



# To Improve A Performance of Induction Motor Using PBO-ANFIS

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## Abstract:

The performance of intelligent control Adaptive Neuro Fuzzy Inferences system (ANFIS) with Pollination based optimization (PBO) is presented for the speed and torque control of an induction motor using direct torque control in detail. Here a DTC method is being presented and analyzed. This technique consists of a neural network controller, pollination based optimization, a reference model, and an algorithm for changing the ANFIS weights altogether to limit the speed of the ac machine. A PBO-ANFIS gives better speed control, dynamic behaviour and superior characteristics of the three-phase ac motor with DTC. In this paper, the conventional controller technique is replaced by PBO-ANFIS controller. The proposed technique is compared with the conventional technique and from the comparative study it is seen that the rise time is reduced from 260ms to 1.266ms, settling time is reduced by 725ms to 12.76ms and transient time is reduced by 520ms to 10.99ms times and torque ripples are reduced by 6%.

**Keywords:** Direct torque control, Pollination based optimization with Adaptive Neuro Fuzzy Inferences System (PBO-ANFIS), Induction motor.

## 1. Introduction

The applications of ac motors are increasing day by day due to its high dependability, economical, less wear and tear, easy to use and require less repair and maintenance cost. High-performance induction motors require flux and speed control. Field-oriented control needs current controllers and co-ordination transformation. The basic speed control methods of the induction motors are scalar and vector torque control. The scalar torque control technique is utilized to find the control values and not used for difficult and changing behaviour [1-2].

On the other hand vector torque control technique uses these benefits with vector axis vales, limiting the required quantities for revolving phasors in the complicated coordinate system with utilizing the space phasors. This technique establishes the uncouple parameters such as flux, torque, and current by varying the magnitude and phase. These techniques for vector torque control such as direct torque control technique is used for producing a unit vector signals [3-5].

During the most recent decade, another control method is known as Direct Torque Control is being created for ac machine. Direct torque control was stated was first proposed Depenbrock and Takahashi. In this technique, Stator voltage phasor are chosen by the comparison of stator flux linkage and reference torque. The easy execution and a quick response are obtained by DTC technique. Moreover, it does not require modulation method for the inverter. Now the controller is executed by an electronics system (that are measured as a standard these days), a genuine flux estimations and torque can change their values. The benefits of direct torque control are that there is no need of coordination transformation and current controller, no need of space vector modulation block but DTC has some draw-back of more torque ripples and slow transient response during start up [6-8].

PBO-ANFIS can be used to identify and control nonlinear component systems as they can rough and having different types of nonlinear abilities to any needed level of accuracy. Moreover, these can be operated in shunt and in less operating time. PBO-ANFIS has in-susceptibility from symphonies desirable and has a more controllable capacity. Since the 1992s, a large number of the researcher, research on the utilization of Adaptive Neuro Fuzzy Inferences system in the region of electrical motors and power electronic devices. As large numbers of papers have been published for the utilization of ANFIS in control system, in breakdown recognition, in the estimation of state variables and in the control of IMD for different parameters [9-10].

This paper presented the fundamental method of speed control, stator voltages control and current control for direct torque control for ac machine simulation model. In the present PBO-ANFIS controller controls the speed and the torque of three phase ac motor, on the basis of rise time, settling time, transient response and torque ripples. The different calculations and structures have been created to limit the speed of an Induction motors. The PBO with ANFIS provides better control than other controllers because of the following points such as [27-28]:

- PBO-ANFIS is faster as it works in parallel structures.
- It works freely without the arrangement of any scientific model.
- There is very less work by the intermediate neuron.
- ANFIS controller is trained properly it gives precise control for speed and torque.
- There is no effect on results by changing the parameters independently.

f) It does not require complex numerical values for linear and non-linear control system.

The main aim of this paper is to limit the speed and torque of three-phase ac motor with direct torque control with PBO-ANFIS technique. Furthermore, the presented method is also compared with conventional control technique.

The remaining of this paper is prepared as below: The section 2 represents a Mathematic modelling of a three-phase ac motor, as Section 3 shows the principal model of DTC for the ac motor. The planned ANFIS method is discussed in detailed in Section 4. The proposed PBO technique is demonstrated in detail in Section 5. The simulink model results are represented in Section 6. At last, Section 7 presented the conclusion of the paper and discussion.

### 2. Mathematical Model of an Induction Motor

The corresponding circuit diagram of three phase ac machine is drawn in figure 1 and the vector diagram is shown in Fig. 2 showing vectors of it [11].

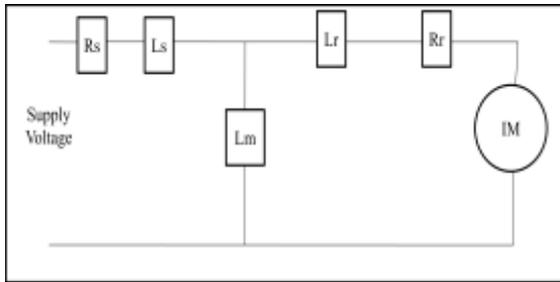


Figure1: Equilateral circuit of ac machine

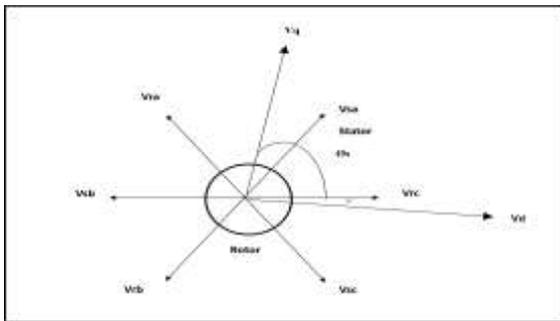


Figure 2: Phasor diagram of ac motor

The equations used in this paper for stator and rotor using transformation rotating with induction motor are shown below.

$$\Phi_s = \Phi_r + \Phi_m \tag{1}$$

$$\frac{d}{dt} i_{sd} = \frac{1}{\alpha L_s} \left[ - \left( R_s + \frac{M^2 R_r}{L_r^2} \right) i_{sd} + N_s \cdot \alpha \cdot L_s \cdot i_{sq} + \frac{M R_r}{L_r^2} \epsilon_{rd} + \frac{M}{L_r} N_r \epsilon_{rq} + \mu_{sd} \right] \tag{2}$$

$$\frac{d}{dt} i_{sq} = \frac{1}{\alpha L_s} \left[ - \left( R_s + \frac{M^2}{L_r T_r} \right) i_{sq} - N_s \cdot \alpha \cdot L_s \cdot i_{sd} - \frac{M}{L_r} \epsilon_{rd} N_r + \frac{M}{L_r T_r} \epsilon_{rq} + \mu_{sq} \right] \tag{3}$$

$$\frac{d}{dt} \epsilon_{rd} = \frac{M R_r}{L_r} i_{sd} - \frac{R_r}{L_r} \epsilon_{rd} + (N_s - N_r) \epsilon_{rq} \tag{4}$$

$$\frac{d}{dt} \epsilon_{rq} = \frac{M R_r}{L_r} i_{sq} - \frac{R_r}{L_r} \epsilon_{rq} - (N_s - N_r) \epsilon_{rd} \tag{5}$$

Where,  $\epsilon = 1 - \frac{M^2}{L_r L_s}$  (6)

The fundamental torque equation of induction motor is shown below:

$$T = T_1 + j \frac{d\Omega_m}{dt} + f\Omega_m \tag{7}$$

$$T = \frac{n_p M}{L_r} (\epsilon_{rd} i_{sq} - \epsilon_{rq} i_{sd}) \tag{8}$$

### 3. Direct Torque Control (DTC)

Nowadays induction motors are controlled with field oriented controlled techniques but for quick response the DTC method is implementing. This method limits the torque and flux of three phase ac machine is controlled directly and independently as it is utilized for appropriate stator voltages [12-15]. The execution of the DTC performs the decoupling among the flux and torque control, needs a data on the size of the stator flux linkage space vector structure. In conventional DTC, the learning segment with stator flux linkage is essential because of there is no need of precise control of induction motor. Regardless of whether the stator flux linkage can be able to be calculated directly, it is generally calculated by an appropriate flux control simulation that depends on the numerical calculation of the three phase ac motor. The basic flux model needs the stator voltage and stator currents for the calculation of ac motor. The conventional figure of DTC model is appeared in Fig.3. The Voltage source inverter is displayed in Fig.4 and the switching table used in conventional DTC with different switching positions is also shown in Table.1 [16].

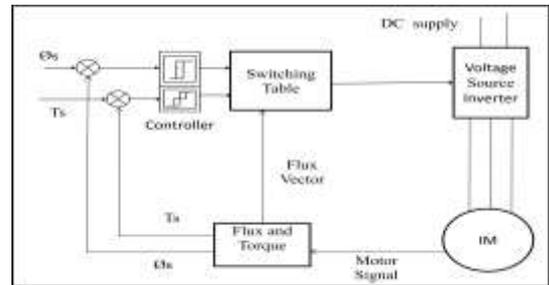


Figure 3: Block diagram of DTC

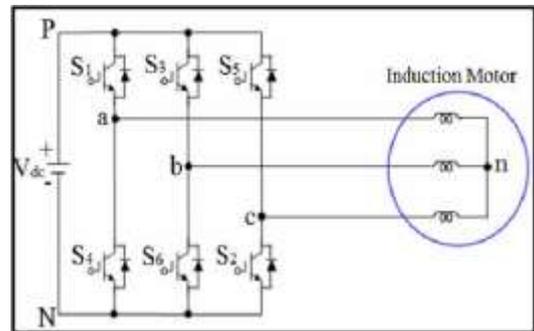


Figure 4: Voltage source inverter model

Table 1: Voltage vector/sector table

V <sub>v</sub>	V <sub>Te</sub>	S <sub>w1</sub>	S <sub>w2</sub>	S <sub>w3</sub>	S <sub>w4</sub>	S <sub>w5</sub>	S <sub>w6</sub>
▲	▲	€2	€3	€4	€5	€6	€1
	●	€0	€0	€0	€0	€0	€0
▼	▼	€6	€1	€3	€2	€4	€5
▼	▲	€3	€4	€5	€6	€1	€2
	●	€0	---	---	---	---	---
▼	▼	€6	€5	€1	€2	€3	€4

#### 3.1. Conventional Proportional Integral Controller

The proportional integral controller with DTC is mostly used in industrial applications because of simple construction; easy to use .The conventional model of PI controller is appeared in Fig. 5. The transfer function for Proportional Integral controller is given as [17].

$$X(s) = K_p + \frac{K_i}{s} + K_p \left( \frac{s+b}{s} \right) \tag{9}$$

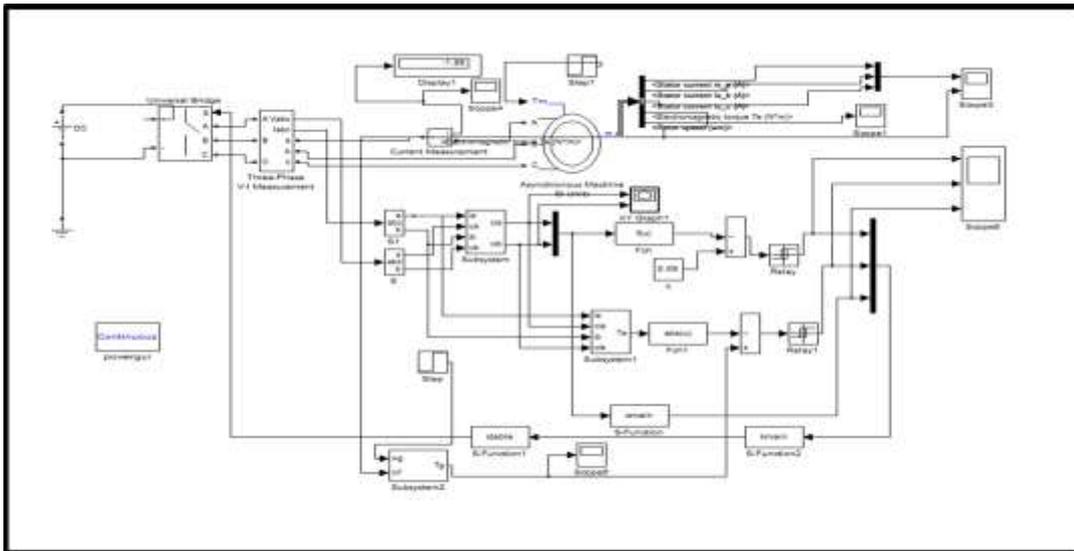


Figure 5: Conventional PI simulation model

### 3.2. Flower Pollination Based Optimization

It is the production of union of gametes by plants with pollen grains formed with man gametes and ovules bear with women gametes with dissimilar parts. It is necessary that the pollen is moved towards stigma for the mixture. The moved and authentication of pollen grains from one plant to the stigma of floweret is known as pollination. A procedure of pollination is mainly facilitated with agent. The pollination is a process of generation and used to produce fruits and seeds in agriculture [8-10]. Pollination is of following type:

**Self-Pollination:** It is the process when pollens pollinate of same type of plants or flowers pollinates is known as self pollination. It happens when same flower consist of either male gametes or female gametes [11].

**Cross Pollination:** It is the process when pollen grains moves from one plant to other plant. This process occurs by the use of abiotic or biotic agents for example birds, snail etc [33-34].

### 3.3. Flower pollination-based optimization algorithm using ANFIS

Flower pollination based optimization technique depends on flower pollination procedure is being utilized for optimization of three phase ac motor. The main process of the flower pollination is the produce large number of shrub. It is totally a novel FPBO technique based on its output. The performance of flower pollination based algorithm depends upon following rules [13-15].

- (i) Biotic and X-pollination is assuming a universal pollination procedure by pollen moving pollinators generating duty flights.
- (ii) A biotic and individual pollination were consisting of narrow pollination.
- (iii) Floret dependability consists of replication chances and it is similar to relation between two same flowers.
- (iv) The switching possibility is connected to the Local and global pollination by using equation,  $P \in [0, 1]$ .

By using the above rules it is easy to calculate the overall pollination behaviours.

### 3.4. Proposed PBO-ANFIS Speed Controller

In this paper, a proposed ANFIS controller with DTC is executed to minimize the starting and running time and also reduce the torque ripples for three phase induction motor. The neural network

controller is utilized to control torque and speed of an ac motor. The ANFIS controller is shown in Fig. 6[25-26, 35]. The fundamental block diagram PBO-ANFIS controller is displayed in Fig.6.

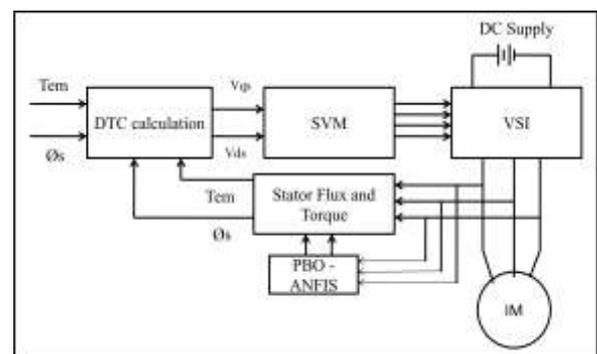


Figure 6: Fundamental Figure of PBO-ANFIS controller with DTC

Every flower has millions or billions of pollen gametes. It's assumed that every plant produces single pollen gamete per flower. Though it is not required to separate pollen gamete, plant and flower or output to it. The output  $y_i$  is used to solve the equitation of a flower and a pollen gamete. To solve this we have to follow the flow chart as shown in Fig.7. [16-18] and flower based optimization is shown below.

#### Presented algorithm for speed and torque control

The speed and toque control procedure is implemented by the following programme

Objective Function minimum or maximum  $f(y)$ ,

$$y = (y_1, y_2, \dots, y_n)$$

Start a population of (n) flowers by apparently for output

For better output  $h^*$  in first population.

Describe a switching possibility  $P \in [0, 1]$

As ( $t < \text{Maximum production}$ )

As  $i = 1: t$

As  $\text{random} < P$ ,

Sketch an step vector  $L$  that obey Levy Global pollination via

$$Yi^{t+1} = Yi^t + L(h^* + Yi^t) \quad (10)$$

Moreover

Sketch  $\alpha$  from a uniform distribution in  $[0, 1]$

Apparently select  $m$  and  $n$  amongst all outputs so local pollination is given as

$$Yi^{t+1} = Yi^t + \epsilon(Yi^t - Yn^t) \tag{11}$$

End if

Calculate novel output

If new outputs are good use as population

End for

For best output current  $h^*$

End while

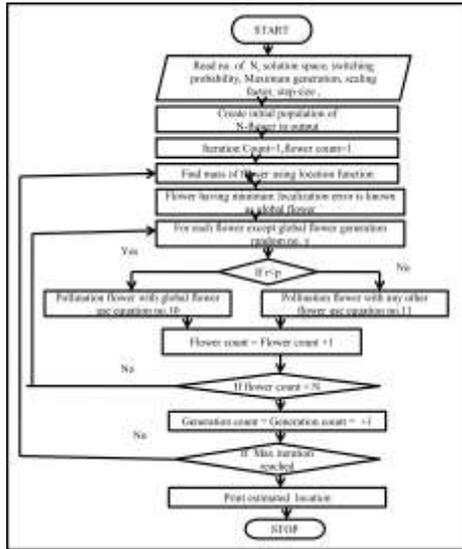
**Table 2:** Parameters for flower pollination based optimization

S. No	Parameter	Nilai
1	Population Size	20
2	Probability Switch	0.8
3	Iteration Parameter	50
4	Dimension	3

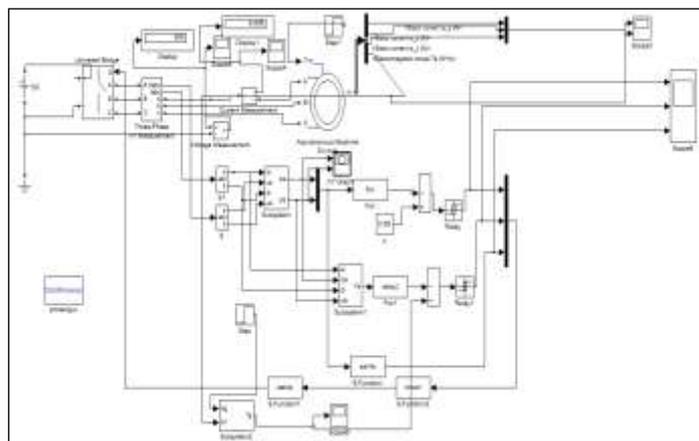
The flower pollination based optimization with neural network procedure can work at local and global level, but actually the flowers with Neighbourhood have more probability of getting pollinated by pollen from local flowers. To regenerate this feature, a proximity probability has been creditably that is utilized to change the concentrated local pollination and global pollination.

### 4. Results and Analysis

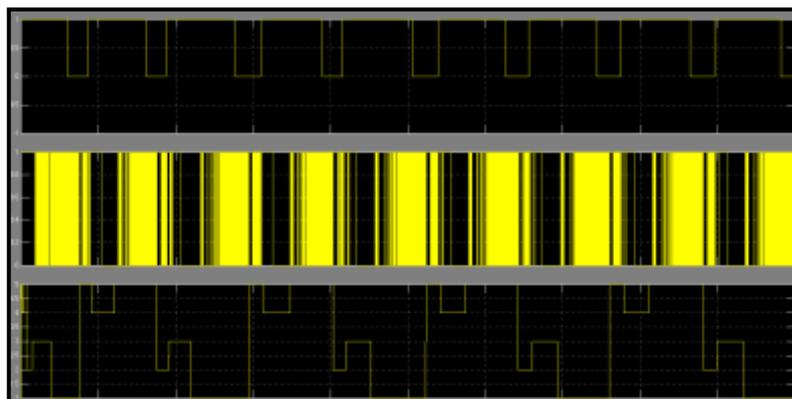
In this paper, PBO-ANFIS controller with DTC is presented to control the speed and torque of ac motor. The simulink model is displaced in figure 8. A motor detail that we have used for simulation is 4KW, 400Volts, 50Hz, 1430 rpm and stator is taken as stationary reference. The output of the simulation model for vector is displaced in Fig.9, electromagnetic torque and stator current is shown in figure 10.



**Figure 7:** Flow chart of FPBO-ANFIS controller



**Figure 8:** Simulation model of PBO-ANFIS with DTC



**Figure 9:** Vector output of DTC with PBO-ANFIS

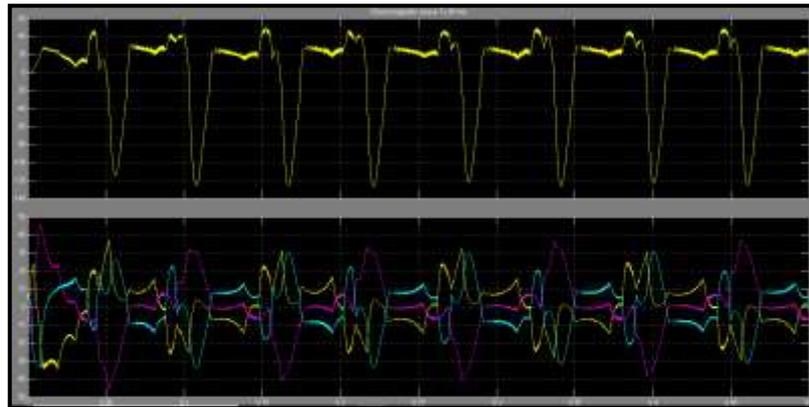


Figure 10. Electromagnetic Torque and Stator current across ac motor

Table 3. Comparative analysis of proposed PBO-ANFIS controller and conventional PI controller

S. No	Technique	Rise Time ms	Settling Time ms	Transient time ms	Torque ripples %age	Electromagnetic Torque Nm
1.	Conventional PI controller with DTC	260	725	520	78.9%	23
2.	PBO-ANFIS controller with DTC	1.266	12.76	10.99	84.2%	46

The Table 3 shows that the rise time is reduced by 260ms to 1.266ms, settling time is reduced by 725ms to 12.76ms, transient time is reduced from 520ms to 10.99 and torque ripples are reduced by 6%.

### 5. Conclusion

In this paper, PBO-ANFIS is used with DTC for speed and torque control for poly phase ac motor is proposed. The proposed control technique is easy to handle for practical applications. To improve the efficiency of the present control technique, the experiments were conducted. The conventional technique is compared with conventional technique on the basis of rise time, settling time and transient response. From the comparative analysis it is seen that the rise time is reduced by 258ms, settling time is reduced by 60ms and transient time is reduced by 419ms and torque ripples are reduced by 6%. The proposed technique also control fluctuations and reduce the torque ripples with well extent of three phase Induction motor.

### Appendix

#### (i) Experimental Setup

The proposed control methods have been tested on a 5.4 HP (4KW) three-phase induction motor and detail specification is displaced in table 4.

Table 4. Motor parameter used for Simulation

Parameter	Unit	Value
Voltage(v)	V	400
Frequency(F)	Hz	50
Speed(N)	Rpm	1430
Resistance of stator(Rs)	$\Omega$	0.8
Resistance of rotor(Rr)	$\Omega$	1.395
Inductance of stator(Ls)	H	$5.839 \times 10^3$
Inductance of rotor(Lr)	H	$2.6 \times 10^3$
Mutual inductance(m)	H	$172.2 \times 10^3$
Inertia of rotor (J)	Kg/m <sup>2</sup>	0.0131
Number of pole pairs(P)		2

### Nomenclature

- ac *alternating current*
- d *direct axis components*
- i *current in amperes*

- IM *induction motor*
- L *inductance in henry*
- Lr *inductance of leakage rotor*
- $\epsilon$  *switching states*
- $\varnothing_m$  *rotor flux position*
- $\varnothing_r$  *rotor angle*
- $\varnothing_s$  *slip angle*
- q *quadrature axis components*
- R *rotor quantities*
- S *stator quantities*
- t *time in seconds*
- T *torque in Newton meter*
- $\alpha$  *constant coefficient*

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