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Design of ANN Based Torque Control of Induction Motor

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***Abstract*—In this paper, The Artificial Neural Network technique used for flux position estimation & sector selection to reduce the torque & flux ripples. Direct Torque Control (DTC) of Induction Motor drive has quick torque response without complex orientation transformation and inner loop current control. The DTC has some drawbacks, such as the high torque & flux ripples, caused by sector changes. The important point in ANN based DTC is the right selection of the stator voltage vector. This project presents simple structured neural networks for flux position estimation and sector selection for induction motors. The Levenberg-Marquardt back-propagation technique has been used to train the neural network. The simple structure network facilitates a short training and processing times. The induction motor is non-linear system, the ANNs are excellent estimators in non-linear systems.**

***Keywords*—**ANN Technique, Direct Torque Control (DTC).

I. INTRODUCTION

A major revolutions in the area of induction motor control was invention of field- oriented control (FOC) or vector control (by Blaschke and Hasse) have been till now employed in high performance industrial applications, has achieved a quick torque response and has been applied in various industrial applications instead of dc motors. In vector control method it is necessary to determine correctly the orientation of the rotor flux vector and main draw back in field oriented control is rotor time constant of standard squirrel-cage induction machine is very large, thus rotor flux linkage changes slowly compared to the stator flux linkage. The new technique was developed for the induction motor torque control i.e Direct torque control (DTC). Direct torque control (DTC) of Induction machines presents a good tracking for both electromagnetic torque and stator flux. This control scheme, as shown in Fig-1, depends only stator measurements.

The switching logic control facilitates the generation of the stator voltage space vector ,with suitable choice of the switching pattern of the inverter.

The main advantages of DTC are:
i.Absence of coordinate transformation
ii,Absence of current regulator
iii.And absence separate voltage modulation block.

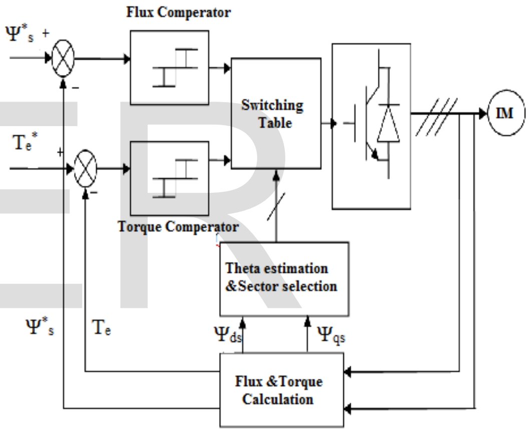


Fig. 1 Basic Direct Torque Control Scheme for AC Motor Drives

The disadvantages in DTC scheme are:
i.Sluggish response (slow response) in both starts up and load changes in either flux or torque.
ii.High torque ripple and slow transient response to the step changes in torque during start-up

This draw backs can be overcome by using Intelligent technique called artificial neural network (ANN). The artificial neural network based DTC improve the induction motor performance in low speed operations and to minimize the torque ripples during short transients.. The sector identification depends on the accurate estimation of stator flux position , This can be measured with the help artificial neuranetwork. The ANNs are cable of learning the desired mapping between the inputs and outputs signals of the system. Since the artificial neural network do not use the mathematical model of the system.

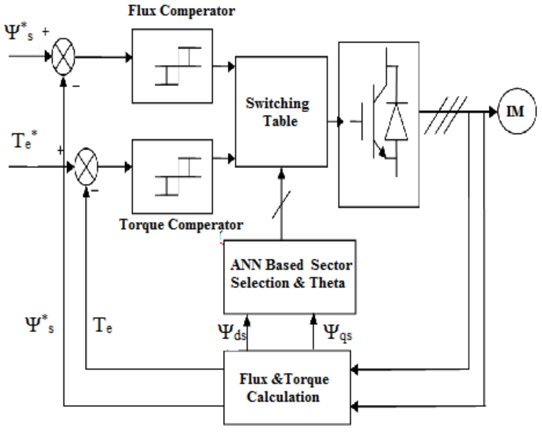


Fig. 2 Proposed ANN based DTC scheme

The induction motor is non-linear system, the ANNs are excellent estimators in non-linear systems. In this paper the load torque of the AC Motors is controlled by using Voltage Source Converter. The voltage source converter is designed by using following technique.

1. Designing the pulses for voltage source converter by using Space Vector Modulation.
2. Reduces the torque and flux ripples by using Artificial neural network technique achieving the motor rotate at rated speed.

II . MODELING OF INDUCTION MACHINE

The induction motors advantages over the rest of the motors. The main advantage is that induction motors do not require an electrical connection between stationary and rotating parts of the motor. Therefore, they do not need any mechanical commutator (brushes), leading to the fact that they are maintenance free motors. Induction motors also have low weight and inertia, high efficiency and a high overload capability. Therefore, they are cheaper and more robust, and less proves to any failure at high speeds.

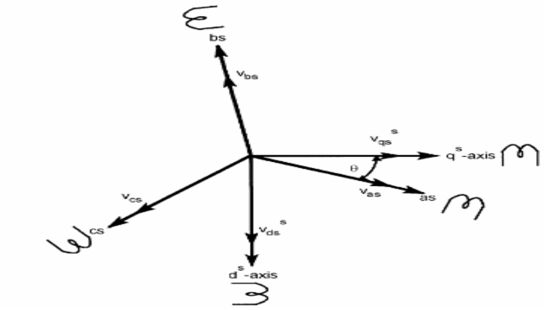


Fig.3 Stationary Frame a-b-c to d^s-q^s Axes Transformation

$$\begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta & 1 \\ \cos(\theta-120^0) & \sin(\theta-120^0) & 1 \\ \cos(\theta+120^0) & \sin(\theta+120^0) & 1 \end{bmatrix} \begin{bmatrix} V_{qs}^s \\ V_{ds}^s \\ V_{os}^s \end{bmatrix} \quad (1)$$

The corresponding inverse relation is

$$\begin{bmatrix} V_{qs}^s \\ V_{ds}^s \\ V_{os}^s \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos\theta & \cos(\theta-120^0) & \cos(\theta+120^0) \\ \sin\theta & \sin(\theta-120^0) & \sin(\theta+120^0) \\ 0.5 & 0.5 & 0.5 \end{bmatrix} \begin{bmatrix} V_{as} \\ V_{bs} \\ V_{cs} \end{bmatrix}$$

(2)

$$V_{as} = V_{qs}^s$$

$$V_{bs} = -\frac{1}{2}V_{qs}^s - \frac{\sqrt{3}}{2}V_{ds}^s \quad (4)$$

$$V_{cs} = -\frac{1}{2}V_{qs}^s + \frac{\sqrt{3}}{2}V_{ds}^s \quad (5)$$

And inversely

$$V_{qs}^s = \frac{2}{3}V_{as} - \frac{1}{3}V_{bs} - \frac{1}{3}V_{cs} = V_{as} \quad (6)$$

$$V_{ds}^s = -\frac{1}{\sqrt{3}}V_{bs} + \frac{1}{\sqrt{3}}V_{cs} \quad (7)$$

$$V_{qs} = V_{qs}^s \cos\theta_e - V_{ds}^s \sin\theta_e \quad (8)$$

$$V_{ds} = V_{qs}^s \sin\theta_e + V_{ds}^s \cos\theta_e \quad (9)$$

For convenience, the superscript e has been dropped from now on from the synchronously rotating frame parameters. Again, resolving the rotating frame parameters into a stationary frame, the relations are

$$V_{qs}^s = V_{qs} \cos\theta_e + V_{ds} \sin\theta_e \quad (10)$$

$$V_{ds}^s = -V_{qs} \sin\theta_e + V_{ds} \cos\theta_e \quad (11)$$

assume that the three-phase stator voltages are sinusoidal and balanced, and are given by

$$V_{as} = V_m \cos(\omega_e t + \phi) \quad (12)$$

$$V_{bs} = V_m \cos(\omega_e t - \frac{2\pi}{3} + \phi) \quad (13)$$

$$V_{cs} = V_m \cos(\omega_e t + \frac{2\pi}{3} + \phi) \quad (14)$$

Substituting Equations (12) - (14) in (6) - (7) yields

$$V_{qs}^s = V_m \cos(\omega_e t + \phi) \quad (15)$$

$$V_{ds}^s = -V_m \sin(\omega_e t + \phi) \quad (16)$$

$$V_{qs} = V_m \cos\phi \qquad (17)$$

$$V_{ds} = -V_m \sin\phi \qquad (18)$$

Or inversely

$$\overline{V} = V_{qs}^s - jV_{ds}^s = (V_{qs} - jV_{ds})e^{+j\theta_e} \qquad (19)$$

the vector magnitudes in stationary and rotating frames are equal, i.e.,

$$\left|\overline{V}\right| = \hat{V}_m = \sqrt{V_{qs}^2 + V_{ds}^2} \qquad (20)$$

Substituting Equations (2.6) – (2.7)

$$\overline{V} = V_{qs}^s - jV_{ds}^s$$

$$= \left(\frac{2}{3}V_{as} - \frac{1}{3}V_{bs} - \frac{1}{3}V_{cs}\right) - j\left(-\frac{1}{\sqrt{3}}V_{bs} + \frac{1}{\sqrt{3}}V_{cs}\right)$$

$$= \frac{2}{3}\left[V_{as} + aV_{bs} + a^2V_{cs}\right] \qquad (21)$$

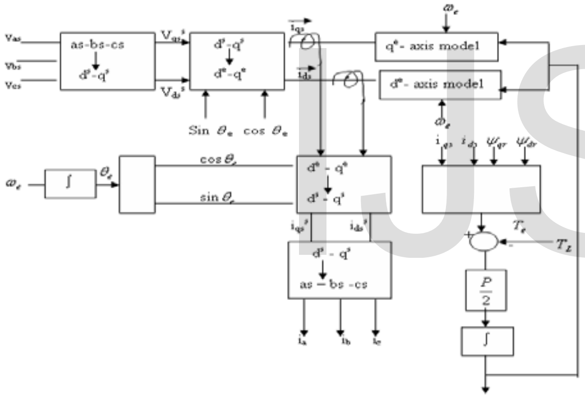


Fig.4 Synchronously Rotating Frame Machine Models With Input Voltage and Output Current Transformations

III. SPEED CONTROL TECHNIQUES

In the past, DC motors were used extensively in areas where variable-speed operations were required. DC motors have certain disadvantages, however, which are due to the existence of the commutator and the brushes which makes the motor more bulky, costly and heavy. They are also robust and immune to heavy loading. The speed of the induction motor has to be controlled and so different types of controllers are used to obtain the desired speed. Various speed control techniques implemented by modern-age Variable Frequency Drive are mainly classified in the following three categories

1. Scalar Control (V/f Control),
2. Vector Control (Indirect Torque Control)
3. Direct Torque Control (DTC).

The aim of our paper is to control the Speed & Torque of the induction motor using Direct torque control technique .

The dynamic modeling of induction motor is done in the SIMULINK using the necessary equations. The Direct torque control of the induction motor is also modeled in the SIMULINK using the necessary equations. Neural Networks is implemented in the system for better control of the induction motor.

A. Direct Torque Control (DTC)

The difference between the traditional vector control and the DTC is that the DTC has no fixed switching pattern. The DTC switches the inverter according to the load needs. Due to elimination of the fixed switching pattern (characteristic of the vector and the scalar control), the DTC response is extremely fast during the instant load changes. Although the speed accuracy up to 0.5% is ensured with this complex technology, it eliminates the requirement of any feedback device. The heart of this technology is its adaptive motor model. This model requires information about the various motor parameters, like stator resistance, mutual inductance, saturation co-efficiency, etc.

DTC main features are as follows:

- Direct control of flux and torque.
- Indirect control of stator currents and voltages.
- Approximately sinusoidal stator fluxes and stator currents.
- High dynamic performance even at stand still.

IV. CONTROL STRATEGY FOR SVM BASED DTC

The block diagram of direct torque and flux control is shown in Figure 6 explains the control strategy. The speed control loop and the flux program as a function of speed are shown as usual and will not be discussed. The command stator flux Ψ_s^* and torque T_e^* magnitudes are compared with the respective estimated values and the errors are processed through hysteresis-band controllers, as shown. The flux loop controller has two levels of digital output according to the following relations

$$H_\psi = 1 \quad \text{for} \quad E_\psi > +HB_\psi \qquad (4.1)$$

$$H_\psi = -1 \quad \text{for} \quad E_\psi < -HB_\psi \qquad (4.2)$$

$$H_{Te} = 1 \quad \text{for} \quad E_{Te} > +HB_{Te} \qquad (4.3)$$

$$H_{Te} = -1 \quad \text{for} \quad E_{Te} < -HB_{Te} \qquad (4.4)$$

$$H_{Te} = 0 \quad \text{for} \quad -HB_{Te} < E_{Te} < +HB_{Te} \qquad (4.5)$$

terminal voltages and currents. The signal computation block also calculates the sector number S(k) in which the flux vector Ψ_s lies.

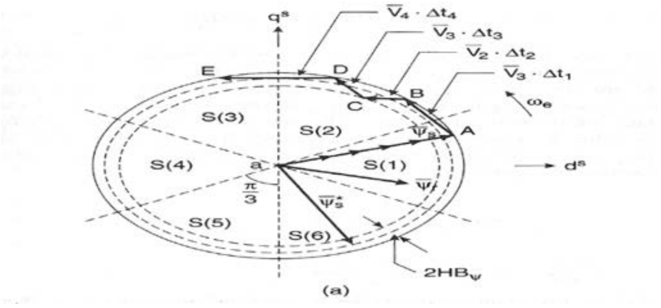


Fig.5 Flux Sector

The voltage vector receives the input signals H_Ψ H_{Te} and S(k) generates the appropriate control voltage vector (switching states) for the inverter by lookup table, which is shown in Table-1 (the vector sign is deleted). The inverter voltage vector (six active and two zero states) and a typical Ψ_s are shown in Figure 5. Neglecting the stator resistance of the machine.

$$\overline{V}_s = \frac{d}{dt}(\overline{\psi}_s) \tag{4.6}$$

(or)

$$\Delta\overline{\psi}_s = \overline{V}_s \,.\Delta t \tag{4.7}$$

The flux in machine is initially established to at zero frequency (dc) along the trajectory OA shown in Figure 5. With the rated flux, the command torque is applied and the Ψ_s^* vector starts rotating.

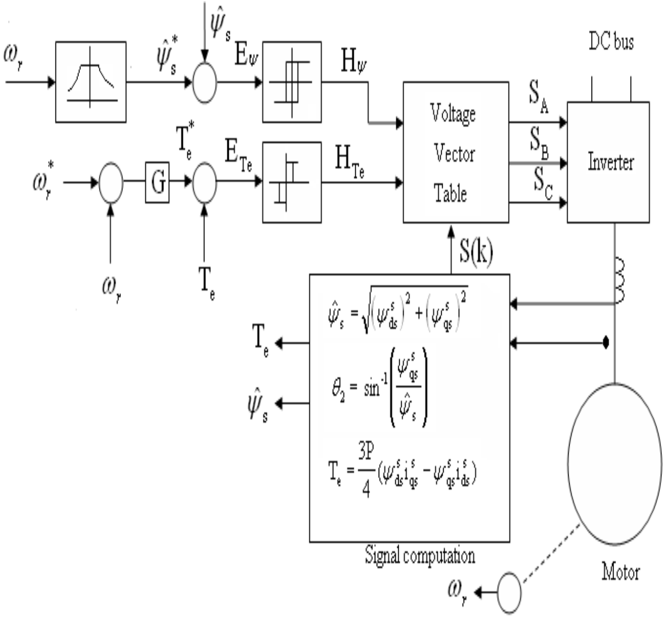
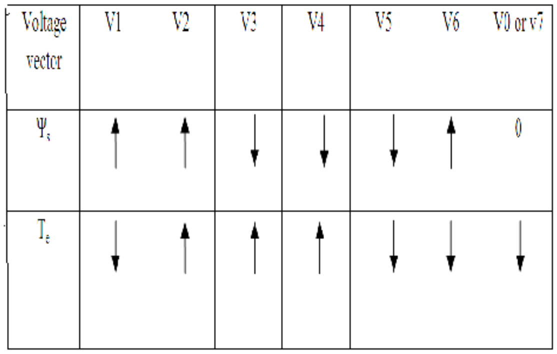


Fig.6 Direct Torque and Flux Control Block Diagram

TABLE I
SWITCHING TABLE OF INVERTER VOLTAGE VECTORS

7

H_Ψ	$H_{\_\Psi}$	S(1)	S(2)	S(3)	S(4)	S(5)	S(6)
$F_D(1)$	T(1)	V_2	V_3	V_4	V_5	V_6	V_1
	T(0)	V_0		V_0	V_7	V_0	V_7
	T(-1)	V_6	V_1	V_2	V_3	V_1	V_5
$F_D(-1)$	T(1)	V_3	V_4	V_5	V_6	V_1	V_2
	T(0)	V_7	V_0	V_7	V_0	V_7	V_0
	T(-1)	V_5	V_6	V_1	V_2	V_3	V_4



Voltage vector	V1	V2	V3	V4	V5	V6	V0 or v7
Ψ_s	↑	↑	↓	↓	↓	↑	0
T_e	↓	↑	↑	↑	↓	↓	↓

2

TABLE :2**FLUX AND TORQUE VARIATIONS DUE TO APPLIED VOLTAGE VECTOR**

V. ARTIFICIAL NEURAL NETWORKS

Numerous advances have been made in developing intelligent systems, some inspired by biological neural networks. Researchers from many scientific disciplines are designing artificial neural networks to solve a variety of problems in pattern recognition, prediction, optimization, associative memory, and control. Conventional approaches have been proposed for solving these problems. Although successful applications can be found in certain well-constrained environments, none is flexible enough to perform well outside its domain. ANNs provide exciting alternatives, and many applications could benefit from using them. This article is for those readers with little or no knowledge of ANNs to help them understand the other articles in this issue of Computer.

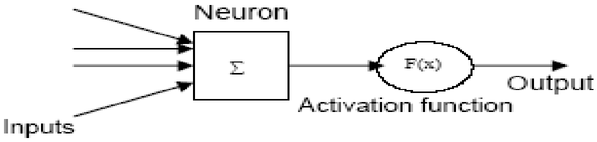


Fig.7 Simple Artificial Neuron

The long course of evolution has given the human brain many desirable characteristics not present Invon Neumann or modern parallel computers. These include massive parallelism, distributed representation and computation, learning ability, Generalization ability.

VI. SIMULATION RESULTS

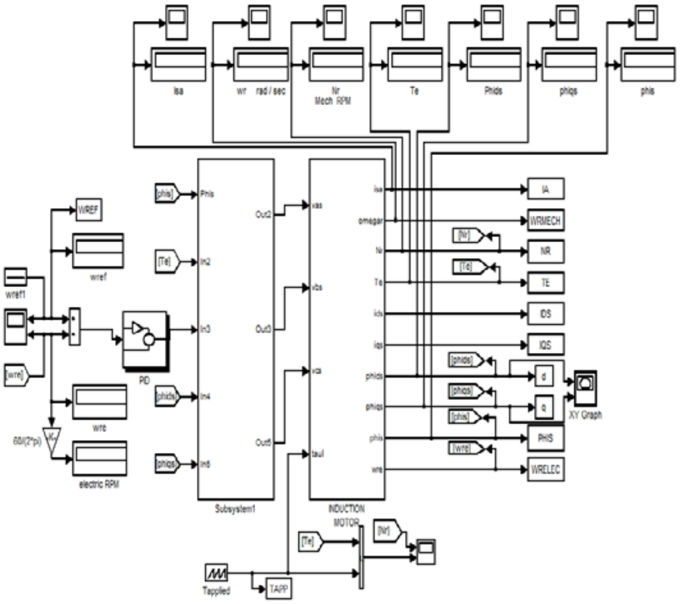


Fig.8 Simulation Block For DTC With PID System

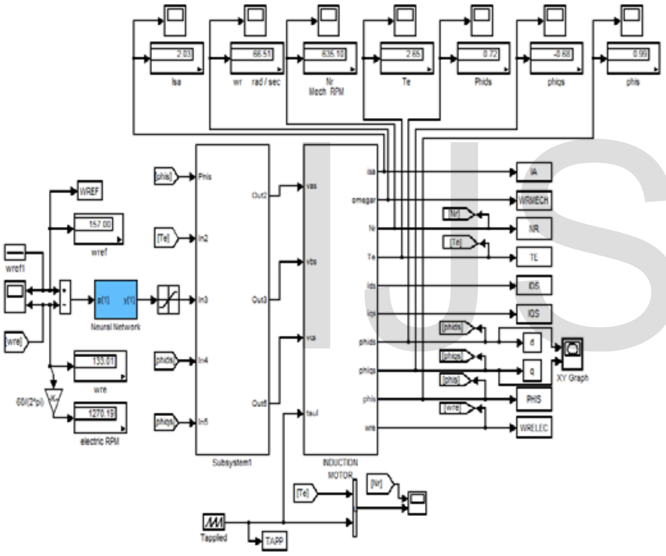


Fig.9 Simulation Block For DTC With ANN System

The main simulation block diagram of the Induction Motor Model and waveforms of 3- Φ Input Voltage, 2- Φ Model output, Stator Current, Rotor Current, Speed & Electro Magnetic Torque Wave forms are shown in below figures.

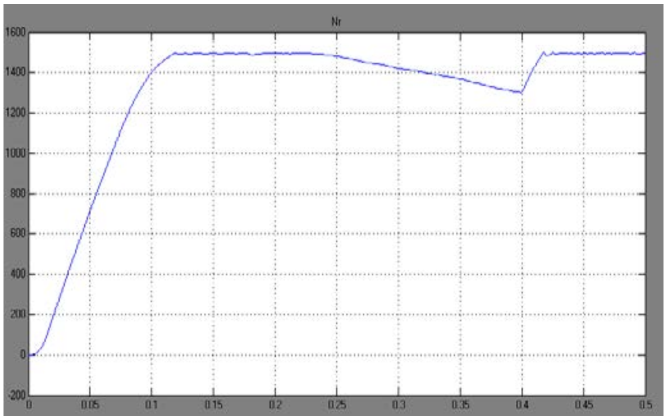


Fig.12 Speed of the Induction Motor using DTC with PID Controller

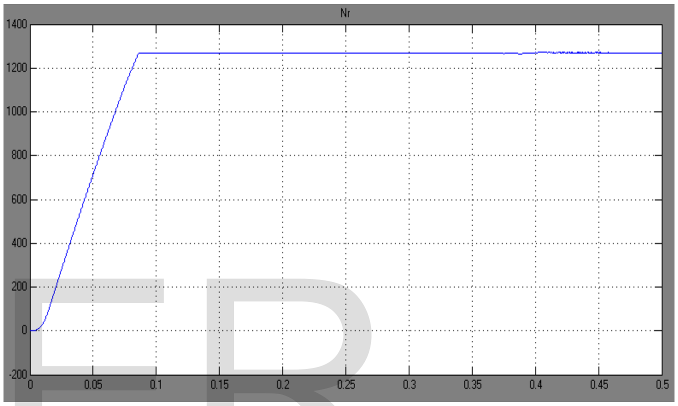


Fig.13 Speed of the Induction Motor With ANN Based SVM

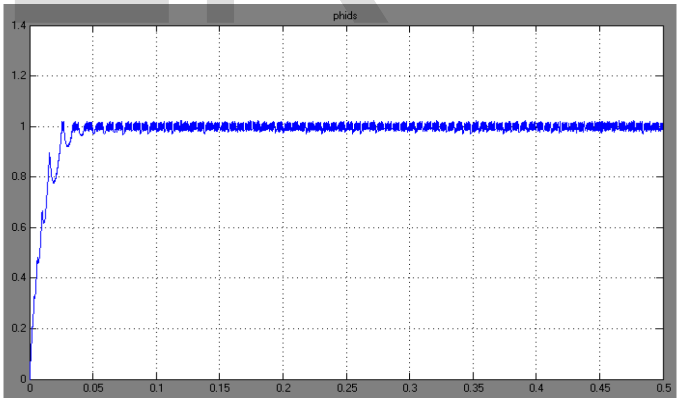


Fig.14 Stator Flux Magnitude conventional DTC

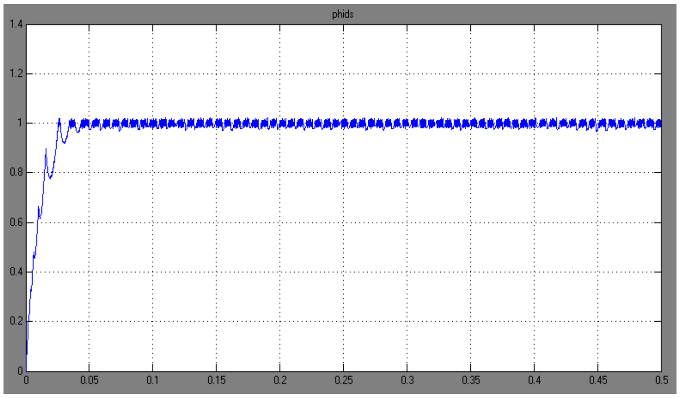


Fig.15 Stator Flux Magnitude of ANN Based DTC

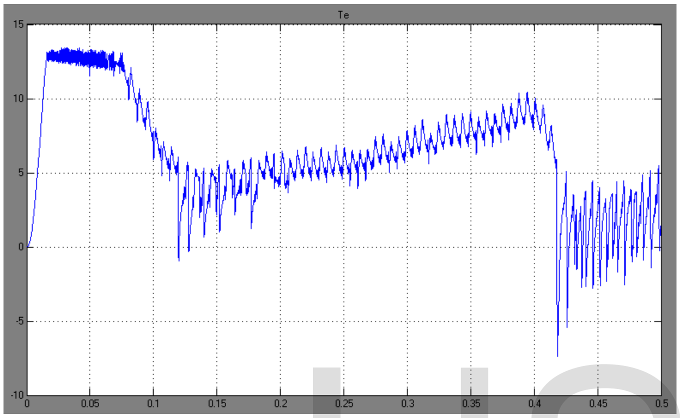


Fig.16 Electromagnetic Torque Response Waveform With PID

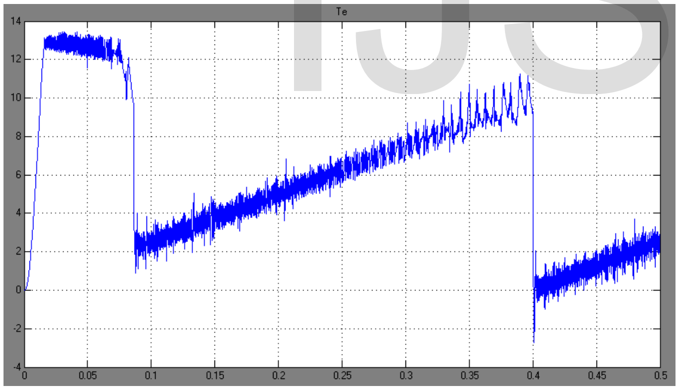


Fig.17 Electromagnetic Torque Response Waveform With ANN DTC

VII. CONCLUSION

From the above the conventional direct torque control technique is used for DTC control of Induction motor. In conventional DTC method some disadvantages such as difficulties in torque and flux control at very low speed, high current and torque ripple, variable switching frequency behavior, high noise level at low speed and lack of direct current control, an adaptive torque controller must be proposed for high performance applications. So an Artificial Neural Network (ANN) control is proposed for conventional DTC scheme. The intelligent technique ANN are used for proper sector selection in DTC so that the rotor speed, torque and flux performances of induction machine is improved. The conventional DTC controller compared with ANN. The results are carried out by using Mat-Lab/simulink

REFERENCES

[1] Bose B.K. “Modern Power Electronics and AC Drives”, Pearson Education, 4th Edition, 2004.

[2] .Krishnan. “Electric Motor Drives, Modeling, Analysis, and Control”, Pearson Education, First Indian Reprint, 2003.

[3] I. Takahashi and T. Noguchi, “A New quick-response and high-efficiency control strategy of induction motor,” IEEE Trans. Ind. septmember., vol. 22, no. 5, pp. 820–827, 1986.

[4] . Takahashi and Y. Ohmori, “High-performance direct torque control of induction motor,” IEEE Trans. Ind. Appl., vol. 25, no. 2, pp. 257–264, 1989.

[5] M. Grzesiak and Bartlomiej Ufnalski, “Neural stator flux estimater with dynamical signal processing,” IEEE Africon 2004, pp. 1137– 1142.

[6] C. Lascu, I. Boldea, F. Blaabjerg. “A Modified Direct Torque Control for Induction Motor Sensor less Drive”. IEEE Tram on Industry Applications, vol 36, No-1, 122-130, January/February 2000.

[7] Burak Ozpineci, L.M.Tolbertr, “Simulink Implementation of Induction Machine Model-A modular approach”, IEEE Transactions 2003.

[8] Xingyi.Xu, D.W.Novotny, “Implementation of Direct stator flux orientation control on versatile DSP based system”, IEEE Trans. Ind. Appl., vol. 24, no. 4, july/august 1991.