Optimization of Induction Motor Using Genetic Algorithm and GUI of Optimal Induction Motor Design in MATLAB

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Abstract In this paper, an optimal design of induction motor using genetic algorithm is discussed and the results obtained are compared with a conventionally designed induction motor. Graphical user interface (GUI)-based user simplified interface is prepared in MATLAB to achieve an optimal design of different power-rated three-phase squirrel cage induction motors. Full-load efficiency and active material cost are chosen as an objective function to be optimized, and based on that, the concept of dual optimization is explained. To achieve the best suitable design, different variables are chosen and different constraints are imposed on the design of induction motor.

Keywords Optimization · Induction motor · Optimal design
Graphical user interface

1 Introduction

Increasing power demand is being a crucial issue in power sector from last some years. Efforts are made to reach power demand and decrease demand generation gap. So to solve this issue of demand generation gap, a new concept of optimization is suggested [1].

A MATLAB-based program is developed for designing a three-phase squirrel cage induction motor. "Full-load efficiency" and "active material cost" are taken as an objective function. A 50 kW, 440 V, 50 Hz, 1000 RPM induction motor is

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chosen for designing, and then, genetic algorithm is implemented on this motor for efficiency and cost improvement in a way to increase efficiency and decrease cost. Results of optimized design of induction motor are compared with the conventionally designed induction motor to check for performance parameters and real-time implementation. Graphical user interface in MATLAB gives the user a flexibility and easiness to user program for problem-solving in a much easier way. So a generalized program is developed to design any kW motor and optimize that design using genetic algorithm and then GUI of the same generalized program is done for development of user-friendly environment.

2 Design Optimization of Induction Motor

The process of optimization of induction motor is expressed as follows:

Find Z (Z_1, Z_2, Z_n), so that $F(Z)$ is minimum [1], where $F(Z)$ is an objective function.

Satisfying; All desired constraints and all design variables within specified limits are satisfied [2].

A. Design Variables

Design variables are basic parameters used in designing induction motor, and they are made free to take any value within its limits to achieve best suitable design. For proposed work, all these variable parameters are adjusted, so that for high efficiency and low cost, an optimal or best design can be achieved (Table 1).

B. List of Constraints

Constraints are imposed on an optimal design of induction so that it satisfies certain requirements. Main performance parameters are chosen as constraints. So while running genetic algorithm, no constraint is violated and satisfactory design can be achieved with all constraints to be satisfied (Table 2).

Table 1 List of design variables

Design variables	Lower limit	Upper limit
Specific magnetic loading (Tesla)	0.35	0.53
Specific electric loading (Ac/m)	25,000	50,000
Stator winding current density (A/mm^2)	3	5
Flux density in the rotor bar (Tesla)	1.2	1.4
Current density of rotor bar (A/mm^2)	4	7
Depth of rotor bar (mm)	5	8
Current density for end ring (A/mm^2)	4	10
Flux density in the rotor bar (Tesla)	1.35	1.70

Table 2 List of constraints

S. No.	Inequality constraints	Violation limit
1	Temperature rise	≤ 50 °C
2	Starting torque	≥ 1.2 * full-load torque
3	Full-load slip	$\leq 3.5\%$
4	kg per kW	≤ 6.5

C. Objective Function

Objective functions are main performance parameter or main goal of whole design. In this paper, proposed scheme of optimization is implemented choosing two different objective functions.

(1) full-load efficiency and
(2) active material cost

where

Full-load efficiency is defined as follows:

$$\text{Efficiency} = \text{kW}/(\text{kW} + P_{\text{total}}/1000) * 100;$$

Active material cost is defined as follows:

$$C_{\text{material}} = C_{\text{iron}} + C_{\text{copper}};$$

Two different designs are prepared for two different objective functions. In design 1, efficiency is chosen as an objective function so a feasible designed is achieved in such a way that highest efficiency can be achieved satisfying all the constraints. In design 2, active material cost is chosen as an objective function so a feasible designed is achieved in such a way that low active material cost can be achieved by satisfying all the constraints and also maintaining good efficiency but not the highest.

3 Results and Discussion

I. Single-Objective Optimization

Efficiency and cost are chosen as two separate objective functions, and GA is implemented as optimization technique. Comparison between conventionally designed motor and optimally designed motor is made in a way to clearly understand performance improvement and comparison.

A 50 kW, 50 Hz, 440 V, 1000 RPM induction motor is chosen. Two different designs are prepared for two different objective functions:

Design 1: full-load efficiency as an objective function and
Design 2: active material cost as an objective function.

From the above results, it is shown that very good value of efficiency can be obtained when efficiency is taken as an objective function and optimization is done using genetic algorithm. But active material cost of the motor is higher compared to Design 2.

Design 2 is prepared to choose active material cost as an objective function; optimization is done; and a visible decrease in active material cost is achieved with little compromise on efficiency.

II. Multiobjective Optimization Technique/Dual Optimization

Results presented in Table 3 shows that Design 1, in which efficiency is taken as objective function, gives higher efficiency at higher cost compared to Design 2. In Design 2, active material cost is taken as an objective function where cost definitely decreases and efficiency also decreases. So we have to choose the best value of efficiency or cost to compromise in another value of objective function. To solve this problem, a method of "dual optimization" can be implemented with two

Table 3 Result comparison of different methods

S. No.	Variable/Parameters	Design 1 (efficiency)	Design 2 (active material cost)
1	Specific magnetic loading (Tesla)	0.3832	0.3879
2	Specific electric loading (Ac/m)	32511	39046
3	Stator winding current density (A/mm^2)	4.93	3.2
4	Flux density in the rotor bar (Tesla)	1.2	1.39
5	Current density of rotor bar (A/mm^2)	4.85	6.59
6	Depth of rotor bar (mm)	7.76	5
7	Current density for end ring (A/mm^2)	4.02	4.11
8	Flux density in the rotor bar (Tesla)	1.70	1.70
9	Efficiency	**92.21**	90.73
10	Full-load slip	**1.88**	2.72
11	Starting torque	**1.88 * FL Tq**	2.72 * FL Tq
12	Temperature rise (°C)	**38.43**	47.32
13	Total weight (kg)	267.62	**234.63**
14	kg required per kW (kg)	5.35	**4.69**
15	Cost of active material (Rs.)	4375 Rs.	**3769.0 Rs.**

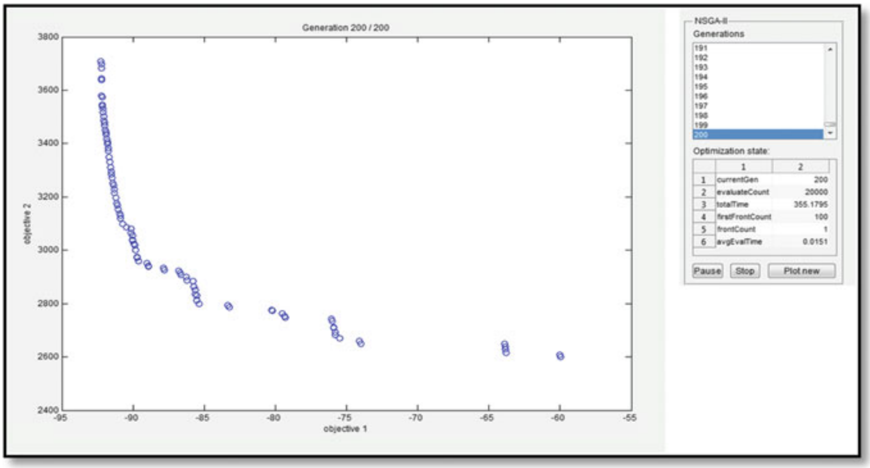

Fig. 1 Results of NSGA-II program in MATLAB for efficiency and cost as objective function

objective functions together. A NSGA-II program in MATLAB [3, 4] is used for dual optimization with efficiency and active material cost as an objective function (Fig. 1).

Above Graph shows the relation between two objective functions. This is obtained using NSGA-II Program in MATLAB. A number of generations selected are 200 and 50 populations for each generation. Average time taken for each Generation is 0.0111 s. From above graph shows that with the higher efficiency, cost of the motor is higher and it decreases with decrease in efficiency. So a proper motor can be designed as per requirement from results obtained using NSGA-II program using the concept of dual optimization.

III. Graphical User Interface (GUI)

As shown in Fig. 2, a MATLAB-based GUI is prepared for designing of induction motor with single-objective function. In Fig. 2 a, demonstration is shown with efficiency as an objective function. GUI gives the user a flexibility to use program easily and shows results in very user-friendly way. In the proposed GUI, certain input parameters are to be fed and interface is made to run, which will give optimized design of induction motor.

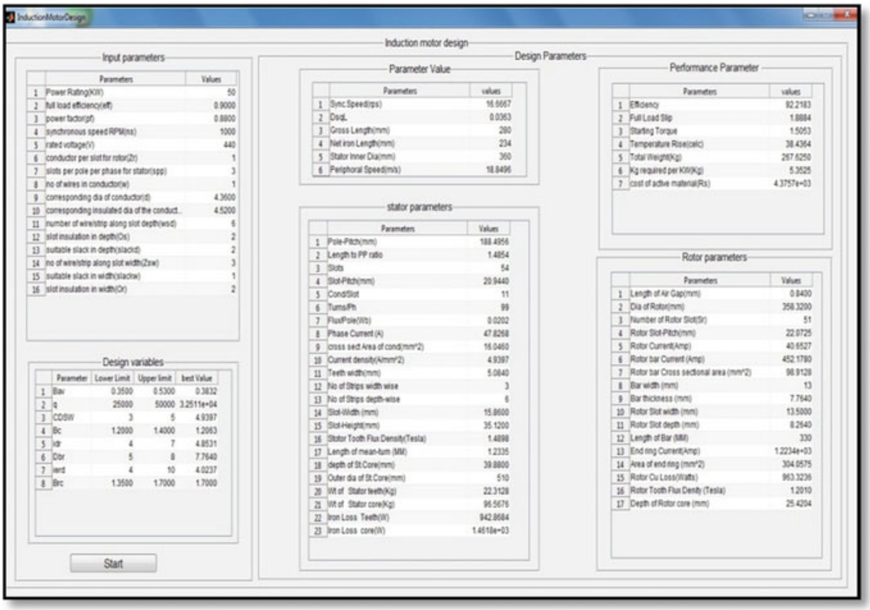

Fig. 2 MATLAB GUI for optimal induction motor design

4 Conclusion

Design optimization of three-phase squirrel cage induction motor is presented in this paper. Results show that when efficiency is considered as an objective function and GA is implemented for optimization, efficiency increases to 2.12%; and when active material cost is considered as an objective function and GA is implemented for optimization, active material cost decreases to 19.15% compared to the conventionally designed induction motor. Dual optimization can be successfully used for two objective functions together, and motor can be designed as per the desired performance requirement.

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