ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

PARTICLE SWARM OPTIMIZATION BASED DIRECT TORQUE CONTROL (DTC) OF INDUCTION MOTOR

T. Vamsee Kiran[1] and N. Renuka Devi[2]

Associate professor, Dept. of EEE, DVR & Dr. HS MIC College of Technology, Andhra Pradesh, India[1]

PG Student [P.E], Dept. of EEE, DVR & Dr. HS MIC College of Technology, Andhra Pradesh, India[2]

ABSTRACT: This paper presents a new direct torque control (DTC) strategy for induction motor based on particle swarm optimization (PSO). In conventional direct torque controlled (DTC) induction motor drive, there is usually undesired torque and flux ripple. So Tuning PI parameters (K_p, K_i) are essential to DTC system to improve the performance of the system. In this work, particle swarm optimization (PSO) is proposed to adjust the parameters (K_p, K_i) of the speed controller in order to improve the performance of the system, and run the machine at reference speed.

Keywords: Direct torque control, PI controller, particle swarm optimization.

I.INTRODUCTION

AC induction motors are the most common motors used in industrial motion control systems, as well as in domestic applications. Simple and rugged design, low-cost, low maintenance and direct connection to an AC power source are the main advantages of AC induction motors. Controlling the speed of an induction motor is far more difficult than controlling the speed of a DC motor since there is no linear relationship between the motor current and the resulting torque in the case of a DC motor. There are several methods to vary the speed of an induction motor over a wide range. The most modern technique is direct torque control method (DTC). The DTC offers many advantages like fast torque response, no need of coordinate transformation and less dependence on the rotor parameters. The conventional PI (proportional, integral) control method is widely used in motor control system due to the simple control structure and easiness of design. However tuning the parameters of PI controller is a difficult task. To enhance the capabilities of traditional PI parameter tuning techniques, several intelligent approaches have been suggested such as genetic algorithms (GA) and the particle swarm optimization (PSO).

Particle Swarm Optimization (PSO) is one of the modern algorithms used to solve global optimization problems. Thus, to solve an optimization problem, PSO applies a simplified social model. Compared to other methods, application of the PSO is simple to implement, it can quickly find a number of high quality solutions, and has stable convergence characteristics. The PSO method is an excellent optimization methodology and a promising approach for solving the optimal PI controller parameters problem.

II. MATHEMATICAL MODELING OF INDUCTION MOTOR

The induction motor has been modelled by using the following equations.

$$V_{qs} = R_s i_{qs} + \frac{d}{dt}\varphi_{qs} \quad (1)$$

$$V_{ds} = R_s i_{ds} + \frac{d}{dt}\varphi_{ds} \quad (2)$$

$$R_r i_{qr} + \frac{d}{dt}\varphi_{qr} - \omega_r \varphi_{dr} = 0 \quad (3)$$

$$R_r i_{dr} + \frac{d}{dt}\varphi_{dr} + \omega_r \varphi_{qr} = 0 \quad (4)$$

$$T_e = \frac{3}{2}\left(\frac{p}{2}\right)\left(\varphi_{ds} i_{qs} - \varphi_{qs} i_{ds}\right) \quad (5)$$

III.THREE PHASE VOLTAGE SOURCE INVERTER

The power circuit topology of a three-phase VSI is shown in Fig.1. S1 to S6 are the six power switches that shape the output, which are controlled by the switching variables a, a′, b, b′, c and c′.

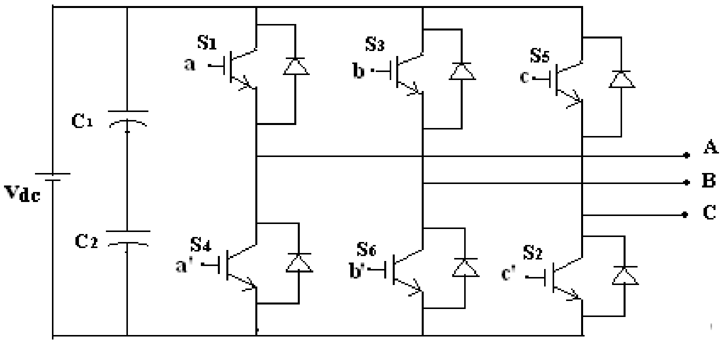

Fig.1 Schematic diagram of two level inverter

When an upper switch is on, i.e., when a, b or c is 1, the corresponding lower transistor is switched off, i.e., the corresponding a′, b′ or c′ is 0. Therefore, the on and off states of the upper switches S_1, S_3 and S_5 can be used to determine the output voltage. The speed and electromagnetic torque of induction motor is controlled by the selection of optimal inverter switching modes.

IV.DIRECT TORQUE CONTROL OF INDUCTION MOTOR

Block diagram of direct torque control of induction motor is shown in fig 2.

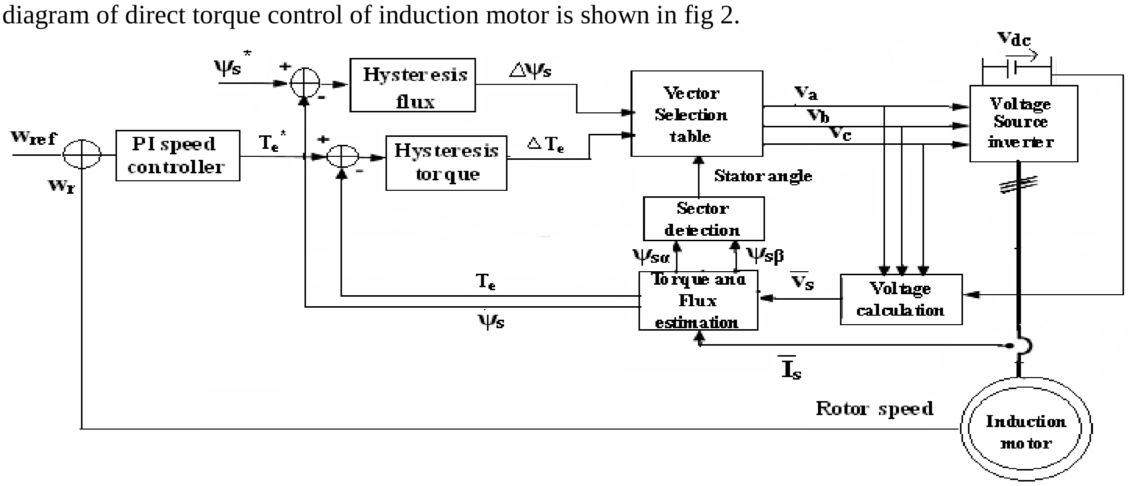

Fig.2 block diagram of IM drive under DTC

Principle of DTC

The electromagnetic torque of 3-phase induction motor is given by,

$$T_e = \frac{3}{2}\left(\frac{p}{2}\right)\frac{L_m}{\sigma L_s L_r}\,|\lambda_r|\,|\lambda_s| sin\eta \qquad (6)$$

Where ψ_r and ψ_s are the rotor and stator flux linkages and η is the angle between the fluxes and σ is the leakage coefficient. Block diagram of direct torque control of induction motor is shown in fig 2. The induction motor is fed by a three phase inverter consisting of six fast switching devices.

The basic control algorithm of DTC is consisted with two independent hysteresis comparators producing the error signal of stator flux and electrical torque. And these error signals are incorporated with a switching table shown in table.1. The feedback signal for independent controllers come from the stator current and voltage space vectors. The voltage space vectors generated from inverter with the sensed dc link voltage the inverter drive signals. the angle of the stator flux vector is used to determine the voltage sector as shown on the fig 3.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

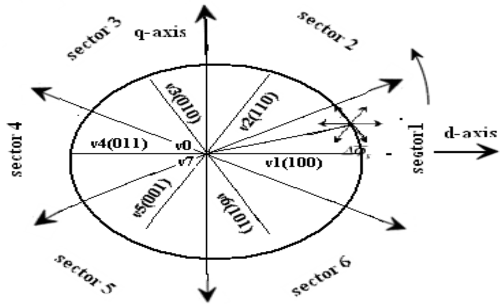

Fig.3 Relationship with voltage vectors and stator flux under DTC

Six nonzero vectors (V1 - V6) shape the axes of a hexagonal as depicted in Fig. 2, and feed electric power to the load. The angle between any adjacent two non-zero vectors is 60 degrees. Meanwhile, two zero vectors (V0 and V7) are at the origin and apply zero voltage to the load. The eight vectors are called the basic space vectors and are denoted by V0, V1, V2, V3, V5, V6, and V7. Assuming the stator flux vector laid on the sector 1 of the d-q plane, V1, V2, V6 could be selected to increase the stator flux vectors. Conversely, V3, V4, V5 could be selected to decrease the stator flux vector. The zero (null) voltage vectors does not effect on the stator flux vector. Voltage vectors are selected to control the torque also. In general, V2 and V3 vectors can be selected to increase the torque and V5, V6, V0 vectors will decrease the torque. Table 1 shows voltage vector selection according to stator flux and torque errors.

Table.1 Selection table of voltage vector

S_Ψ	S_T	Sector I	Sector II	Sector III	Sector IV	Sector V	Sector VI
1	1	V_2	V_3	V_4	V_5	V_6	V_1
	0	V_7	V_0	V_7	V_0	V_7	V_0
	-1	V_6	V_1	V_2	V_3	V_4	V_5
0	1	V_3	V_4	V_5	V_6	V_1	V_2
	0	V_0	V_7	V_0	V_7	V_0	V_7
	-1	V_5	V_6	V_1	V_2	V_3	V_4

V. PARTICLE SWARM OPTIMIZATION

Particle swarm optimization is a heuristic global optimization method put forward originally by Doctor Kennedy and Eberhart in 1995. It is developed from swarm intelligence and is based on the research of bird and fish flock movement behaviour.

PSO has two primary operators; velocity and position update. In this paper the main objective of PSO is minimization of speed error. Fig.4 shows the block diagram for PI controller and the corresponding objective function is as shown in equation (7) and (8).

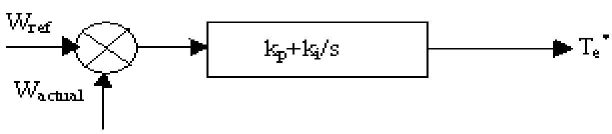

Fig.4 PI controller

$$e(t)=(W_{ref} - W_{actual}) \quad (7)$$
$$e(t)=t_e^*/(k_p+k_i*t) \quad (8)$$

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

VI.PSO ALGORITHM

A. Step.1 initialization

- Determine the particle size m and set the values of parameters c1 and c2.
- Initialize weight factor w.
- Randomly generate the particles to be the candidate solutions to the optimization problem called population vector.
- The size of Population vector (pv)=[k_p k_i]mx2.
  Where m=particle size.
- Population vector (PV) is generated by using the formula
  PV=$k_p$min+ (rand (m, 1)*($k_p$max-$k_p$min).
- Substitute this data in objective function to obtain fitness vector.
- Fitness vector= [ ]mx1.

B. Step.2 velocity vector calculation v(t)

- In the original version of PSO, each component of velocity vector is kept within the range [−Vmax,Vmax].
- Vmax= ($k_p$max- $k_p$min)/n;
  Where n=number of iterations.
- Order of velocity vector=ps x ncv.
  Where ps=particle size,
  ncv=number of control variables.

C. Step.3 Calculation of pbest and gbest

- $pbest_{population}$ = population vector(pv).
- $pbest_{fitness}$ = fitness vector(fv).
- Gbest is the best position among all individual best positions achieved so far.

D. Step.4 Iteration process

- Weight updating
  W(t)=alpha*w(t-1).
  Where alpha= random number.
- Velocity updating
  V(t)=w(t)*v(t-1)+c1*r1*(pbest-xi)+c2*r2(gbest-xi).
  Where xi=current location.
- Position updating
  Xi^{k+1} =v(t)+xi^{k}
  Where Xi^{k+1} = new position.
  Xi^{k} =previous location.

E. Step.5 Stopping criteria

- The objective function (fitness) value is calculated for each agent according to above steps, that is Epbest.
- Compare particle's fitness evaluation (Epbest) with its Gbest. If current value is better than Gbest then set Gbest equal to the current value and that position equal to the current location xi in D-dimensional space.

F. Step.6 Exit condition

- If Epbest<error,
  (or)
- The number of iterations reaches the maximum allowable number.
- If one of the above conditions is satisfied then stop. Else go to step 4.

The optimal values of kp and ki are substituted in the conventional DTC and the results have obtained.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

VII.RESULTS AND DISCUSSION

The optimized values obtained from PSO program is substituted in DTC system and the results have observed. To validate the performance of PSO based DTC different load torques has been applied as shown in fig 5(a), 6(a), 7(a), and 8(a). The motor speed waveforms related to the PSO based DTC in comparison with conventional PI based DTC are as shown in fig 5(b), 6(b), 7(b), 8(b).

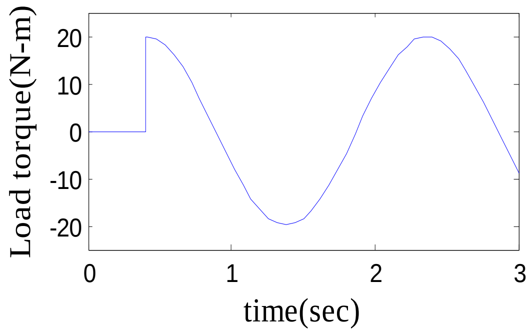

Fig.5 (a) External load torque disturbance

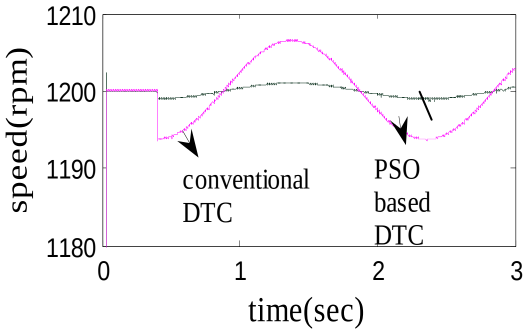

Fig.5 (b) Speed comparison with conventional and PSO based DTC

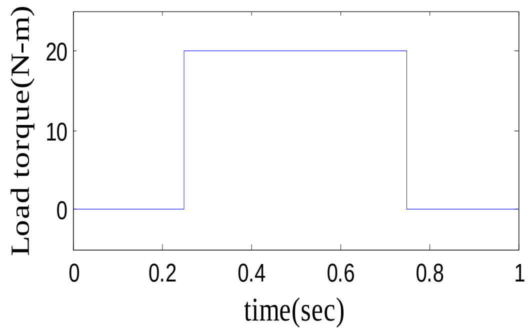

Fig.6 (a) External load torque disturbance

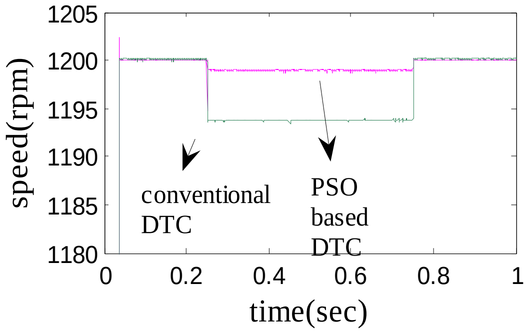

Fig.6 (b) Speed comparison with conventional and PSO based DTC

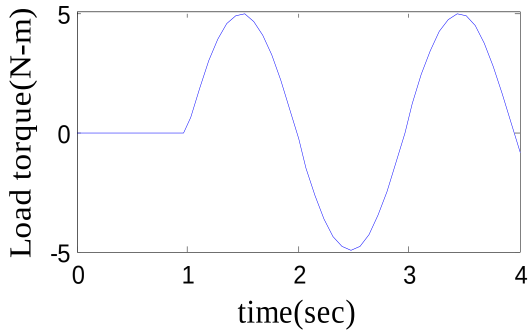

Fig.7 (a) External load torque disturbance

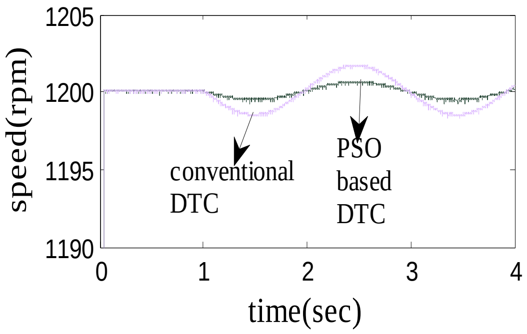

Fig. 7(b) Speed comparison with conventional and PSO based DTC

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering
Vol. 2, Issue 7, July 2013

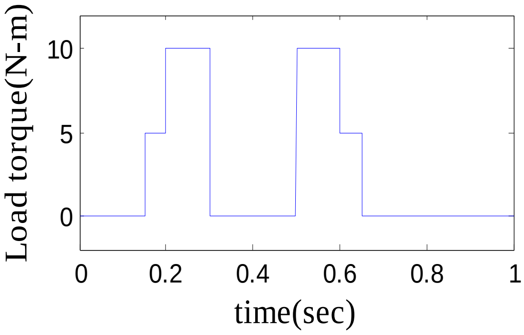

Fig.7 (a) External load torque disturbance

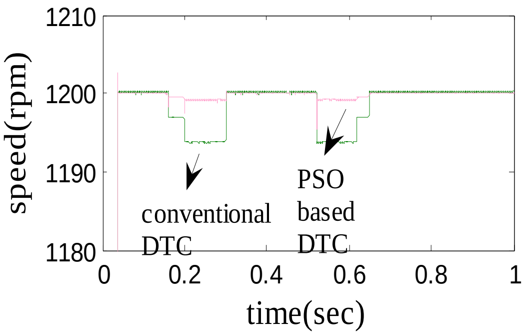

Fig.8 (b) Speed comparison with conventional And PSO based DTC

It has been observed that the speed performance of a PSO based DTC is better when compared with the conventional DTC.

VIII.CONCLUSIONS

In this paper, the proposed PSO based DTC control scheme has been implemented. The simulation results of this method have improved the speed performance of the induction motor irrespective of the load torque fluctuations. The proposed PSO method has optimized the parameters of PI controller by minimizing the speed error. It can be concluded that the PSO algorithm employed in DTC of induction motor has resulted in the optimal generation of k_p, k_i values. This proposed method has finally improved the dynamic speed behaviour of the induction motor when compared with that of a Conventional PI controller based DTC of Induction motor.

REFERENCES

[1] Bo zhou, "Application of particle swarm optimization on DTC for induction motor", IEEE DOI 10.1109/ICNC.2008.300
[2] O.S. EI-Laban , H.A. Abdel Fattah, H.M.Emara, and A.F.Sakr, "partical swarm optimized direct torque control of induction motors". IEEE Trans, 2006.
[3] M. A. Abido, "optimal power flow using particle swarm optimization", electrical power and energy system vol.24,pp. 563-571,2002
[4] Ioan Cristian Treela. "the particle swarm optimization algorithm": convergence analysis and parameter selection. *Information processing Lett.*, 85(2003)317- 325.
[5] Ahmud Iwan Solihin, Lee Fook Tack and Moey LeapKean. "Tuning of PID controller using particle swarm optimization" (PSO). 2011.
[6] Hassan Farhan Rashag, S.P.Koh, Ahmed N. Abdalla, nadia M. L. Tan, K. H. Chong and S. K. Tiong, " DTC torque ripple minimization based on PSO-PID controller". *Scientific research and Essay.*, vol. 7,pp(15), 1564-1572, 2012.
[7] J. Kennedy and R. C. Eberhart, " Particle Swarm Optimization," in Proc. IEEE Int. of Neural Networks, Piscataway, NJ, USA, 1942-1948, 1995.
[8] R. C. Eberhart and Y.Shi,"Guest editorial," IEEE Trans. Evol. Comput. (Special Issue on Particle Swarm Optmization), vol. 8, pp. 201-203 no. 3, Jun. 2004.
[9] Eberhart R C, Shi Y. (1998). Comparison between genetic algorithms and Particle Swarm Optimization. Porto VW. Saravanan N,Waagen D, et al.Evolutionary Programming VII.[S.l.]:Springer,1998:611-616.

BIOGRAPHIES

N. Renuka Devi pursuing M-Tech (power electronics) in DVR & Dr. HS MIC College of Technology. Received B-tech degree in electrical engineering from Prasad V potluri Siddhartha institute of technology, Vijayawada in the year 2011.

T. Vamsee Kiran is graduated from Bapatla Engineering College in the year 2000 and M.E in Applied Electronics from PSG College of Technology, Coimbatore in the year 2002. He worked in Sir C.R. Reddy College of Engineering, K.L.College of Engineering and is presently working as Associate Professor in DVR & Dr. HS MIC College of Technology, and has got 12 years of teaching experience. He has submitted his Ph.D thesis in JNTU College of Engineering, Hyderabad. He presented papers in National, international Conferences and International Journals. His research interests include Power Electronics Drives and Multilevel Inverters.