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OPTIMUM TUNING OF PI CONTROLLER PARAMETER FOR SPEED CONTROL OF INDUCTION MOTOR

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Abstract

Industrial processes are depending on the variation different parameters, which majorly makes the system unstable. In order to overcome this problem of parameter variation in the system process the PI controllers are widely used in industrial plants because it is simple and robust. For the smooth operation of the industrial process optimum tuning of the PI parameters is needed. So the control engineers are on look for automatic tuning procedures. In recent years, many intelligence algorithms are proposed to tuning the PI parameters. This work proposed a new Particle swarm optimization (PSO) technique to determine the optimal proportional-integral (PI) controller parameters, for speed control of a field controlled induction motor.

Key words:- Induction motor, Particle swarm optimization, Inertia weight improved PSO, PI controller.

1. Introduction:

Induction motors are the most widely used electrical motors due to their reliability, low cost and robustness. However, induction motors do not inherently have the capability of variable speed operation. Due to this reason, earlier dc motors were applied in most of the electrical drives. But the recent developments in speed control methods of the induction motor have led to their large scale use in almost all electrical drives.

Induction motors have been widely used in various industries as actuators or drivers to produce mechanical motions and forces. The induction motor, which is the most widely used motor type in the industry, has been favored because of its good self-starting capability, simple and rugged structure, low cost and reliability. Since it is estimated that more than 50% of the world electric energy is generated and consumed by electric machines, to improve efficiency of electric drives are important [1-2]. Generally, induction motors require both wide operating range of speed and fast torque response in operational conditions, regardless of load variations. Namely, induction motors have a high efficiency at rated speed and torque. Used in adjustable speed drive systems. Induction motors have been widely used in various industries as actuators or drivers to produce mechanical motions and forces.

Induction motors play a vital role in the industrial sector especially in the field of electric drives and control. Without proper controlling of the speed, it is impossible to achieve the desired task for a specific application. Since induction motors are manufactured in different sizes and for a variety of applications, a challenge for the variable speed drives industry is to develop efficient yet versatile control algorithms [3]. The strategies of controlling induction motors can be divided into two groups: the first one is scalar control that uses voltage and frequency of machine's supply in order to adjust rotor speed. The second method is vector control of motor variables transformed into an orthogonal set of d–q axes such that speed and torque can be separately controlled. Often, vector control is preferred because of fast and accurate response, quick recovery from any disturbances, and insensitivity to parameter variations [4].

Its efficient control requires a convenient model with accurate parameters. In order to achieve the control objectives, there are some approaches were presented in the resent years. Conventional control makes use of the mathematical model for the controlling of the system. When there are system parametric variations or environmental disturbance, behavior of system is not satisfactory and deviates from the desired performance [10]. The classical control is used in majority of the electrical motor drives. To obtain the exact mathematic model of the system, one has to do some identification techniques such as the system identification and obtain the plant model. Moreover, the design and tuning of conventional controller increases the implementation cost and adds additional complexity in the control system and thus, may reduce the reliability of the control system.

There are a number of significant control methods available for induction motors including scalar control, vector or field-oriented control, direct torque and flux control, sliding mode control, and the adaptive control. The artificial intelligent approaches are widely used in control goals, such as authors of [5] proposed the PSO technique for the optimal solution of PI fed induction motor. Article [6] proposed the application of Hybrid Particle Swarm Optimization (HPSO) for losses and operating cost minimization control in the induction motor drives. The main advantages of the proposed technique are; it's simple structure and its straightforward maximization of induction motor efficiency and its operating cost for a given load torque. A nonlinear adaptive controller is proposed for speed and torque control [7] of induction motors with unknown rotor resistance.

A novel hybrid [8] solution for the LCI based induction motor drive using a parallel assembly of an LCI and a voltage source inverter (VSI), is proposed. The operation of the proposed circuit is investigated and described. It is shown that all problems caused by the output capacitors and the dc-commutation circuit in the conventional LCI-based induction motor system can be overcome by the proposed solution. Article [9] deals with robust estimation of rotor flux and speed for sensor less control of motion control systems with an induction motor. Instead of using sixth-order extended Kalman filters (EKFs), rotor flux is estimated by means of a fourth-order descriptor-type robust KF, which explicitly takes into account motor parameter uncertainties, whereas the speed is estimated using a recursive least squares algorithm starting from the knowledge of the rotor flux itself.

The major objective of this work is to find out effective value of the PI controller using PSO for the speed control of a direct field oriented Control Induction motor drive for a simple speed demand problem as well as for a complex speed problem. Here PSO have been applied to search for the optimal PI controller parameters of FOC IM drive. The error criteria for both the methods are set to improve transient error and steady state error. Hence the fitness function is taken here are Integral Square Error (ISE), Integral Absolute Error (IAE) and Integral Time Square Error (ITSE) [6,8,14]. The performance of optimization techniques in terms of convergence rate, error minimization and time complexity are compared with other methods listed in the literature.

2. Circuit arrangement of Induction Motor

An, induction motor model to predict the voltage required achieving a desired output torque is given in Fig.1.shows the power circuit of the 3-phase induction motor connection.

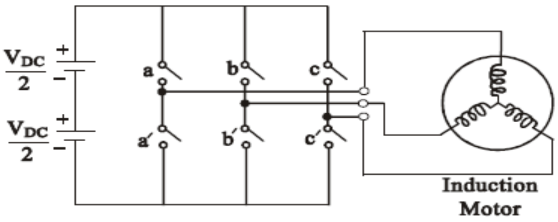


Fig. 1. Power circuit connection diagram for the IM

3. Optimization Technique

A. Particle Swarm Optimization

Natural creatures typically behave as a swarm. One among the most streams of artificial life researches is to look at however natural creatures behave as a swarm and reconfigure the swarm models within a computer. Swarm behavior will be sculptured with a number of straightforward rules. Fish schooling and swarm of birds will be sculptured with such straightforward models. Consistent with the analysis results for a flock of birds, birds find food by flocking (not by every individual). The observation leads the idea that every one info is shared within flocking. PSO is largely developed through simulation of bird flocking in two-dimension space).

3.1 Representation of the swarm for problem

If there are n- solutions, the particle position is represented as a vector of length.

$$S_i = (P_{i1}, P_{i2}, \dots\dots\dots P_{in}) \qquad (1)$$

Where, S_i is the position vector.

3.2 Initialization of the Swarm

Each element of the swarm is initialized randomly within the effective operating limits. The particles are initialized as follows as given in eq. (2) and the velocity of particles initialized as given in eq. (3)

$$P_{initial} = P_{min} + rand * (P_{max} - P_{min}) \qquad (2)$$

$$V_{initial} = V_{min} + rand * (V_{max} - V_{min}) \qquad (3)$$

Where, rand is a random positive number between 0-1.

$$V_{max} = (P_{max} - P_{min}) * 0.5 \qquad (4)$$

$$V_{min} = -V_{max} \qquad (5)$$

3.3 Moving the particles

The particles in the swarm are moved to new positions with the help of new velocities. The velocity and the position of the k^{th} dimension of the i^{th} particle are updated as follows

$$V^{k+1} = W\,V^k + c_1 Rand_1 \times \left(P_{best} - S^k\right) + c_2 Rand_2 \times \left(g_{best} - S^k\right) \qquad (6)$$

$$S^{k+1} = S^k + V^{k+1} \qquad (7)$$

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} \times iter \qquad (8)$$

Where, pbest = (pbest ,pbest ,....pbest) is the best previous position yielding the best fitness value for the i^{th} particle; and gbest = (gbest ,gbest ,....gbest) is the best position discovered by the whole population. c_1 and c_2 are the acceleration constants reflecting the weighting of stochastic acceleration terms that pull each particle toward p_{best} and gbest positions, respectively. $rand_1$ and $rand_2$ are two random numbers in the range [0, 1].

B. IWIPSO (Inertia Weight Improved PSO)

In this section, for getting the better global solution, the traditional PSO algorithm is improved by adjusting the weight parameter, cognitive and social factors. Based on (8), the velocity of individual i of IWIPSO algorithm is rewritten as

$$V_i^{(K+1)} = w_{new} V_i^K + c_1 Rand_1 \times \left(Pbest_i - S_i^K\right) + c_2 Rand_2 \times \left(gbest - S_i^K\right) \qquad (9)$$

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} \times iter \qquad (10)$$

$$w_{new} = w_{min} + w \times rand_3 \qquad (11)$$

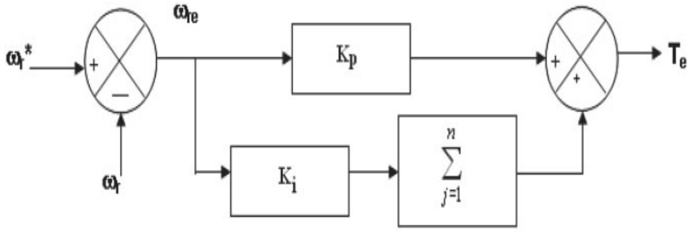
$$c_1 = c_{1max} - \frac{c_{1max} - c_{1min}}{iter_{max}} \times iter \qquad (12)$$

$$c_2 = c_{2max} - \frac{c_{2max} - c_{2min}}{iter_{max}} \times iter \qquad (13)$$

Where, w_{min}, w_{max}: initial and final weight, c_{1min}, c_{1max}: initial and final cognitive factors and c_{2min}, c_{2max}: initial and final social factors.

4. PROPOSED METHOD

In this work we used PI controller for optimal regulation of rotor speed at the desire speed. The general structure of the PI controller. The general block diagram of the PI speed controller is shown in Figure 2. The output of the speed controller (torque command) at n-th instant is expressed as follows:



$$T_{e(n)} = T_{e(n-1)} + k_p \Delta\omega_{re(n)} + k_i \Delta\omega_{re(n)} \qquad (14)$$

Input can be define as

$$u(t) = k_p * e(t) + k_i \int e(t)\, dt \qquad (15)$$

That K_i and K_p are proportional and integral coefficient in PI controller.

Proportional integral (PI) controller can be used to control the speed of IM. The PI controller is normally avoided because differentiation can be problematic when input command is a step. Generally, the speed error, which is the difference of reference speed ($\omega_r(n)$) and actual speed ($\omega_a(n)$), is given as input to the controllers. These speed controllers process the speed error and give torque value as an input. Then the torque value is fed to the limiter, which gives the final value of reference torque. The speed error and change in speed error at n-th instant of time are given as

$$\omega_{re(n)} = \omega_{r(n)} - \omega_{a(n)} \qquad (16)$$

$$\Delta\omega_{re(n)} = \omega_{r(n)} - \omega_{a(n-1)} \qquad (17)$$

In PI controller design methods, the most common performance criteria are integrated absolute error (IAE), the integrated of time weight square error (ITSE), integrated of squared error (ISE) and integrated of time weight absolute error (ITAE) that can be evaluated analytically in the frequency domain[11, 13]. These four integral performance criteria in the frequency domain have their own advantage and disadvantages. For example, disadvantage of the IAE and ISE criteria is that its minimization can result in a response with relatively small overshoot but a long settling time because the ISE performance criterion weights all errors equally independent of time. Although the ITSE performance criterion can overcome the disadvantage of the ISE criterion, the derivation processes of the analytical formula are complex and time-consuming [11,12]. The IAE, ISE, ITAE and ITSE performance criterion formulas are as follows:

$$IAE = \int_0^{\infty} t\, dt \qquad (18)$$

$$ISE = \int_0^{T} (e\hat{}2)\ dt \qquad (19)$$

$$ITAE = \int_0^{T} t(e)\ dt \qquad (20)$$

$$ITSE = \int_0^{T} t(e\hat{}2)\ dt \qquad (21)$$

5. Results and Analysis

The proposed PSO technique is run on Matlab 7.5. For obtaining the optimum solution of the proposed PI controller, P and I coefficients are considered for controller as two dimensions of PSO algorithm and for high accuracy and achieving almost precise adjustments to conduct the PSO algorithm. Kp is taken [0 100] and Ki considered [0 8] [5]The simulation results have been obtained with 50 runs while considering the followings parameters .

Table-I

Number of particles	20
Wmin	0.4
Wmax	0.9
No. of iteration	50

The objective characteristic of PSO is obtain as shown in fig.3

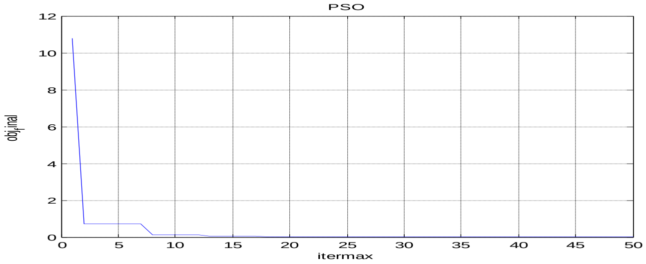


Fig. 3 Characteristic of PSO

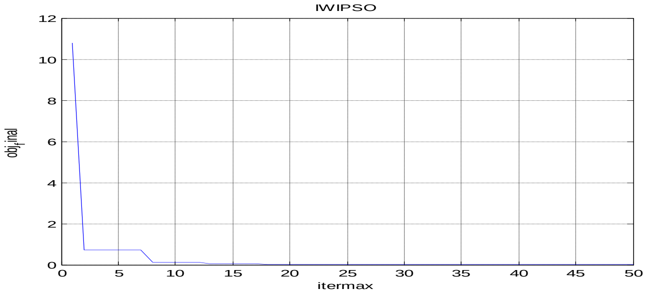


Fig. 4 Characteristic of IWIPSO

We obtained Optimum solution of K_p = 87.8184 and K_i= 6.7318 using IWIPSO.

Table-II

	PSO	WIPSO
	No. of particles 20	No. of particles 20
K_p	88.0184	87.8184
K_i	6.9818	6.7318

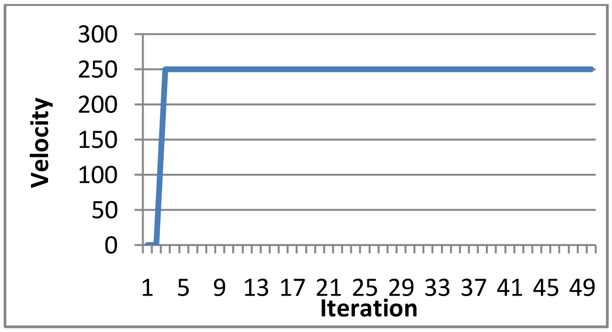


Fig. 5 Speed Characteristic with iteration

6. Conclusions

In this paper, we have obtained optimum solution of the proposed PI controller parameter using PSO and IWIPSO technique. Simulation results for this optimized controller show that in different speed references and for different loads, speed can follows its reference values without any overshoot at minimum time. According simulation results, IWIPSO is a Powerful algorithm to approximate the PI controller coefficient.

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