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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A. Konkani et al. (eds.), Advances in Systems, Control and Automation,

Lecture Notes in Electrical Engineering 442, https://doi.org/10.1007/978-981-10-4762-6_12

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).

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 1 List of design variables

Table 2 List of constraints	S. No.	Inequality constraints	Violation limit
	1	Temperature rise	\leq 50 °C
	2	Starting torque	\geq 1.2 * full-load torque
	3	Full-load slip	\leq 3.5%
	4	kg per kW	\leq 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:

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

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

Result comparison of unrefert meth			
Variable/Parameters	Design 1 (efficiency)	Design 2 (active material cost)	
Specific magnetic loading (Tesla)	0.3832	0.3879	
Specific electric loading (Ac/m)	32511	39046	
Stator winding current density (A/mm ²)	4.93	3.2	
Flux density in the rotor bar (Tesla)	1.2	1.39	
Current density of rotor bar (A/mm ²)	4.85	6.59	
Depth of rotor bar (mm)	7.76	5	
Current density for end ring (A/mm ²)	4.02	4.11	
Flux density in the rotor bar (Tesla)	1.70	1.70	
Efficiency	92.21	90.73	
Full-load slip	1.88	2.72	
Starting torque	1.88 * FL Tq	2.72 * FL Tq	
Temperature rise (°C)	38.43	47.32	
Total weight (kg)	267.62	234.63	
kg required per kW (kg)	5.35	4.69	
Cost of active material (Rs.)	4375 Rs.	3769.0 Rs.	
	Specific magnetic loading (Tesla) Specific electric loading (Ac/m) Stator winding current density (A/mm ²) Flux density in the rotor bar (Tesla) Current density of rotor bar (A/mm ²) Depth of rotor bar (mm) Current density for end ring (A/mm ²) Flux density in the rotor bar (Tesla) Efficiency Full-load slip Starting torque Temperature rise (°C) Total weight (kg) kg required per kW (kg)	Specific magnetic loading (Tesla)(efficiency)Specific electric loading (Ac/m)32511Stator winding current density (A/mm²)4.93Flux density in the rotor bar (Tesla)1.2Current density of rotor bar (A/mm²)4.85Depth of rotor bar (mm)7.76Current density for end ring (A/mm²)1.70Efficiency92.21Full-load slip1.88Starting torque1.88 * FL TqTemperature rise (°C)38.43Total weight (kg)2.35	

Table 3 Result comparison of different methods

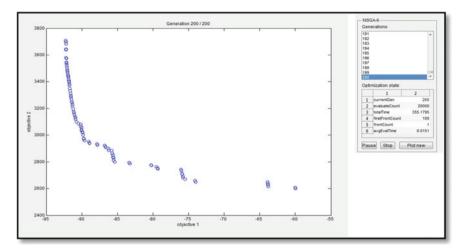


Fig. 1 Results of NSGA-II program in MATLAB for efficiency and cost as objective function

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.

			Induction motor d				
inp	ut parameters-		Parameter Valu	Design Par	ameters Performance Parameter	Dedemons Deserves	
Parat	neters	Values	Parameter vau	c	renumance rarameter		
Power Rating(Kill)		50	Parameters	values	Parameters	values	
full load efficiency(eff)		0.9000	1 (Sync Speed)rps)	16.6667	1 Effdency	92,2183	
power factor(pf)		0.8800	2 Dod.	0.0363	2 Full Load Slp	1.8884	
synchronous speed R	PM(ns)	1000	3 Gross Length(mm)	290	3 Starting Torque	1.5053	
rated voltage(v)		440	4 Net iron Length(mm)	234	4 Temperature Rise(celc)	38.4364	
conductor per slot for r	alor(2r)	1	5 Stator Inner Dia(mm)	360	5 Total Weight(Kg)	267.6250	
slots per pole per pha	se for stator(spp)	3	6 Periphoral Speed(mis)	18.8496	6 Kg required per KN/Kg)	5.3525	
no of wires in conduct	pr(w)	1			7 (cost of active material(Rs)	4.3757e+03	
corresponding dia of c	(b)robubne	4,3600					
corresponding insulati	ed dia of the conduct	1. 4.5200	stator parameter	15			
number of wirelship al	ong slot depibliesd	6	Parameters.	Values			
slot insulation in depth	(Os)	2	1 Pule-Pitch(mm)	188,4956			
suitable slack in depth	(sladid)	2	2 Length to PP ratio	14054			
no of wive/strip along s	lot width(Zzw)	3	3 Slots	54	Rotor parameters		
suitable slack in width	(slacks)	1	4 Skt-Ptds(mm)	20.9440	Parameters	Values	
slot insulation in width	(01)	2	5 CondStat	11	1 Length of Air Gap(mm)	0.8400	
			6 TumsPh	99	2 Dia of Rotorimmi	358.3200	
			7 FluxPole(Wb)	8 6202	3 Number of Rotor Slot(Sr)	51	
			# Phase Current (A)	47.8268	4 Rotar Stat-Pitchinmi	22.0725	
			9 cross sed Area of condimm*2)	16.0450	5 Rotor Current(Amp)	40.6527	
	10.000		10 Current density(Almm*2)	4 9 3 9 7	6 Rotor bar Current (Amp)	452,1780	
	sign variables		11 Teeth width(mm)	5.0840	7 Rotor bar Cross sectional area (mm*2)	90,9128	
Parameter Lower			12 No of Ships width wise	30000	Barwidh (mm)	13	
	3500 0.5300		12 No of Strips decth-wise		9 Barthickness (mm)	7.7640	
		3.2511e+04	13 No of Sergs Organises	15,8600	10 Roty Skt width (mm)	13,5000	
1 CDSW	3 5		15 Skit-Heightimm)	35 1200	11 Rotor Skit depth (mm)	8 2640	
	2000 1.4000		15 Stot-Height(Him) 16 Stotor Tooth Flux Densite(Tesla)	1,4090	12 Length of Bar (MM)	8,2949	
5 10	4 7	4.8531	15 Stater Footh Plux Densit(Tesla) 17 Length of mean-tum (MM)	1.4090	13 End ring Current/Amp)	122348+03	
6 Obr	5 8	7.7640		1,2335	13 End ing current/vmp) 14 Area of end ring (mm*2)	304.0575	
7 jerd	4 10		18 depth of St.Core(mm) 19 Outer dia of St.Core(mm)	510	14 /vea or end ning (mmr2) 15 Rotor Cu Loss (Wats)	304 05/5 963 3236	
8 Brc 1	3500 1.7000	1.7000			15 Rotor Co Loss(mats) 16 Rotor Tooth Flui Denity (Tesla)	953.3236	
			25 Wit of Stator teeth(Kg)	22.3128	15 Rotor rooth Flux Denty (resix) 17 Depth of Rotor care (mm)	25.4204	
			21 Wt of Stator core(Kg)	95.5676	T1 Patter 0.4000, CD4 (4/4)	25.4294	
			22 Iron Loss Teeth(III)	942.8684			
			23 Jron Loss core(IN)	1.4518e=03			
Sta	eft						

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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