Available online at www.sciencedirect.com

SciVerse ScienceDirect

Physics Procedia 25 (2012) 2109 – 2115

Physics Procedia

2012 International Conference on Solid State Devices and Materials Science

# A Fast Induction Motor Speed Estimation based on Hybrid Particle Swarm Optimization (HPSO)

Solly Aryza[1], Ahmed N Abdallah[1], Zulkeflee bin Khalidin[1], Zulkarnain Lubis[2], Ma Jie[1]

*1Faculty Electrical Engineering, University Malaysia Pahang, Pekan 26600, Pahang, Malaysia*

*2Faculty Electrical Engineering, Kolej University TATI, Kemaman 24000, Terenggano, Malaysia*

**Abstract**

Intelligent control and estimation of power electronic systems by fuzzy logic and neural network techniques with fast torque and flux show tremendous promise in future. This paper 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; its simple structure and its straightforward maximization of induction motor efficiency and its operating cost for a given load torque. As will be demonstrated, Hybrid Particle Swarm Optimization (HPSO) is so efficient in finding the optimum operating machine's flux level. The results demonstrate the good quality and robustness in the system dynamic response and reduction in the steady-state and transient motor ripple torque.


Keyword: Neural network, HPSO, Induction Motor

## 1. Introduction

Induction motors are critical components in industrial processes. A motor failure may yield an unexpected interruption at the industrial plant, with consequences in costs, product quality, commonly 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. 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

 doi:10.1016/j.phpro.2012.03.357

have been widely used in various industries as actuators or drivers to produce mechanical motions and forces. 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.

Its efficient control requires a convenient model with accurate parameters, the minimization of the objective function is carried out using the Particle Swarm Optimization. Particle Swarm Optimization (HPSO) is an evolutionary algorithm inspired by social interaction. Hybrid Particle swarm optimization (HPSO) is an evolutionary computation technique (a search method based on a natural system) developed by Kennedy and Eberhart [20]. The basic concept of the HPSO technique 'lies in accelerating each particle towards its p best and g best locations, with a random weighted acceleration at each time step. HPSO has many parameters and these are described as follow: is called the inertia weight that controls the exploration and exploitation of the search space because it dynamically adjusts velocity. V max is the maximum allowable velocity for the particles (i.e. in the case where the velocity of the particle exceeds Vmax, then it is limited to Vmax [3.5]. Hybrid Particle swarm optimization (HPSO) is one of the modern heuristic algorithms [16-17]. HPSO has attracted great attention due to its features of easy implementation, robustness to control parameters and computation efficiency compared with other existing heuristic algorithms, and has been successfully. Hybrid Particle swarm optimization (HPSO) is an evolutionary computation technique the system initially has a population of random solutions. Each potential solution, called an electromagnetic torque is given by particle. The main steps in the particle swarm optimization process are described as follow [18-19]:

(a) Start a population of particle with random position and velocities in d dimension of the problem space and fly them.

(b) Evaluate the fitness of each particle in the swarm.

(c) For every iteration, compare fitness with its previous best fitness (p best) obtained. If the current value is better than p best location equal to the current value and the p best location equal to the current location in the dimensional space.

(d) Compare p best of particle with one another and update the swarm global best location with the greatest fitness (g best).In this paper, a new minimum-time minimum-loss control algorithm for induction motors using system particle swarm optimization is suggested to obtain high performance, as well as high efficiency, under practical constraints on voltage and current. The validity of the suggested scheme, which carries out minimum-time speed control in the transient state and minimum-loss control in the steady state, will be revealed via simulation, including an induction motor model.

The paper is organized as follow. In Section two, the dynamical model for vector control with nonlinear load is presented. The brief overview induction motor based HPSO in Section three. And finally, simulation results are given in Section four to validate the effectiveness of the proposed controller. Conclusion is outlined in Section five.

## 2. Steady state based HPSO induction motor controller PI

The steady-state characteristics of new designed induction motors or motors of known geometric and material data can be determined with a good accuracy by the finite element method [9-10]. The development of the finite element method and the software related to it enables taking into account both the stator winding voltage supply and motion of the rotor. However the multilevel inverters need more power switch elements and cause more cost and complication to the whole system. Due to the property of a matrix converter, there are more sets of space vectors can be applied to steady state. As a result, the drive systems fed by the matrix converter that needs not any additional power switch element can attain the same performance as the multilevel inverter [12-13].

Figure one shows the general control scheme proposed for the Steady State-based HPSO induction motor matrix converter. In this scheme the two comparators with hysteresis used in the standard steady state configuration to control flux and torque were replaced by HPSO working as equivalent of PI controllers whose output was fed to space vector modulator (SVM)[5],[15]

The HPSO stator flux controller loop provided the input Vx and Vy inputs with the estimated stator flux position and the converter input voltage to modulate the required output voltage vector in the matrix converter.

The proposed system took into account the steady state operating principal and the overall induction motor behavior and used an AI controller that directly performed the motor control functions.

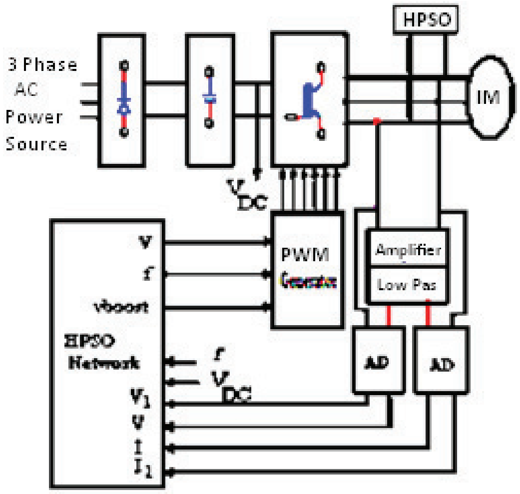


Figure 1.Steady State Based HPSO

Proportional integral (PI) controllers control the speed of IM. The PI and differential (PID) 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 (ωr(n)*) and actual speed (ωr(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 instant of time are given as:

$$\omega_{re\,(n} = \omega^*_{r(n)} - \omega_{r(n)} \quad (1)$$

$$\Delta\omega_{re(n)} = \omega_{re(n)} - \omega_{re(n-1)} \quad (2)$$

$$V_{app}(t) = L\frac{di(t)}{dt} + R.i(t) + V_{emf}(t) \quad (3)$$

$$V_{emf} = K_b.\ \omega(t) \quad (4)$$

$$T(t) = K_t.i(t) \quad (5)$$

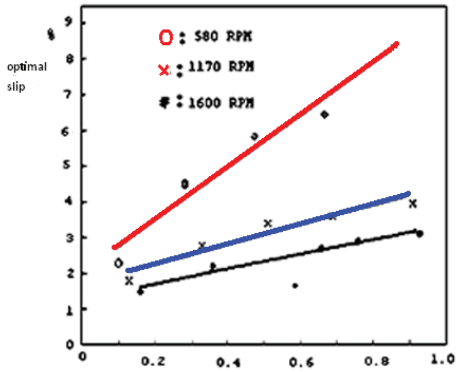


Figure2. Vector diagram showing slip at various speed motor

## 3. Parameter HPSO of induction motor

We think that a magnetic flux axis d is set up on the magnetic flux electric current. In the induction motor vector control, the voltage and ampere equations on the d-q axes are following. The parameters of the motor used for simulation are as follows:

| Parameters | Values and Units |
|---|---|
| $R_r$ | 0.0025ohm |
| $R_s$ | 0.0015 ohm |
| f | 60 Hz |
| $K_b$ | 0.1433 Vs rad-1 |
| V | 120 volt |
| L | 0.052 H |

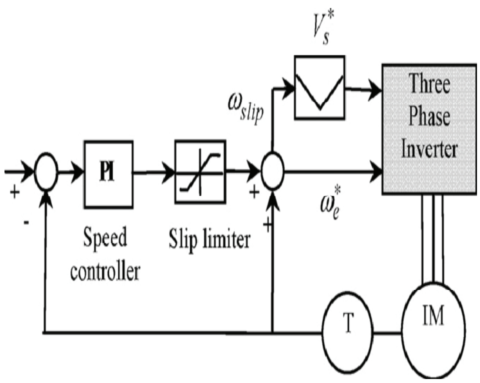


Figure3. Electric Current Vector

Ampere equation:

$$\frac{d}{dt} I_\mu = \frac{R_R}{L_R} I_\mu + \frac{R_R}{L_R} I_{sq} \tag{6}$$

$$\omega_i - \omega_R = \frac{R_R}{L_R} - \frac{I_{sq}}{I_\mu} \tag{7}$$

In this section, the procedure of HPSO in online system parameter identification is described. Here, each particle represents all parameters of estimated model. The proposed algorithm sequentially gives data set by sampling periodically. While starting, in the first period, the best system parameter is found by minimizing the SSE introduced. Here, the simulation for next period does not begin until the fitness of global best becomes lower than a predefined threshold. After that, the estimated parameters will not be updated unless changes in the system parameters are detected to detect any change. In system parameters, the global optimum in the later period is noticed as a sentry particle.

In the beginning of each of the next periods, the sentry reevaluates its fitness and if the fitness changes significantly or it becomes bigger than a predefined threshold, the changes in parameters are confirmed. If no changes are detected, the algorithm leaves this period without changing the positions of particles. In contrast, when any change in parameters occurs, the sentry alerts the swarm to reset their best location memories and then the algorithm runs further to find the new optimum values. For this purpose, the fitness of global optimum particle and personal bests of all particles are evaporated at the rate of a big evaporation constant. As a result, other particles have a chance to find better solutions than those stored on their pervious global and personal memories. Moreover, the velocities of particles are increased to search in a bigger solution space for new best solution.

## 4. Result and discussion

To certify both, steady state and transient behavior of the proposed algorithm some simulation has been carried out. The three phase induction motor has the following parameters: To know everything, I use a range $R_r$ = 0.0025 ohms, $R_s$ = 0.0015 ohms, f = 60Hz, P = 2, V= 120 V, for my induction motor.

A. Steady State

The steady state of stator flux and Electromagnetic

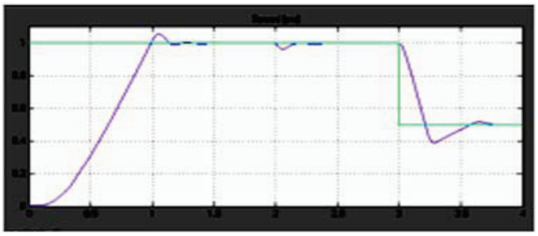

Figure4. Motor speed and reference speed during using HPSO

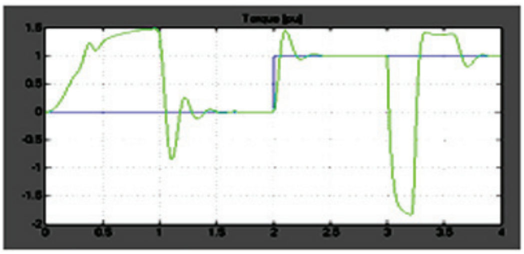


Figure5. Torque from Motor Induction Based HPSO

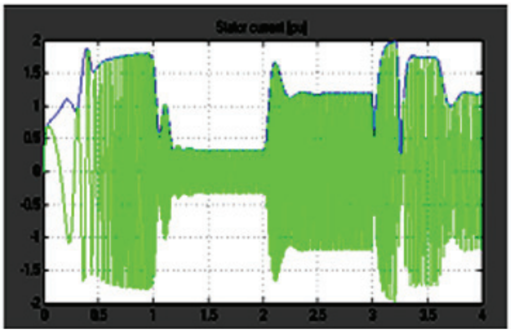


Figure6. Stator Current from HPSO Based Induction Motor

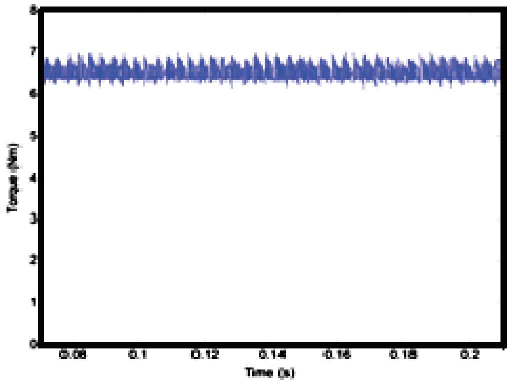


Figure7. Electromagnetic Torque

In the Figure 4, 5, 6, and 7, showed the speed, torque and stator currents of induction motors using system HPSO, where everything is quite stable when compared to using other systems

## 5. Conclusion

The proposed controller in this paper used the information provided by the torque and stator flux errors to modify the standard steady state voltage vector selection process. The voltage vector selected in the new HPSO scheme is the one producing the lowest possible start-up stator current and a reduced torque ripple hence improving the standard steady state scheme performance. Comparing with the DSP serial calculations of the steady state system for matrix converter induction motor, the control precision of steady state can be significantly improved by using the HPSO algorithm.

Another hand, the HPSO induction motor model allows the estimation of important parameters of motor such as speed, stator flux, rotor flux and torque without using the sensors. The results obtained show a good torque response for 0.9 power factor operation.

## Reference

[1] Z.-L. Gaing, A particle swarm optimization approach for optimum design of PID controller in AVR system, IEEE Trans.

Energy Con. 19 (June (2)) (2004) 384–391.

[2] Boeringer, D. W., & Werner, D. H. (2004). Particle swarm optimization versus genetic algorithms for phased array synthesis. IEEE Transactions on Antennas and Propagation (52), 771–779.

[3] O. A .Mohammed, S. Liu and Z. Liu, Phase-variable model of PM synchronous machines for integrated motor drives IEE Proc.-Sci. Meas. Technol., Vol. 151, No. 6, November 2004.

[4] Duane Hanselman, Brushless Permanent Magnet Motor Design, Second ed. Magna Physic Publishing, p.p. 108 and 195, 2003.

[5] C. W. Jiang and B. Etorre, A self-adaptive chaotic particle swarm algorithm for short term hydroelectric system scheduling in deregulated environment. Energy Convers. Manage, vol. 46, no. 17, pp.2689–2696, Oct. 2005.

[6] B. H. Yu, X. H. Yuan, and J. W. Wang, Short-term hydro-thermal scheduling using particle swarm optimization method, Energy Convers. Manage vol. 48, no. 7, pp. 1902–1908, Jul. 2007.

[7] Feng, H. (2006). Hybrid stages particle swarm optimization learning fuzzy modeling systems design. Tamkang Journal of Science and Engineering, 2(9), 167–176.

[8] D.H. Kim, Genetic algorithm combined with particle swarm optimization bacterial foraging and its application to PID controller, Thesis of Tokyo Institute of Technology, Japan, 2006.

[9] M. A. Abido, Optimal power flow using particle swarm optimization, Elect. Power Energy Syst., vol. 24, pp. 563–571, Oct. 2002.

[10] Huang, C., & Wang, M. (2005). A particle swarm optimization to identifying the ARMAX model for short-term load forecasting. IEEE Transactions on Power. Systems, 2(20), 1126–1133.

[11] Q, J Guo, H, B Yu, A, D Xu, A Hybrid PSO-GD Based Intelligent Method for Machine Diagnosis, Digital Signal Processing, 2006, 16,402–418.

[12] Iwasaki, N., & Yasuda, K. (2005). Adaptive particle swarm optimization using velocity feedback. International Journal of Innovative Computing, Information and Control, 3(1), 369–380.

[13] Jun, Z., Xin, F., Huayong, Y., d Z. Jianmin, Z. A particle swarm optimization approach for PID parameters in hydraulic servo control system. In Proceedings of the sixth world congress on intelligent control and automation (pp. 7725– 7729). Dalian, China (2006),

[14] Ke, J., Li, Q., & Qian, J. (2004). Particle swarm optimization based nonlinear observer. In Proceedings of the fifth world congress on intelligent control and automation (pp. 1580–1583). Hangzhou, China.

[15] Kim, D.H., & Cho, J.H. (2005). Optimal learning of fuzzy neural network using particle swarm optimization algorithm. ICCAS2005 June 2–5, KINTEX, Gyeonggi-Do, Korea.

[16] Ojo, 0. Dong, G.; Efficiency optimizing control of induction motor using natural variables. Applied Power Electronics Conference and Exposition, 2004. APEC '04. Nineteenth Annual IEEE Volume 3, 2004 Page(s):1622- 1627 Vol.3.

[17] Shi, Y., Eberhart, R.C., 1999. Empirical study of particle swarm optimization. In: IEEE International Proceedings on Evolutionary Computations. vol. 3, pp. 1945–1946.

[18] Shi, Y., Eberhart, R.C., 1998. A modified particle swarm optimizer. In: IEEE International Conference on Evolutionary Computations, pp. 69–73.

[19] Poli, R., Kennedy, J., Blackwell, T., 2007. Particle swarm optimization an overview. Swarm Intelligence 1, 33–57.

[20] Kennedy, J., Eberhart, R.C., 1995. Particle swarm optimization. In: Proceedings of the IEEE International Conference on Neural Networks, vol. 4, pp. 1942–1948