# APPLICATION OF GENETIC ALGORITHMS IN THE DESIGN OPTIMIZATION OF THREE PHASE INDUCTION MOTOR


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**ABSTRACT**

In the recent works connected with Genetic Algorithms (GAs) in the design optimization of Electrical Machinery, it has been observed that the GAs locate the global optimum region faster than the conventional direct search optimization techniques. Optimization of electric machines is making trade-off between different objectives such as a particular item of performance, cost of device or quality or reliability. In this paper, literature study of GAs used in general in electrical machine design in the recent years and also the optimized design results obtained in the research work are presented.



**Keywords:** Optimization Techniques, Genetic Algorithms, Induction Motor, Cross Over Methods.


## 1. INTRODUCTION

Genetic Algorithms (GAs) mimic the principles of Natural Genetics and Natural selection to constitute search and optimization procedure. The idea was that, if nature's power to produce from a randomly created population, a population with individuals that are better to fit the environment could be reflected upon the algorithm, that algorithm could be used to solve complex problems. In the most general sense, GA-based optimization is a stochastic search method that involves the random generation of potential design solutions and then systematically [9] evaluates and refines the solutions until a stopping criterion is met [1]. There are three fundamental operators involved in the search process of a genetic algorithm: selection, crossover, and mutation [10]. The genetic algorithm implementation steps are shown Fig 1.

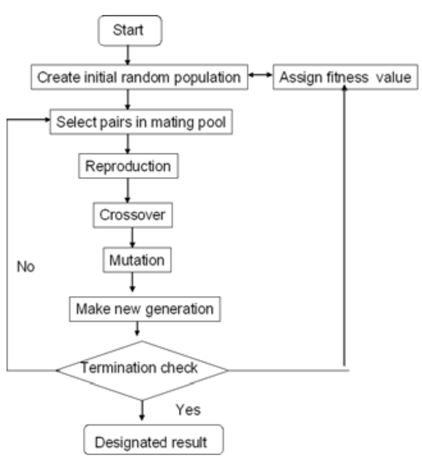


**Fig. 1: Flowchart of Genetic Algorithm**

Optimization of induction motor design is one of the important aspects in electrical engineering design. The induction motor design optimization problem is formulated in mathematical terms as a nonlinear programming problem. The optimal design of an induction motor for minimum cost is taken to minimize the production cost of the motor. The problem consists of an objective cost function which is minimized. The motor design procedure consists of a system of non-linear equations which imposes induction motor characteristics, motor performance, magnetic stresses and thermal limits [8]. The research in this study has applied cost optimization in the design of three phase induction motor with single objective. The various aspects associated with the design of three phase induction motor including the constraints is studied. The design has been carried out using conventional optimization techniques such as Hooke and Jeeves Method, Powell's method & Rosenbrock Method and also using GAs. The results obtained in the design using GAs are discussed in this paper.

## 2. OVERVIEW OF GAs

A genetic algorithm is a problem solving method that uses genetics as its model of problem solving. It's a search technique to find approximate solutions to optimization and search problems. GA handles a population of possible solutions. Each solution is represented through a chromosome, which is just an abstract representation. For GAs to find a best optimum solution, it is necessary to perform certain operations over these individuals. The process starts by generating an initial population of chromosomes. This first population must offer a wide diversity of genetic materials. The gene pool should be as large as possible so that any solution of the search space can be engendered. Then, the GA loops over an iteration process to make the population evolve. Each iteration consists of selection, reproduction, evaluation and replacement.

### Selection

Selection is the process of choosing two parents from the population for crossing. After deciding on an encoding, the next step is to decide how to perform selection. According to Darwin's theory of evolution the best ones survive to create new offspring. Selection is a method that randomly picks chromosomes out of the population according to their evaluation function. The higher the fitness function, the more chance an individual has to be selected. Some of the selection methods are :

**Roulette Wheel Selection:** Roulette selection is one of the traditional GA selection techniques. Roulette wheel selection is easier to implement but is noisy. The rate of evolution depends on the variance of fitness's in the population.

**Tournament Selection:** An ideal selection strategy should be such that it is able to adjust its selective pressure and population diversity so as to fine-tune GA search performance. Unlike, the Roulette wheel selection, the tournament selection strategy provides selective pressure by holding a tournament competition among individuals.

**Elitism:** The first best chromosome or the few best chromosomes are copied to the new population. The rest is done in a classical way. Such individuals can be lost if they are not selected to reproduce or if crossover or mutation destroys them. This significantly improves the GA's performance.

**Crossover (Recombination)**

Crossover is the process of taking two parent solutions and producing from them a child. After the selection (reproduction) process, the population is enriched with better individuals. Reproduction makes clones of good strings but does not create new ones. Crossover operator is applied to the mating pool with the hope that it creates a better offspring.

**Mutation**

After crossover, the strings are subjected to mutation. Mutation is performed to one individual to produce a new version of it where some of the original genetic material has been randomly changed. Mutation prevents the algorithm to be trapped in a local minimum. Mutation plays the role of recovering the lost genetic materials as well as for randomly disturbing genetic information. It is an insurance policy against the irreversible loss of genetic material. Mutation has traditionally considered as a simple search operator. If crossover is supposed to exploit the current solution to find better ones, mutation is supposed to help for the exploration of the whole search space. Mutation is viewed as a background operator to maintain genetic diversity in the population. It introduces new genetic structures in the population by randomly modifying some of its building blocks. Mutation helps escape from local minima's trap and maintains diversity in the population.

**Fitness Scaling**

Fitness scaling is performed in order to avoid premature convergence and slow finishing. The various types of fitness scaling are: Linear scaling, σ-Truncation and Power law.

## 3. RECENT WORKS OF GAs

In [2], GAs use binary encoding, and perform a comparison between GAs and classical hill-climbing direct-search method. This comparison showed that the GAs carry out more iterations than the conventional techniques. However, the GAs are able of finding global optimum and avoiding local, being the major advantage of the GAs compared to more classical techniques. Another property of the GAs is that there is no need for a good initial point to start the optimization from. The choice of setting process parameters, like crossover probability and mutation rate have been explored. The findings support the effects of these parameters discussed.

In [3], an optimal design method based on the genetic algorithm to optimize three-phase induction motor (IM). Encoding adopted is binary. Roulette wheel selection, single-point crossover, and bit mutation have been used. The torque of the motor as the objective function was selected. It has been concluded through results that the GAs offer advantages over other approaches.

In [4], an optimal design method to optimize three-phase induction motor in manufacturing process has been presented. The optimally designed motor is compared with an existing motor having the same ratings. GA is used for optimization and three objective functions namely torque, efficiency, and cost are considered. The motor design procedure consists of a system of non-linear equations, which imposes induction motor characteristics, motor performance, magnetic stresses and thermal limits. Computer simulation results are given to show the effectiveness of the proposed design process.

In [5], it has been highlighted that the conventional evolution strategy (ES) algorithm, which consist of simulated annealing and Genetic Algorithm falls into trap of local minima with high probability in solving the optimization problem that has many design variables. A modified ES algorithm to overcome the problem has been adopted by introducing shaking technique. Through the results from sample motor design, it is suggested that the proposed method is useful for multi-objective optimal design of an induction motor.

In [11], design optimization of the pole face to a magnetizer has been carried out using GAs. A discussion upon determination of the representation scheme has been brought up. The encoding is binary. The conclusion is that the GAs had been successfully applied to the shape optimization of magnetizer. The paper also makes the GAs parallelizable, making it possible to evaluate each chromosome independently from each other.

In [12], the development of a new algorithm for Electric Motor Design has been highlighted. In principle, the new algorithm utilizes a mixed method that consists of GAs in conjunction with direct search method. T. The direct search method improves convergence speed with greater accuracy, far better than what could be achieved using GAs (as its accuracy depends on the bit length). The results suggest that the proposed method is valid for the optimal design of electric machinery.

## 4. DESIGN OPTIMIZATION OF INDUCTION MOTOR

In the research work, optimized design of Induction motor, emphasizing cost as the objective function, has been carried out using conventional optimization techniques first and then using GAs. X is a set of independent variable concerning the electrical and magnetic circuits of the machine. Out of the 50-odd variables concerning the electrical and magnetic circuits of the machine, only some have a predominating influence on the cost and performance of the motor [7]. In the problem under consideration, eleven such predominant parameters listed in the Table 1 are considered as independent variables while the other parameters are either referred in terms of the 11 parameters listed in Table 1 or treated as fixed for a particular problem. All lengths are expressed in centimeters and air gap flux density in Tesla [6]. The values of these variables have been calculated manually, which did not violate any of the constraints given is also given and they are taken as initial values.

**Table 1: Independent Variables**

| Description | Independent variable | Initial Values |
|---|---|---|
| Stator Bore Diameter | $X_1$ | 8.4 |
| Stator Stack Length | $X_2$ | 7.26 |
| Depth of Stator slot | $X_3$ | 1.6 |
| Width of Stator slot | $X_4$ | 0.39 |
| Depth of Stator core | $X_5$ | 2.075 |
| Depth of Rotor slot | $X_6$ | 1.175 |
| Width of Rotor slot | $X_7$ | 0.148 |
| Air gap flux density | $X_8$ | 0.5 |
| End ring depth | $X_9$ | 0.77 |
| End ring width | $X_{10}$ | 0.702 |
| Air gap length | $X_{11}$ | 0.034 |

The function to be minimized is formed by considering the cost of electrical conducting and magnetic materials. A penalty function is introduced in the design to incorporate the Constraints on specifications so that while optimizing the design, no constraint is violated [7]. The various constraints imposed in the design are given in Table 2.

**Table 2: Constraints Imposed**

| Description of the Constraint | Magnitude |
|---|---|
| Starting Current | ≤ 9.09 A |
| Starting Torque | ≥ 11.90 N m |
| Pull-out Torque | ≥ 12.05 N m |
| Full Load Slip | ≤ 0.17 |
| Full Load Temperature Rise | ≤ 75 º C |
| Full Load Power Factor | ≥ 0.8 |

The design procedure assumes a unimodal function. The motor designed has the following specifications: Motor rating 1 HP; Input Voltage 400 V, 50Hz., 3-Phase; No. of Poles –4; 1500 rpm; The function to be minimized is F, formed by considering the cost of electrical conducting and magnetic materials. For this, the cost of Iron (Steel), Copper and Aluminium were taken as Rs.32, Rs.330, and Rs.90 per Kilogram respectively. F is the summation of costs of Stampings, Stator Copper and Rotor Cage Aluminium [6].

In the design using GAs, software "**Xl bit**", as Add-In MSEXCEL 2007, is used. The test set-up used is as follows: Population: 100, Generation: 200, Variable type: Non-Integer, Crossover Rate: 0.7, Mutation rate: 0.002 and Fitness Scale: Linear Normalize.

The design is tested with three different crossover methods: Elitism, Roulette Wheel, and Tournament Selection. The results obtained are analyzed. The initial value or base value of each parameter (basic variables and constraints) is taken as 1.0 and the optimized results obtained through the simulations are presented with reference to the base value in the figures. Factor of variation of each basic variable with respect to its base or initial value is shown in Figure 2. Factor of variation of each constraint with respect to their base or initial values imposed is shown in Figure 3. Optimized cost of each material used and also the total cost are shown in Table 3.

**Table 3: Optimized Materials' Cost & the Total Cost**

| Material | Cost with Initial Values | Cross-over methods | | |
|---|---|---|---|---|
| | | Elitism | Tournament Selection | Roulette Wheel |
| Steel | 258.42 | 224.95 | 223.37 | 222.59 |
| Copper | 1965.7 | 1557.95 | 1558.92 | 1557.76 |
| Aluminium | 13.72 | 14.22 | 14.55 | 14.77 |
| Total | 2237.84 | 1797.12 | 1796.84 | 1795.12 |

From the Table 3, given above, it may be observed that the GAs have optimized the cost of the motor by about 20 %, in all the three methods used. The research work has confirmed once again the supremacy of GAs in the design optimization problem, over the conventional optimization techniques discussed.

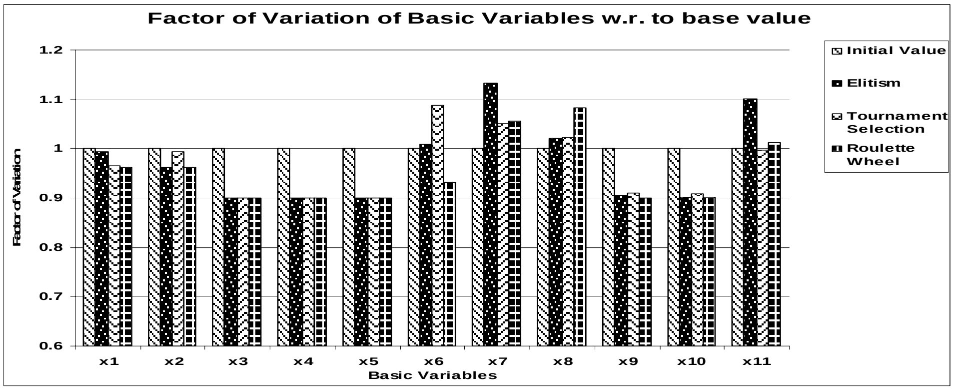


**Fig. 2: Factor of variation of basic variables w.r. to their base values**

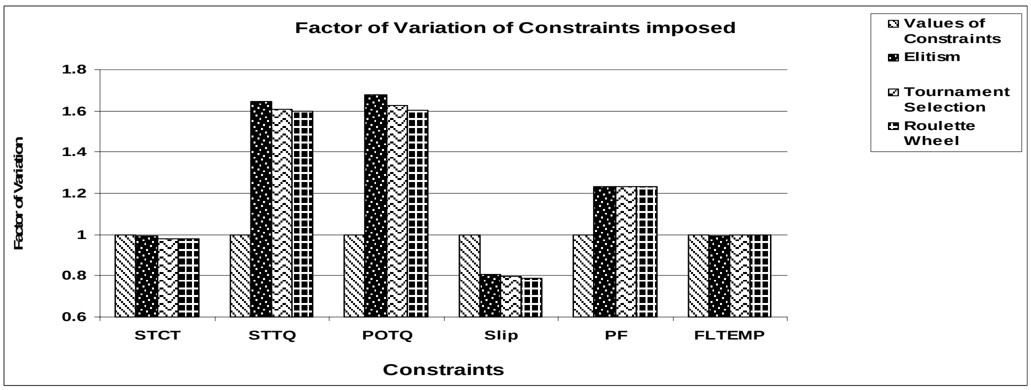


**Fig. 3: Factor of variation of constraints w.r. to their base values**

## 5. CONCLUSION

This paper has presented, in a nut shell, a literature study of genetic algorithms (GA) used in electrical machine optimization and also the important results of a part of the research work carried out has been presented. In recent years, GA's have been recognized as potent tools in design optimization of electrical machinery. Further progress in the research work combining conventional Optimization techniques and GA approach will result in best results in the design under consideration.

## REFERENCES


[1]. B. Abdelhadi, A. Benoudijit and N. Nait, (2004), Identification of Induction machine parameters using a new adaptive genetic algorithm, Electric power components and systems, vol. 32, pp. 763-784.

[2]. N. Bianchi and S. Bolognani, (1998), Design optimization of electric motors by genetic algorithm, IEEE Proc. on electrical power appliances, pp. 475-483.

[3]. M. Cunkas and R. Akkaya (2004), Design optimization of induction motor by genetic algorithms. Int. Aegean Conf. on Electrical Machines and Power Electronics, pp.408-413.

[4]. M. Cunkas and R. Akkaya (2006), Design optimization of induction motor by genetic algorithm and comparison with existing motor, Mathematical and Computational Applications, vol. 11, no. 3, pp. 193-203.

[5]. M.K.Kim, C.G.Lee and H.K.Jung, (1998), Multiobjective optimal design of three-phase induction motor using improved evolution strategy, IEEE Trans. on Magnetics, vol. 34, pp. 2980-2983.

[6]. Krishnamoorthy and K. Dharmalingam (2010), Application of Optimization techniques and Genetic Algorithms in the Design of Three phase Induction Motor, Int. Conf. ICAIEA.

[7]. P. Marimuthu and M.R. Krishnamurthy, (1982), Optimization of Pole-changing single winding induction motor design, Int. Conf. on electrical machines, Budapest, GP3/7, pp. 826-829.

[8]. R. Ramarathnam, B.G. Desai and V.Subbarao, (1971), Optimization of polyphase induction motor design - A nonlinear programming approach, IEEE Trans. on Power Apparatus and Systems, vol. 90, pp. 570-579.

[9]. B. Sareni, L. Krahenbuhl and A. Nicolas, (2000), Efficient Genetic algorithms for solving hard constrained optimization problems, IEEE Trans. on Magnetcis, vol. 36, pp. 1027-1030.

[10]. S. Singiresu Rao, (2009), Engineering optimization, John Wiley & sons.
[11]. G.F. Uler, O.A. Mohammed and C.S. Koh, (1994), Utilizing, Genetic algorithms for the optimal design of electromagnetic devices, IEEE Trans. on Magnetics, vol. 30.
[12]. O.H. Yong-Hwan, T.K. Chung, M.K. Kim and H.K. Jung, (1999), Optimal design of electric machine using Genetic algorithms coupled with Direct method, IEEE Trans. on Magnetics, vol. 35.

**Biography**

Mr.A.Krishnamoorthy received the B.E.degree in Electrical and Electronics Engineering from Govt. College of Engineering, Salem, India, in 1990 and the M.E. degree in Electrical and Electronics Engineering (Applied Electronics) from Coimbatore Institute of Technology, Coimbatore, India, in 1992. He has registered for PhD in Sathyabama University, Chennai, India, under the supervision of Dr.K.Dharmalingam. He has about 18 years of teaching experience in reputed engineering colleges and universities. He has presented about 15 papers in National Conferences, 3 papers in International Conferences and published 2 papers in International Journals. He is presently working as a Professor & Head / EEE at Sakthi Mariamman Engineering College, Chennai.

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