

Chapter 15

Particle Swarm Optimization Method to Design a Linear Tubular Switched Reluctance Generator

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ABSTRACT

In this chapter, the Particle Swarm Optimization method is applied to four different structural configurations of a linear switched reluctance generator with tubular topology. The optimization process involves the search of the values for a defined set of geometric parameters that maximize the rate of change of the generator's inductance with the relative displacement of its mover part. The optimization algorithm is applied to each structural configuration in order to find the optimum geometry as well to identify the most suitable configuration for electric generation.

INTRODUCTION

The generation capabilities of a switched reluctance machines depends on the velocity of its movable part and on the rate of change of the machine's inductance with its relative displacement. The first factor relies on the nature of the external force that drives the generator and, consequently, imposes the operation velocity. The second factor relies on the geometric configuration of the machine which can be controlled, during the project, in order to maximize its generation capabilities. For this reason it becomes mandatory to choose the best dimensional parameters a value that regulates the generator geometry.

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However, when the number of variables is huge, it becomes impractical to perform the design procedure to all possible values combination. So, to avoid this exhaustive process, optimization methods are applied to reduce the search of the optimum variable values. In general, electric machine optimization is characterized by non-linear problems with objective functions dependent on large set of variables. For functions with more than 3 variables is impossible to map its evolution with the respective variables and thus, to identify the location of its maximum (or minimum) values. For these reasons, is discarded the application of exact methods that implies a continuum evaluation of the objective function gradient because they can be trapped in local maximum (or minimum) and because they need to perform additional function evaluations which, in these problems, are the most time and resource consuming steps. An alternative approach to exact methods, are the global optimization ones which are based in deterministic or stochastic procedures to perform the values search. In deterministic methods, a direct search of values is conducted according to the function evolution. The search through stochastic methods is supported through decisions based on random and/or probabilistic parameters. The latter methods are, usually, based on behavior and evolution of living beings communities.

Some of these methods are widely used in the design optimization of electric machines. In (Yao & Ionel, 2011) a comparison is made between the differential evolution (DE) and response surface (RS) optimization algorithms applied to permanent magnet synchronous motor. The application of genetic algorithm (GA) in the design optimization of permanent motors can be found in (Bianchi & Bolognani, 1998; Jolly, Jabbar, & Liu, 2005) and in (L. Moreau, Zaim, & Machmoum, 2012; Naayagi & Kamaraj, 2005; Owatchaiphong & Fuengwarodsakul, 2009) for the design optimization of rotary switched reluctance machines. A design optimization procedure that involves differential evolution algorithm and a finite element method (FEM) software is presented in (Wen, Zarko, & Lipo, 2006) for the optimization of a permanent magnet machine and in (Kurfurst, Duron, Skalka, Janda, & Ondrusek, 2011) the self-organizing migrating algorithm (SOMA) is applied to the optimization of the same type of electric machine. A non-classical stochastic method, elitist non-dominated sorting genetic algorithm version II, is proposed in (M. Balaji & Kamaraj, 2012c) and is applied to optimize the pole shape of a switched reluctance generator. In (Ziyan, Dianhai, & Chang-Seop, 2013) an optimal design of a switched reluctance motor is proposed using a multi-objective worst-case scenario algorithm based on FEM simulations and Kriging.

Other stochastic method that is commonly used for this type of optimization problems is the Particle Swarm Optimization (PSO) method that simulates the behavior of populations (like a flock of birds) in the search for food. In (Van der Geest, Polinder, Ferreira, & Zeilstra, 2012) the particle swarm algorithm is coupled with a FEM software to perform the design optimization of different permanent magnet machines. A design optimization of a transverse flux linear motor using particle swarm optimization method is presented in (H. M. Hasanien, 2011) and in (Wen et al., 2006) the same optimization method is applied to a permanent magnet motor. Also, for the optimization design of a permanent magnet machines, a multimodal function optimization based on the particle swarm method is proposed by (Jang-Ho et al., 2006) and in (Arkadan, ElBsat, & Mneimneh, 2009) this optimization algorithm is applied to a synchronous reluctance motor drive. In (Wang, Chen, Cai, & Xin, 2013) the particle swarm optimization algorithm is combined with the differential evolution algorithm for the optimization of a tubular permanent magnet synchronous generator and a multiobjective particle swarm approach is applied by (dos Santos Coelho, Barbosa, & Lebensztajn, 2010) to the design of a brushless DC wheel motor. A modified particle swarm optimization method is used in (G. Chen, Guo, & Huang, 2007) for the parameter identification of an induction motor.

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