented control (FOC), direct torque control and model predictive control, they are also generally designed and optimized on the controller level, and have not combined with the design optimization of motors. Actually, these methods are not system level holistic design. And by this component level approach, one can hardly achieve the optimal system performance. Therefore, how to design and optimize novel high performance drive systems is an important problem in both research community and industrial applications.

Furthermore, the computational efforts of the drive systems' optimization process are vast as they are multidisciplinary, high dimensional and highly nonlinear. This paper presents a multilevel optimization framework and sequential subspace optimization method (SSOM) to deal with this problem. A drive system with a flux stitching permanent machine (FSPMM) and a FOC control system will be investigated.
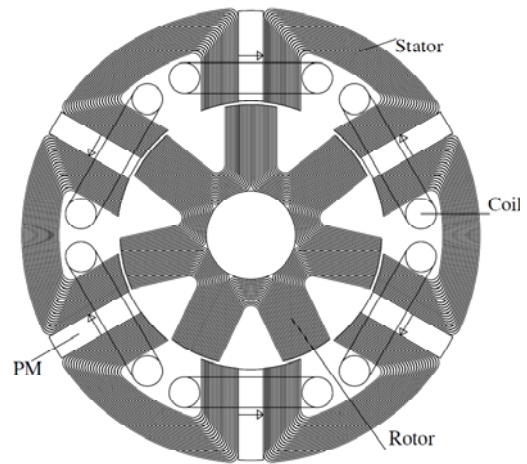

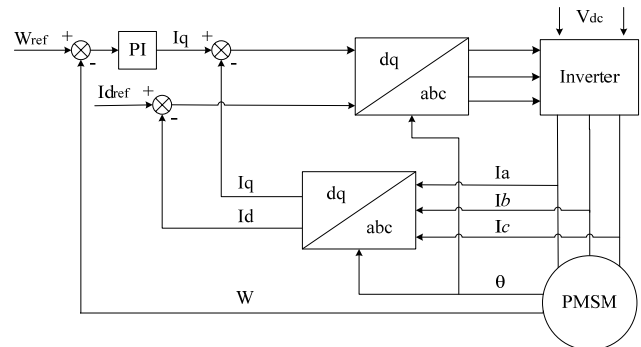Fig. 1. Structure of the axial laminated-structure FSPMM

Fig. 2. The diagram of FOC scheme

II. DRIVE SYSTEM WITH FSPMM

Fig. 1 illustrates the structure of a new axial structure FSPMM. From our previous studies, this FSPMM has many advantages, such as greater torque density and higher efficiency [7], [8]. Nine parameters are selected for the optimization of this drive system in this work. They are dimensions of stator and rotor tooth, PM, air gap and winding, and PI control parameters in FOC. Two objectives and eight constraints are also defined. Objectives are maximizing the ratio of torque to volume and minimizing the torque ripple. Constraints are respect to the steady and dynamic performance parameters of the system.

III. Multilevel Optimization Framework with SSOM

Fig. 3 shows the flowchart of the proposed multilevel optimization method based on SSOM [9]. Three levels are defined for this drive system. The first level is for the motor's significant parameters. The second level is for the motor's non-significant parameters. The last level is for the control parameters. In each level, sequential optimization method (SOM) is used as the optimization method. Fig. 4 illustrates the flowchart of SOM [10]. SOM consists of two optimization processes, namely coarse and fine optimization processes. The aim of the former process is to reduce the design space while the goal of the later process is to find the optimal solutions.
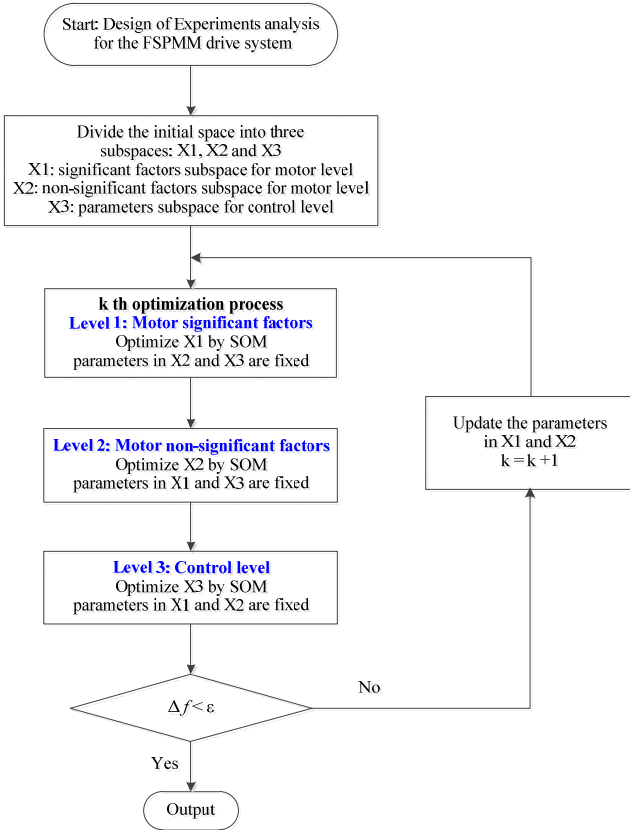

Fig. 3. SSOM multilevel framework

IV. Results and Discussion

After optimization and comparison, we can get two conclusions.

1) For the initial design scheme, the torque is about 7.5 Nm, efficiency is about 86.9%. With the multilevel optimization framework and SSOM, the torque can reach to 8.6 Nm, efficiency is about 86.3%.

2) Considering the computation cost, if we optimize this problem with genetic algorithm (GA), about 90000 finite element samples are needed; the computation cost is too expensive. If we use the proposed multilevel method, only about 5000 finite element samples are needed, which is much less than that of GA.
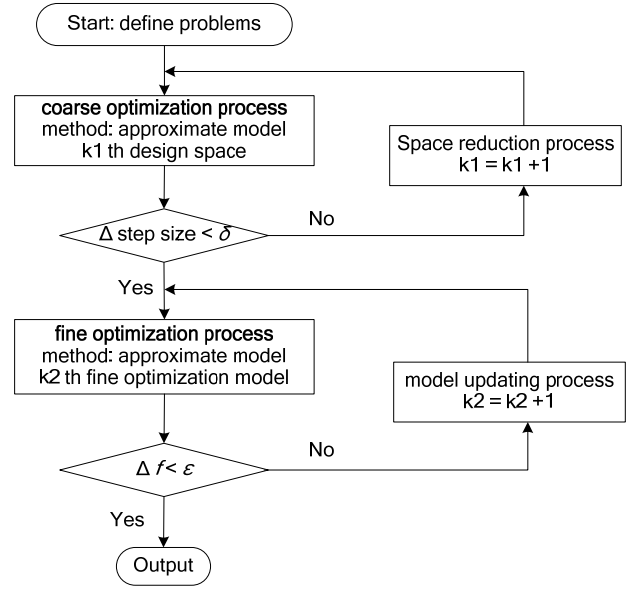

Fig. 4. A flowchart of SOM

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