Multi Algorithm Of A Single Objective Function Of A Single Phase Induction Motor

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***Abstract*—The application of four algorithms (GA, PSO, SA, FA) in parameters design of a single-phase induction motor is proposed in this paper. The Four algorithms consider the motor efficiency as an objective function and with five equality and five inequality constraints. Under efficiency as an objective function the performance of the algorithm improved in the order 19.7%, 15.3%, 15.22% and 15.2% as follows, GA, SA, FA and PSO respectively, this means that for the choice of algorithm in terms of efficiency as an objective function GA is preferred. The most performed algorithm is the GA for the single phase induction motor, a code has been provided under MATLAB software. The results show that the GA method gives more suitable design optimization against conventional methods.**

Keywords—Design Optimization; Single Phase Induction Motor (SPIM); Maximum Efficiency; Genetic Algorithm (GA)

1. Introduction

Single Phase Induction motors are electrical energy conversion devices widely used in industries, transportation, and other aspects of modern life. Therefore its performance improvement with high efficiency could significantly reduce the cost of industrial and residential energy systems.

Over the years effort is been made to improve the efficiency performances of single phase induction motors by providing new design methods. Machine design is influenced by design factors like economics (cost minimization), material limitation (size minimization), costumer and regulating bodies' specifications (voltage, power rating, frequency, etc.).

1.1. Methodology

The methods adopted to achieve the set objectives for this study are as follows.

a. The mathematical formulations of design efficiency objective functions and implementing them by using optimization tools.
b. Embedment of the efficiency objective functions and Genetic Algorithm into friendly interactive graphical users interface in Matlab environment.

Relationships Governing Single Phase Induction Motor [1]

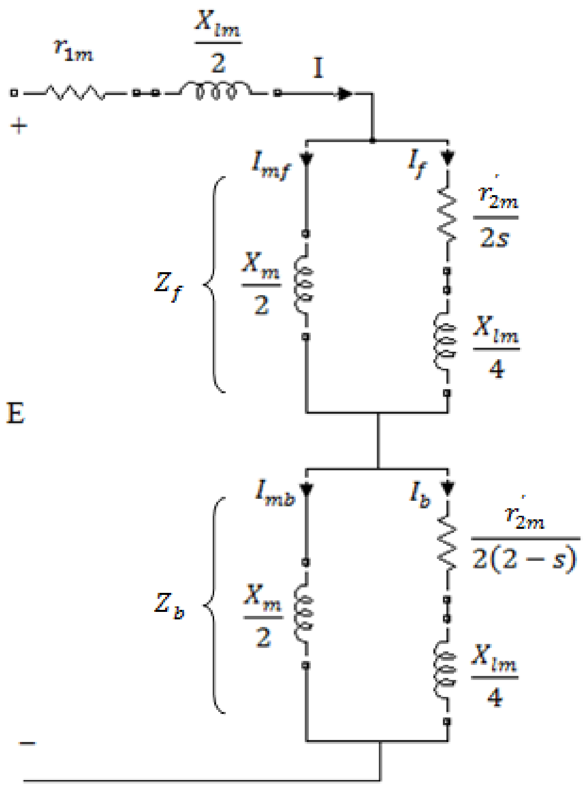

Figure.1. equivalent circuit of SPIM based on double revolving field theory

Like other types of electrical machines, SPIMs are also designed to meet a given set of specifications. The motor has to be designed to give sufficient starting torque with rea-sonable performance during its working period. Fig. 1 illus-trates equivalent circuit of SPIM based on double rotating field theory. The power flow diagram for a SPIM is shown in Fig. 2.

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Considering figures 1 and 2 relationships governing single phase induction motor may be expressed as follows[1]: single-phase induction motor to maximize the efficiency using Genetic Algorithm (GA) The present paper will be organized as follows. Section 2 briefly explains GA algorithm. Section 3 presents relationships governing sin-gle-phase induction motor. Section 4 discusses the optimal design with variables and constraints. Section 5 gives the detailed discussion on the results of GA algorithm and their comparison with conventional design.

$$r_{1m} = \frac{\rho \cdot l_{mtm} \cdot T_m}{a_m}$$

$$a_m = \pi \cdot \frac{d_m^2}{4}$$

$$r_{1a} = \frac{\rho \cdot l_{mta} \cdot T_a}{a_a}$$

$$a_a = \pi \cdot \frac{{d_a}^2}{4}$$

$$r'_{2m} = 2 \cdot {N_m}^2 \cdot {K_{wm}}^2 \cdot \rho \cdot \left[\frac{l_b}{A_b \cdot N_b} + \frac{0.64 \cdot D_m}{P^2 \cdot A_e} \right]$$

$$X_{lm} = X_s + X_{zz} + X_e + X_b + X_{sk}$$

$$X_m = K_x \cdot (0.2546 \cdot K_m \cdot C_{sk})$$

$$K_x = 2 \cdot \pi \cdot f \cdot (N_m \cdot K_{wm})^2 \cdot 10^{-8}$$

$$k_m = \frac{\pi \cdot D_i . L/2}{l'_g \cdot S_f \cdot P}$$

$$C_{sk} = \frac{\sin(\alpha/2)}{\frac{\pi \cdot \alpha}{360}}$$

Efficiency

The efficiency of a single phase induction motor can be written as

$$eff = \frac{P_m}{P_{in}} = \frac{(1-s)P_g - P_{fw}}{(1-s)P_g + P_d}$$

where P_d the electrical losses within the induction motor is given as

$$P_d = r_1 I_m^2 + (R_c + r_a) I_a^2 + s\left[(R_f - R_b)(I_m^2 + a^2 I_a^2) + 2aI_m I_a (R_f + R_b)\sin\theta\right] +$$
$$2R_b(I_m^2 + a^2 I_a^2 - 2aI_m I_a \sin\theta)$$

The Design Variables

The following quantities are chosen as the independent design variables for the Efficiency - objective optimization a single phase induction motors under consideration: Stator bore diameter D , Stator tooth width W_{st}, Rotor tooth width W_{rt}, Depth of stator slot d_{ss} , Depth of stator core d_{sc} , Depth of rotor slot d_{rs} , Stator outer diameter D_o , Stator axial length L.

Limits of Variables

The design carried out is for a 0.75 kW, single phase induction motor operating under a 380 Volts, 50 Hz power supply. The minimum and maximum value limits of the independent variables are as shown in table below.

Table 3.1a: Single Phase
Minimum and maximum limits of independent variables

	Values (m)	
	min	max
D	9.02	9.6
W_{st}	0.51	0.59
d_{ss}	1.60	1.70
W_{rt}	0.52	0.57
d_{rs}	1.60	1.70
d_{sc}	2.0	2.9
d_{rc}	2.27	2.35
L	13	13.4
D_o	17.0	17.8

3.1. Development of Objective Functions

The following objective functions will be developed for the optimal design of an induction motor.

1) Efficiency of motor η

Formulation of Efficiency

The efficiency η of a machine is given as,

$$\eta = \frac{P_{out}}{P_{out} + P_{cu} + P_{sfe}} \quad 3.15$$

The overall copper losses P_{cu} occurring in the stator and rotor slots of a single phase induction motor is given as

$$P_{cu} = R_{cu}\left(\frac{J_s I N_m \sum_{k=1}^{k} \frac{(3.4(D+d_{ss})(C_s-h)+2L)N_{mk}}{S_s}}{\sum_{k=1}^{k} N_{mk}} + \frac{8}{S_r}(N_s k_w I)^2\left(\frac{L}{A_b}K_r + \frac{l_{er}}{2A_{er}\sin\left(\frac{2\pi p}{S_r}\right)}\right)\right)$$

3.16

Therefore the efficiency of a single phase induction motor is given as,

$$\eta = \frac{P_{out}}{P_{out}+R_{cu}\left(\frac{J_s I N_m \sum_{k=1}^{k} \frac{(3.4(D+d_{ss})(C_s-h)+2L)N_{mk}}{S_s}}{\sum_{k=1}^{k} N_{mk}} + \frac{8}{S_r}(N_s k_w I)^2\left(\frac{L}{A_b}K_r + \frac{l_{er}}{2A_{er}\sin\left(\frac{2\pi p}{S_r}\right)}\right)\right)\cdots}$$

$$+R_{fe}\left(s_s W_{st} L d_{ss} k_1 f^{k_2} B_{st}^{k_3} + \frac{\pi}{4}\left(D_0{}^2-(D_0-2d_{sc})^2\right) L k_1 B_{sc}^{k_3} f^{k_2}\right)$$

3.17

Development of an Induction Motor Optimum Design and Analysis Tool (IMODAT)

The IMODAT accommodates both the conventional and optimal method of induction motor design. It allows input rated data, design data, data processing and results visualization.

A GUI is a graphical display in one or more windows containing controls called components that enable a user to perform interactive task. GUI components can include menus, toolbars, push buttons, radio buttons, list boxes and sliders- just to name a few. GUI created using Matlab tools can also perform any type of computations, read and write data files, communicate with other UIs and display data as tables or as plots

Fig.3.4 (b): GUI for outputting single phase conventional results.

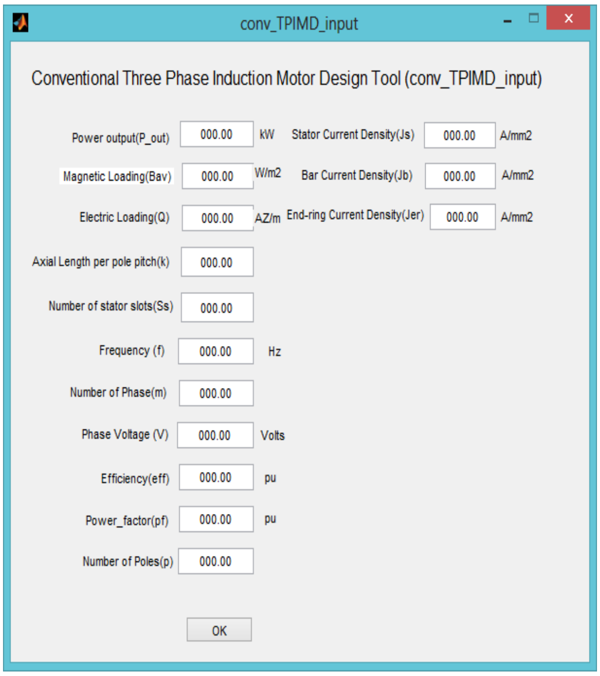

Fig. 3.5 (a): GUI for inputting conventional three phase design data

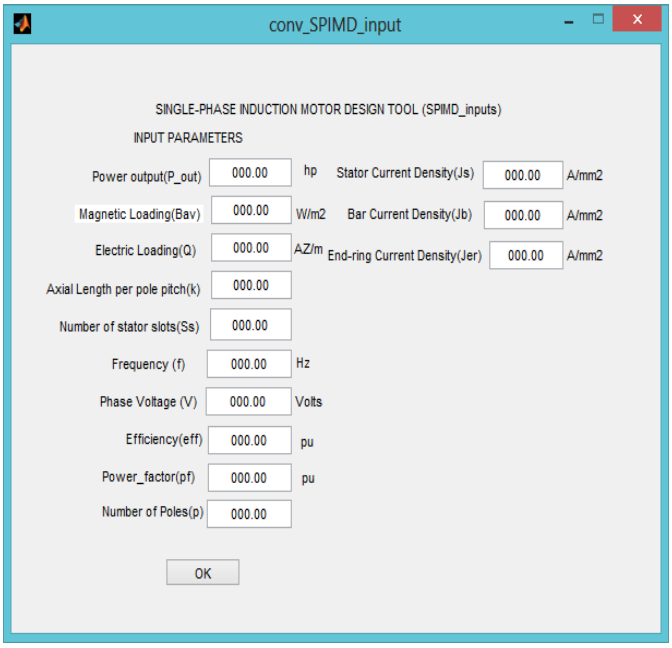

Fig. 3.4 (a): GUI for inputting conventional single phase design data

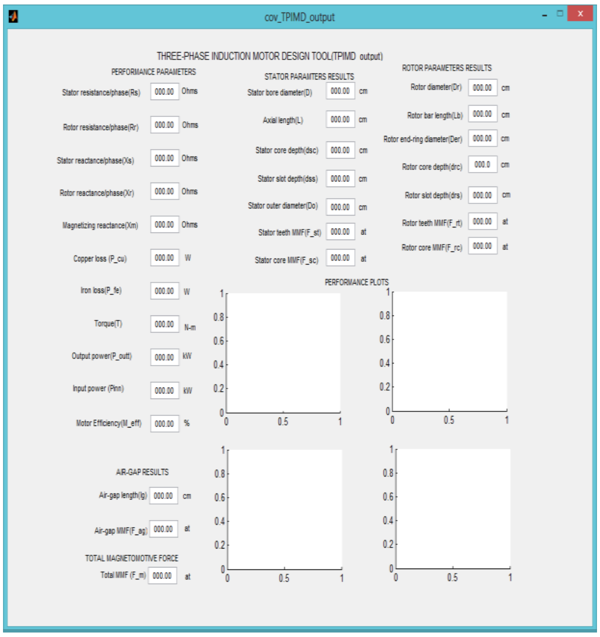

Fig. 3.5 (b): GUI for outputting three phase conventional results.

Result

Table 4.55:Compararison of optimized 1 hp single phase induction motor using efficiency as an objective function with conventional design

Design Variables	Conventional Method	GA	PSO	SA	FA
$D\ (cm)$	9.430	9.477	9.30	9.44	9.437
$wst(cm)$	0.550	0.559	0.552	0.544	0.542
$wrt(cm)$	0.540	0.536	0.555	0.536	0.525
$d_{ss}(cm)$	1.650	1.698	1.607	1.600	1.643
$d_{rs}(cm)$	1.650	1.700	1.676	1.690	1.658
$d_{sc}(cm)$	2.420	2.059	2.339	2.251	2.409
$d_{rc}(cm)$	2.300	2.27	2.299	2.321	2.328
$L(cm)$	13.330	13.286	13.392	13.380	13.029
$D_o(cm)$	17.580	17.00	17.115	17.33	17.548
$Weight\ (kg)$	9.562	7.585	8.764	8.910	8.922
$Losses(Watt)$	94.24	9.645	61.237	62.700	60.959
$Efficiency\ (\%)$	78	97.135	92.005	92.11	92.008
$power\ factor$	0.78	0.795	0.793	0.797	0.801

Table 4.55 is used in comparing the sizing variables obtained from the conventional design method with those obtained from the four algorithms used in terms of efficiency as the objective function.

From table 4.55, the stator and rotor sizing variables have similar values, but comparing their efficiency, the optimization algorithms improve the efficiency in the order of 19.7%, 15.2%, 15.3% and 15.22% for GA, PSO, SA and FA respectively. Comparing in terms of losses there is a loss reduction of 35.02%, 35.02%, 33.47% and 35.3% for GA, PSO, SA and FA respectively. There is also a reduction of weight by 18.3%, 5.6%, 5.3% and 3.1% and an improvement of power factor by 1.8%, 1.6%, 2.1% and 2.68% for GA, PSO, SA and FA respectively.

Conclusion

This means that for the choice of algorithm in terms of efficiency as an objective function GA is preferred. The most performed algorithm is the GA.

Table 4.56: Single Phase Induction Motor Performance Index comparison of the optimization algorithm in terms efficiency as objective function

	GA	PSO	SA	FA
$Efficiency\ (\%)$	19.7%	15.2%	15.3%	15.22%

Reference

[1] Split Phase SPIM Characteristics Optimization using PSO Algorithm M.A.Taghikhani Department of Engineering, Imam Khomeini International University, Qazvin, Iran taghikhani@ikiu.ac.ir
[2] OPTIMUM DESIGN OF MULTIPLE WINDING INDUCTION MOTOR
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[3] Boyd, S and etal (2007) "A tutorial on geometric programming" Optim Eng (2007) 8:67-127
[4] Boyd, S and Vandenberghe, L (2004) "Convex Optimization" Cambridge University Press.
[5] C. Close, D. Frederick, J. Newell. "Modeling and Analysis of Dynamic Systems", John Wiley and Sons, Inc., 3rd ed, 2002
[6] C. T. Kelley. Iterative Methods for Linear and Nonlinear Equations, volume 16 of Frontiers in Applied Mathematics. SIAM, Philadelphia, PA, _rst edition, 1995.
[7] C. T. Kelley. Iterative Methods for Optimization. Frontiers in Applied Mathematics. SIAM,Philadelphia, PA, _rst edition, 1999
[8] C.D. Perttunen D.R. Jones and B.E. Stuckman. Lipschitzian optimization without the lipschitz constant. Journal of Optimization Theory and Application, 79(1):157181, October 1993.