PARAMETER ESTIMATION OF INDUCTION MOTORS BY PSO ALGORITHM

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ABSTRACT*— After the emergence of alternative current networks and their popularity, asynchronous motors became more widespread than other kinds of industrial motors. In order to control and run these motors efficiently, an accurate estimation of motor parameters is needed. There are different methods to obtain these parameters such as rotor locked test, no load test, DC test, analytical methods, and so on. The most common drawback of these methods is their inaccuracy in the estimation of some motor parameters. In order to remove this concern, a novel method for parameter estimation of induction motors using particle swarm optimization (PSO) algorithm is proposed. In the proposed method, transient state of motor is used for parameter estimation. Comparison of the simulation results pertained to the PSO algorithm with other available methods justifies the effectiveness of the proposed method.*

Keywords— Induction motor, Motor parameter estimation, Algorithm

NOMENCLATURE

B Depreciation coefficient.

C1, ***C2*** Constants in range of 1.4-2.

Error Sum of square of errors which made by voltage by voltage and current measurement.

I Induction motor's current.

Is Induction motor's simulated current.

J Inertia constant of induction motor.

Llf Rotor leakage inductance of induction motor.

Lm Magnetizing inductance.

Lls Stator leakage inductance of induction motor.

N Induction motor's measured speed.

Ns Induction motor's simulated speed.

Pid(t) Best answer of ***i***th particle in ***t***th trial.

Pgd(t) Best answer between all particles till ***t***th trial.

Rlf Rotor resistance of induction motor.

Rls Stator resistance of induction motor.

Rm Magnetizing resistance.

V Induction motor's applied voltage.

Vid(t) Velocity of ***i***th particle in ***t***th trial.

Xid(t) Center of ***i***th particle in ***t***th trial.

Φ1, Φ2 Random coefficients in range of 0-1.

ω Velocity weight factor which is usually between 0.4 and 0.9.

1. INTRODUCTION

AN effective analysis of induction motors needs accurate estimation of motor parameters. As an instance, in order to apply speed control to an induction motor, an accurate calculation of its parameters is needed [1]. Although parameters of induction motors can be obtained by rotor locked test, no load test and DC test, but these tests are not accurate enough for some applications such as speed control. So, in this paper, a novel method using PSO algorithm is proposed to obtain these parameters. PSO works by 'flying' a population of co-operating potential solutions called particles through a problem's solution space [2]. As mentioned, motor parameters such as ***Rls, Lls, Rlr, Llr*** and ***Lm*** can be obtained by rotor locked, no load and DC tests. In order to gain B and J by analytical methods we need to calculate the time in which motor reaches its steady-state, so it has low accuracy. Natural algorithms are based on natural mechanisms, namely: neural networks, genetic algorithm [3], ant algorithm and particle swarm optimization (PSO) algorithm. Inventive algorithms have a lot of applications and pervasively used in mathematical calculations. In this work, parameter estimation of motor is done using PSO algorithm and the obtained results are compared with those of available methods.

The rest of paper is organized as follows: Section II inspects PSO algorithm and gives its performance flowchart. Section III shows calculation process of PSO. In Section IV, the proposed method is implemented on a typical system. Advantages and disadvantages of traditional methods and proposed method are discussed in section V. Section VI closes the paper providing some concluding remarks.

I. PSO ALGORITHM

Figure 1 shows one phase of induction motor's equivalent circuit. For convince, the magnetizing resistance (***Rm***) is ignored in calculations.

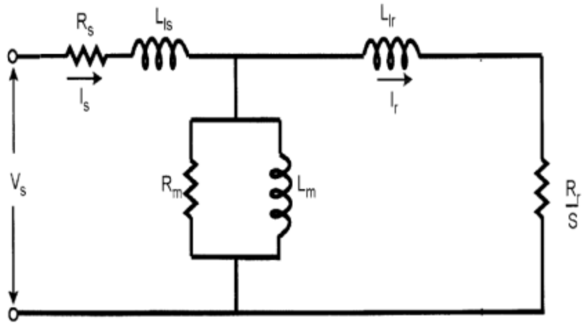

Fig. 1. Equivalent circuit of an induction motor

PSO algorithm is an optimization method based on probability which has been proposed in 1995 by Kennedy and Eberhart inspired by birds when seeking for food [4]. PSO has a flexible and well-balanced mechanism to enhance and adapt to the global and local exploration and exploitation abilities within a short calculation time [5]. In this algorithm, firstly, a set of preliminary answers is generated, then synchronizing of generations is made to find the optimal answer. Each element is defined multi-dimensional by ***Xid(t)*** and ***Vid(t)*** values which are the position and velocity of particles, respectively. The best answer for each particle and all particles are determined then [6].

As the first step of procedure, preliminary values of parameters is generated randomly. Then in each trial, a set of answers is made by previous optimal values. This process is continued until a constant value is obtained for each answer [7]. The canonical particle swarm algorithm is a new approach which is proposed for furthermore optimization programs drawing inspiration from group behavior and the establishment of social norms [8] and would lead to better estimated parameters. Equations (1) and (2) show how the answer is optimized.

$$X_{id}(t+1) = X_{id}(t) + V_{id}(t+1) \quad (1)$$

$$V_{id}(t+1) = \{\omega V_{id}(t) + c_1\phi_1[\rho_{id}(t) - X_{id}(t)] + c_2\phi_2[(\rho_{gd}(t) - X_{id}(t)]\} \quad (2)$$

The PSO flowchart is presented in figure2.

II. CALCULATION PROCESS IN PSO

A. Induction motor simulation

Through state equations, current and speed of induction motor is simulated. Equations are calculated by Rung Kutta method.

B. Current and speed measurement

Voltage and current of an induction motor are obtained by hall sensor in starting time of motor and the speed measurement is done by tachometer. Note that measurement devices must be accurate enough to have a good and accurate simulation.

C. Parameter estimation with sum of square of errors

Figure 2 shows how parameters of an induction motor are calculated. In the first step; voltage, current and speed of motor are measured and are applied to the motor model. Then, current and speed of motor are simulated by applying preliminary parameters and the measured voltage. In this step, the real current and speed of motor are compared with simulated current and speed. This comparison is shown with sum of square of errors.

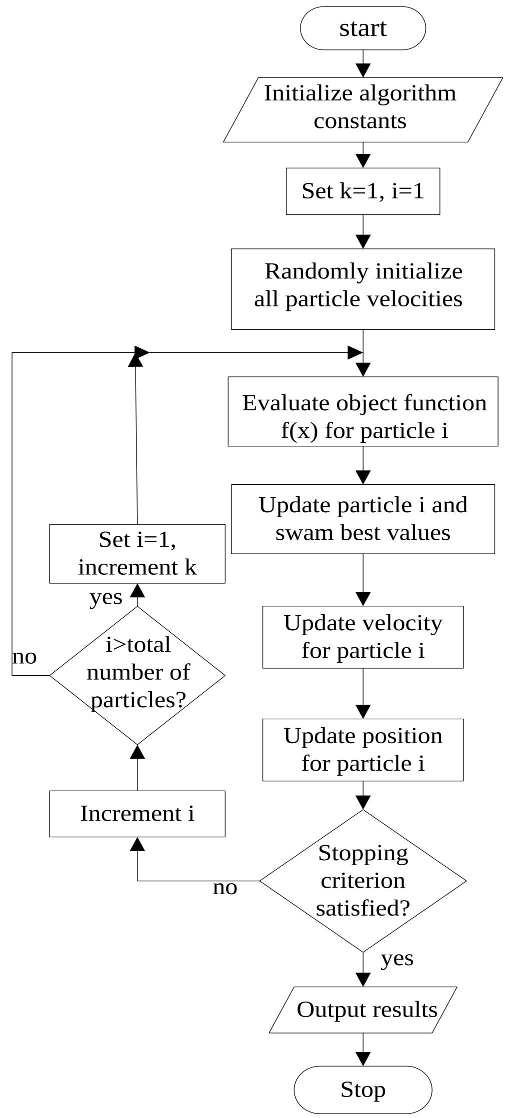

Fig. 2. Flowchart of PSO algorithm

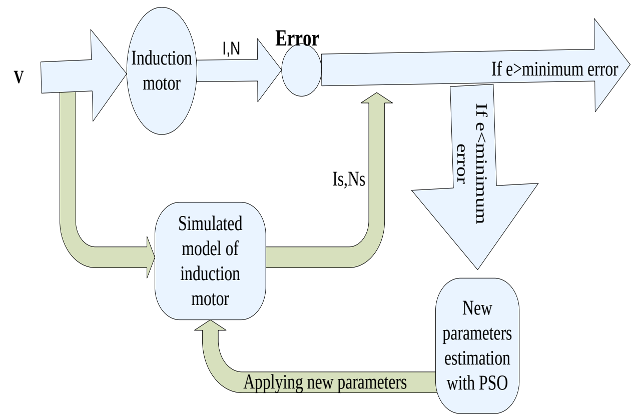

Fig. 3. Process of parameter estimation by PSO algorithm

According to some of square of errors and calculations done by algorithm, new results are applied to the system. This process continues until sum of square of errors reaches its minimum value and optimal answer emerges.

The simulations of this work are done by MATLAB software. The speed is measured by tachometer and the current is recorded with digital oscilloscope.

III. CASE STUDY

To illustrate the effectiveness of the proposed method, the parameters of a given induction motor is obtained by the method and compared with real values. Firstly, parameters of the motor was calculated by rotor locked, no load and DC tests in a standard electrical machine laboratory. Then, these parameters were estimated by PSO algorithm using the performance data of starting and steady-state time of the motor. Table 1 lists some motor operation data.

Table 1. Motor Operation Data

P = 375 (w)	V_L = 380 (v)
f = 50 (Hz)	Star connection

A. Comparison between real diagram with simulated diagram of speed and current

In this section, the motor current and speed are simulated by estimated parameters through PSO algorithm.

Algorithmic calculation process is illustrated by convergence of the parameters in sequenced trials. These trials continue until sum of square of errors reaches its minimum value.

Here, in 200th trial, this value has been minimized and the motor parameters are estimated.

As the minimum error obtained in 200th trial, current and speed diagrams in 200th trial is illustrated in Figures 4 and 5.

The obtained results for motor parameters in these trial is also outlined in Table 3.

In order to compare the obtained results of PSO algorithm with those of traditional methods (no load test and ...), Table 2 illustrates these results.

Sum of square of errors of speed and current in both methods shows that the proposed method has lower error than traditional one.

Figures 6-7 show current and speed Diagram of simulated and real in traditional method.

The obtained results for motor parameters in traditional method is also outlined in Table 4.

A comparison between Figures 4-5 and Figures 6-7 shows the supremacy of the proposed method against the traditional one.

Table 2. Case Study Results

PSO Method	Traditional Method
J = 0.0018 (Kg.m^2)	J = 0.0013 (Kg.m^2)
B = 0 .00001(N.m.s)	B = 0.003 (N.m.s)
L_m = 0.9581 (H)	L_m = 0.8467 (H)
R_{ls} = 23.05 (ohm)	R_{ls} = 20.6 (ohm)
L_{ls} = 0.0714 (H)	L_{ls} = 0.0814 (H)
R_{lr} = 23.43 (ohm)	R_{lr} = 19.15 (ohm)
L_{lr} = 0.0823 (H)	L_{lr} = 0.0814 (H)
Error=0.165	Error=0.207

IV. ADVANTAGES AND DISADVANTAGES OF DIFFERENT METHODS

A. Disadvantages of rotor locked test, no load test and DC test

a) Parameter estimation has low accuracy in these tests, especially when estimating J and B.

b) Rotor locked test of high power motors are rather hard.

c) In order to apply no load and rotor locked test, motor cannot be in the operation condition

B. Advantages of rotor locked, no load and DC tests

a) These tests can be done by some simple devices like voltmeter, ampere meter and wattmeter.

b) These tests do not need to examine the transient state of motor.

C. Disadvantage of PSO algorithm

An accurate device is needed to record the transient state of motor.

D. Advantages of PSO algorithm

a) It doesn't need to run the motor out of operational condition.

b) If the motor is under load during the test conditions, the motor torque can be calculated, too.

c) Parameter estimation of this method is accurate.

Table 3. Motor Estimated Parameters in 200th trial of pso algorithm

L_{ls} = 0.0714 (H)	J = 0.0018 (Kg.m^2)
R_{lr} = 23.43 (ohm)	B = 0 .00001(N.m.s)
L_{lr} = 0.0823 (H)	L_m = 0.9581 (H)
Error=0.165	R_{ls} = 23.05 (ohm)

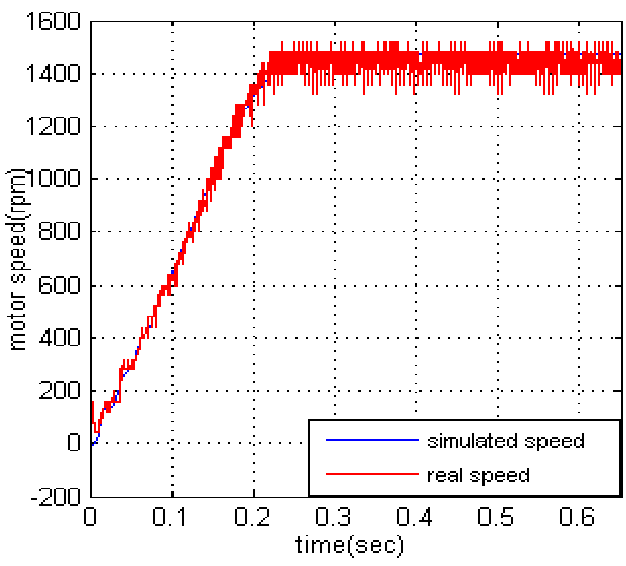

Fig. 4. Diagram of simulated and real speed in 200th trial

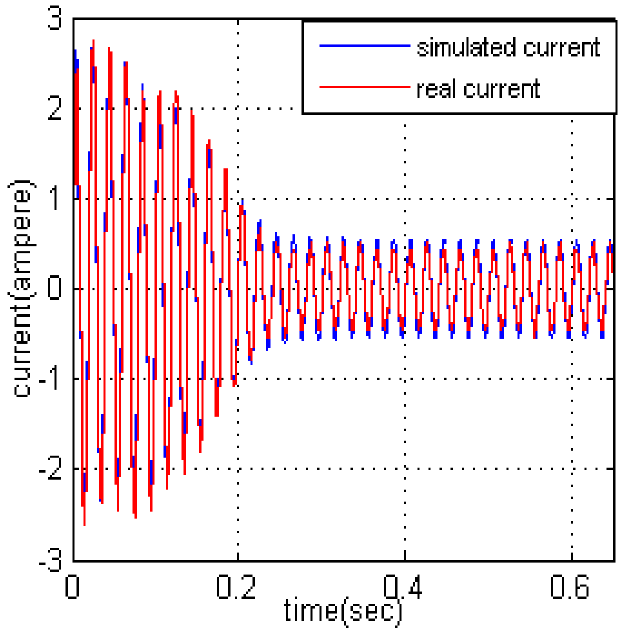

Fig. 5. Diagram of simulated and real current in 200th trial

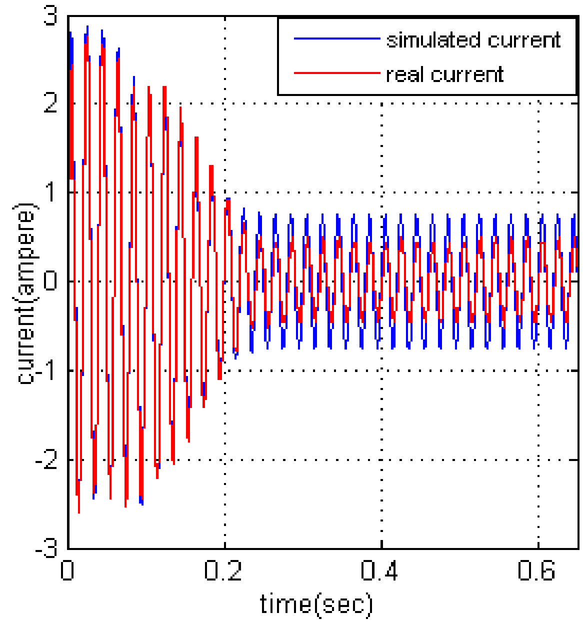

Fig. 7. Diagram of simulated and real current in traditional tests

Table 4. traditional tests (no load, rotor locked, and dc test)

L_{ls} = 0.0814 (H)	J = 0.0013 (Kg.m^2)
R_{lr} = 19.15 (ohm)	B = 0.003 (N.m.s)
L_{lr} = 0.0814 (H)	L_m = 0.8467 (H)
Error=0.207	R_{ls} = 20.6 (ohm)

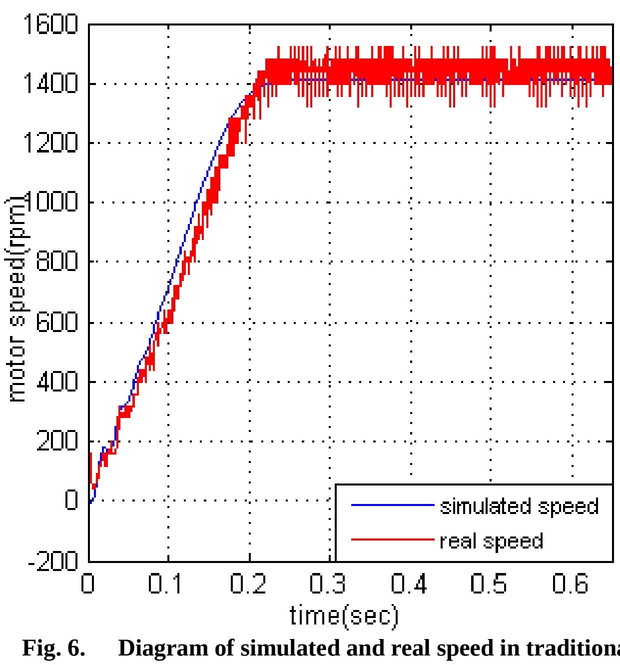

Fig. 6. Diagram of simulated and real speed in traditional tests

V. CONCLUSION

The main purpose of this paper was to estimate parameters of a given induction motor by an innovative PSO algorithm. As an instance, the inertia constant J is hard to obtain with traditional and analytical methods, so some high accuracy devices are needed in these tests. The inertia constant J is hard to obtain if motor has low power and inertia. Using PSO algorithm and also current and speed sampling at starting time, a good parameter estimation was obtained. Comparison between simulated current and speed with those of real ones, shows the advantage of the proposed method rather than traditional one.

ACKNOWLEDGMENT

Authors gratefully acknowledge contribution of Dr. S.H. Shahalami and Dr. E. Fallah in this project.

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