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Comparison between two target functions for optimization of single phase shaded-pole motor using method of genetic algorithms

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Abstract

Method of genetic algorithms (GAs) has been started to be widely used, as an optimization technique of electrical machines, in the recent years. In this paper the GA method will be applied on the shaded-pole motor, aiming towards an improvement of its operational and performance characteristics. The authors develop two new improved motor models, starting from the basic one. In the first motor model the electromagnetic torque, as a target function for optimization is suggested, while in the second one the optimization is based on the efficiency factor, used as a target function. The results gained from the both motor models are analyzed and compared to the basic model. The conclusions regarding the more favorable target function for optimization of a single phase shaded-pole motor are presented.

Keywords: Optimization; Genetic algorithms (GAs); Single phase shaded-pole motor; Performance characteristics

1. Introduction

In engineering practice the concept of any optimization means creating better and more economical product or solution, by using existing resources. The problem of design optimization of electric motors, arises because of the stiff competition among the producers at the one side, and because of the request for the best performance characteristics at the other.

During the design stage of an electric motor, all efforts are focused to achieving desired motor model on faster, more economical and more reliable way. During the application of an existing electric motor for particular purposes, the main task is to improve its performance characteristics by simple modifications

Researchers have been using classical optimization techniques, mainly based on the gradient methods, a long time back. Recently, it is evident for an introduction of different evolutionary computational techniques based on the stochastic approach. Such methods are claimed to be faster, more efficient and more successful when searching for the global optimum of a function.

The genetic algorithm (GA) is selected as the most suitable stochastic methodology for optimization of electric motors, in general. The previous works of the authors, concerning the optimization of different electromagnetic devices, verify the GA as quite corresponding method [4].

In this paper, the authors present the GA optimization procedure, applied on a single phase shaded-pole motor, as a particular case. In the essence, the target is to find more efficient model of the motor by improving the parameters of an existing motor model.

2. Shaded-pole motor

Single phase shaded-pole motors have found wide application in many household devices due to their simple construction, as well as their capability for sustaining overloading at locked rotor position, since the value of short circuit current is very close to the value of rated current. In spite of that, their analysis is always complicated due to: particular arrangements of the windings; magnetic field elliptically rotating in the air gap; significant level of field space harmonics. It is always a challenge to optimize the design of this special motor, both while producing and applying as a drive. In the paper as an object of investigations the single phase shaded-pole motor type AKO-16, product of "MIKRON", is considered.

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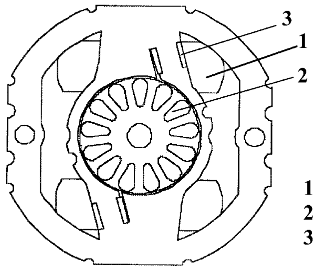

Fig. 1. Cross section of the shaded-pole motor.

The rated data are as follows: U_n = 220 V; f_n = 50 Hz; I_{1n} = 0.125 A; $2p$ = 2; P_1 = 18 W; n_n = 2520 rpm. In Fig. 1 the cross section of the shaded-pole motor under consideration is presented.

This motor is used as a prototype and, in order to improve its performance characteristics, an optimization procedure based on GA is carried out.

3. Method of genetic algorithms

Since fairly recent the genetic algorithms have been presented as computer algorithms, a wide range of applications have been appeared in various scientific areas. Consequently, they have been proved as powerful tool for solving complicated tasks related to optimization problems. In their essence, the GAs is evolutionary searching algorithms, based on the rules of the natural genetics and the natural mechanics of unit selection. They are practically implemented in the most simplified natural way, based on the survival principles of the fittest unit.

In this stochastic process, the least-fit solution is receiving the minor chance for reproduction; to the contrary, the most-fit solution is receiving the major chance to be reproduced. The reproductive success of a problem solution is directly linked to the fitness value, which during the evaluation has to be previously assigned. The process starts from a randomly created population of strings, and after a sufficiently large number of generations, it stops giving the optimal solution with the best properties.

During the optimization, reproduction, mutation and crossover between the units and generations, the determine results are finally achieved. The probability of their occurrence is recognized and determined through the corresponding genetic operators. Their percentage or per unit values of appearance in the genetic procedure, are always user's and problem's dependent.

4. Optimization procedure

Design optimization of a shaded-pole motor is very important, but quite complicated problem. In general, it is a complex multi-variable, non-linear and constrained procedure. The optimization procedure is briefly explained.

In general case, during the process of design optimization, after the relevant machine parameters have been determined, depending on the problem which is solving, at the beginning an objective function is defined and derived by the user. The optimization procedure is always searching for an extremity of this function, i.e. its maximum or minimum. In order to provide the derived solution to be practically acceptable, certain requirements should be satisfied. That means some important electrical or magnetic quantities, such as current density in the windings Δ [A/mm^2], or magnetic flux density in the air-gap B_δ [T] must be lower than the prescribed limits.

4.1. Derivation of target functions

Method of genetic algorithms is applied as an optimization technique for improvement of the performance characteristics of the single phase shaded-pole motor under consideration. This powerful numerical tool enables to create optimal solution by optimization of certain machine parameters and to derive the motor model with improved performance characteristics. The main task is to define and to select the most suitable target (objective) function.

- Knowing that the electromagnetic torque is one of the most important quantities of the motors, the first idea is to use its value as target function during the optimization procedure—Model 1.
- The efficiency of electric motors, through minimization of the losses, is always aiming towards greater values; naturally, the other interesting target function is the efficiency factor of the shaded-pole motor—Model 2.

It is obvious that such definition of the target functions on the basis of which the motor under consideration will be optimized, is always a maximizing problem.

On the basis of the theory, for both target functions, the most suitable mathematical models for application of the optimization procedure by using the GA are derived [1]. The authors have developed an original program for optimization of different types of electrical machines and electromagnetic devices by using the genetic algorithms; the program works under C^{2+} programming language [3].

In both the motor models variable parameters of the optimization procedure are accepted to be: the current density of the main stator winding Δ [A/mm^2]; the wire diameter of the winding d [mm]; the number of turns of the stator winding W; the air-gap magnetic flux density B_δ [T]; the angle of the rotor skewing α_{sk} [deg].

Basing on the experience and expected results, the range of variation of the most important motor parameters mentioned above, is placed in the following constraints:

- Current density in the stator winding Δ (5/10) [A/mm^2];
- Magnetic flux density in the air-gap B_δ (0.4/0.45) [T];
- Angle of the rotor skewing α_{sk} (15/20) [deg].

The optimization program by using genetic algorithms creates the population of 6000 generations for each of the