ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 5, May 2015

Flower Pollination Based Design for Enhancing Efficiency of Induction Motor

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ABSTRACT: This paper presents a flower pollination based optimization (FPO) methodology for designing efficient induction motor (IM). The FPO, inspired from the pollination process of plants, explores the problem space for finding the global best solution of the given optimization problem. The methodology optimizes only seven primary design variables with a view to enhance the efficiency of the IM. The proposed design philosophy is applied on a sample induction motor and the optimal design parameters are presented in this paper.

KEYWORDS: induction motor design; efficiency enhancement; flower pollination based optimization

NOMENCLATURE

$C(x)$	a set of inequality constraints
$\Phi(x)$	objective function to be optimized
IM	induction motor
npd	number of primary design variables
pdv_i	i-th primary design variables
PM	proposed method
P_{nl}	no load loss
P_{cus}	stator copper loss.
P_{cur}	rotor copper loss.
η	a set of limit violated constraints
w	weight constant of the penalty terms

I. INTRODUCTION

Induction motors (IM) have been popularly used almost in all drive systems due to their robustness and lower price and consuming major portion of the overall generated power. In order to reduce the loss components associated with the usage of IMs, it is necessary to design the IMs to be more efficient. The design of IM for enhancing the efficiency is so complex as it involves nonlinear design equations and mixes both the art and engineering [1].

Several classical approaches such as nonlinear programming [2], Lagrangian relaxation method [3], direct and indirect search methods [4], Hooks and Jeeves method [5], finite element method [6] and sequential unconstrained minimization technique [7] were suggested by the researchers for designing IMs. Most of these approaches require derivatives and pose convergence problems. To overcome the drawbacks of these approaches, nature inspired algorithms such as genetic algorithm [8,9], evolutionary algorithm [10], and particle swarm optimization[11] were employed in solving the IM design problems. These algorithms attempted to offer best and robust results for the design problem.

Recently, a Flower Pollination based Optimization (FPO), inspired from the pollination process of plants, has been suggested for solving optimization problems [12]. In this approach, problem solutions are denoted by pollens of flowers

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and the pollination is associated with sharing of pollens between local flowers and also from the global best flower. This paper attempts to apply FPO in solving the IM design problem with an objective of enhancing the efficiency.

II. PROBLEM FORMULATION

The IM design problem comprising a large number of design variables can be formulated as an optimization problem. But most of the design variables have no direct influence on the efficiency of the IM. A limited number of variables that have significant impact on the efficiency are treated as primary design variables and the rest are considered as secondary design variables. In the design problem, flux density in the core, rotor current density, stator current density, air gap length, ampere conductor, average value of air gap flux density, core length to pole pitch are taken as primary design variables. The design problem can be tailored as

$$\text{Maximize} \quad \Phi(x) = \frac{output\ in\ KW}{output\ in\ KW + P_{nl} + P_{cus} + P_{cur}} \tag{1}$$

Subject to

$$C(x) \le 0 \Leftrightarrow \left\{ \begin{array}{l} \text{power factor} \ge 0.75 \\ \text{maximum flux density of stator teeth} \le 2 \\ \text{per unit no load current} \le 0.5 \\ \text{slip at full load} \le 0.05 \\ \text{maximum flux density of rotor teeth} \le 2.0 \\ \text{stator temperature rise} \le 70 \\ \text{starting to full load torque ratio} \ge 1.5 \end{array} \right\} \tag{2}$$

$$x_i^{\min} \le x_i \le x_i^{\max} \qquad i = 1,2,\cdots ndv \tag{3}$$

III. PROPOSED METHOD

The proposed method employs the FPO in solving the IM design problem. It requires representation of design variables in the form of flowers and construction of a fitness function. Each flower [12] in the IM design problem is modelled to represent the primary design variables, outlined in the previous section, as

$$f_i = \left[pdv_1, pdv_2, \cdots, pdv_{ndv} \right] \tag{4}$$

The fitness function is formed as

$$\text{Maximize} \qquad F = \frac{\Phi(x)}{1 + w \sum_{i \in \eta} \left[C_i(x) \right]^2} \tag{5}$$

Initially a population of flowers is randomly generated and the fitness of each flower is calculated using Eq. (5). The global or local pollination is stochastically performed to all the flowers in the population, thereby generating a new set of flowers. The process of generating a new set of flowers is represented as an iteration, which is continued by considering the population obtained in the previous iteration as the initial population for next iteration. The flower having the best fitness function value is stored along with its objective function at each iteration. The FPO iterative process of generating new population can be terminated after a fixed number of iterations.

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IV. Simulation Results

The proposed FPO based design method (PM) is used to obtain the optimal design of 7.5 kW, 400 V, 4 pole, 50 Hz IM. The superior performance of the PM is illustrated by comparing the results with that of firefly optimization based design method (FODM) [13] in Table 1. The table contains the optimal design representing the values of the primary design variables and its efficiency. It is seen from the table that the PM offers an efficiency of 86.742%, which is higher than that of FODM. The table also contains the values of the constraints of Eq. (2) along with their limits. It also seen that the PM brings all the constraints of Eq. (2) within the respective limits, as the limit violated constraints are included as penalty terms in the fitness function of Eq. (5). It is obvious that the PM offers better design in terms of larger efficiency.

Table 1 Comparison of Results

	Primary Design Variables		PM	FODM
Primary Design Variables x	pdv_1	flux density in the core	1.35936	1.36501
	pdv_2	rotor current density	0.4314	0.42688
	pdv_3	stator current density	22230.93	23181.60
	pdv_4	air gap length	0.59732	0.58873
	pdv_5	ampere conductor	3.49026	3.48672
	pdv_6	average value of air gap flux density	2.09362	2.03984
	pdv_7	core length to pole pitch	1.10293	1.10194
Constraints $C(x)$	$C_1 \geq 0.75$		0.831	0.827
	$C_2 \leq 2$		1.710	1.677
	$C_3 \leq 0.5$		0.463	0.430
	$C_4 \leq 0.05$		0.028	0.020
	$C_5 \leq 2$		1.746	1.753
	$C_6 \leq 70$		45.289	45.894
	$C_7 \geq 1.5$		3.849	3.900
Objective function $\Phi(x)$	% Efficiency		**86.742**	**86.736**

V. Conclusion and Future Work

The FPO, inspired from the pollination process of plants, searches for optimal solution for multimodal optimization problems. A novel methodology using FPO was developed for solving IM design problem, which is a complex non-linear optimization problem involving large number of decision variables. The PM was applied on a IM design problem and exhibited that the PM provides the optimal values for primary design variables that improve the efficiency of the motor. The design problem can be modified to include the other objectives such as improving the starting torque of the IM in future and solved using FPO.

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ACKNOWLEDGEMENTS

The author gratefully acknowledges the authorities of Annamalai University for the facilities offered to carry out this work

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