RESEARCH ARTICLE OPEN ACCESS

Design And Analysis Of Artificial Neural Network Based Controller For Speed Control Of Induction Motor Using D T C

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ABSTRACT:
This paper presents an improved version of direct torque control (DTC) based on Artificial Neural Network technique used for flux position estimation and sector selection. This controller mainly reduces the torque and flux ripples. Direct torque control of induction motor drive has quick torque response without complex orientation transformation and inner loop current control. The major problem associated with DTC drive is the high torque ripples. The important point in ANN based DTC is the right selection of voltage vector. This project presents simple structured neural network for flux position estimation and sector selection for induction motor. The Levenberg-Marquardt back propagation technique has been used to train the neural networks. The simple structure network facilitates a short training and processing times. The neural network based controller is found to be a very useful technique to obtain high performance speed control.

Keywords: Artificial neural network (ANN) technique, direct torque control (DTC), field orientated control (FOC).

I. INTRODUCTION

The induction motor is very popular in variable speed drives due to its well-known advantages of simple construction, ruggedness, and inexpensive and available at all power ratings. major revolutions in the area of induction motor control was invention of 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. Direct torque control of Induction machines presents a good tracking for both electromagnetic torque and stator flux.The ANNs are capable of learning the desired mapping between the inputs and outputs signals of the system without knowing the exact mathematical model of the system. 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.

II. OBJECTIVE AND BENEFITS OF PROJECT

Induction Motors (IMs) are widely used in high performance drives. Its history is very extensive and also control is important in applications. There are many IMs in a number of industrial, commercial and domestic applications of variable speed drives. Since IMs demands well control performances: precise and quick torque and flux response, large torque at low speed, wide speed range, the drive control system is the most sensitive point of IMs The switching logic control facilitates the generation of the stator voltage space vector, with suitable choice of the switching pattern of the inverter.

Like a every control method has some advantages and disadvantages, DTC method has too. Some of the advantages are lower parameters dependency, making the system more robust and easier implements and the disadvantages are difficult to control flux and torque at low speed, current and torque distortion during the change of the sector in d-q plane, variable switching frequency, a high sampling frequency needed for digital implementation of hysteresis controllers, high torque ripple. The torque ripple generates noise and vibrations, causes errors in sensor less motor drives, and associated current ripples are in turn responsible for the EMI. The reason of the high current and torque ripple in DTC is the presence of hysteresis comparators together the limited number of available voltage vectors.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 neural network. 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. 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. Designing the pulses for voltage source converter by using Space Vector Modulation.

- Reduces the torque and flux ripples by using artificial neural network technique achieving the motor rotate at rated speed.
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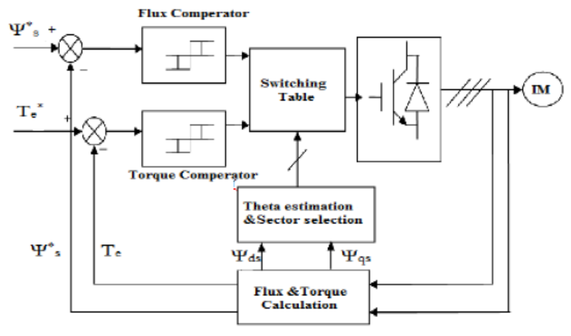

Fig. 1 Basic Direct Torque Control Scheme for AC Motor Drives

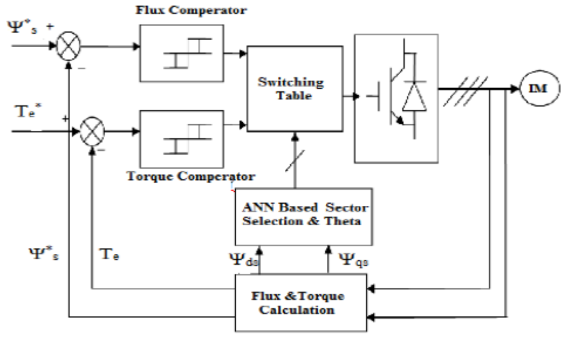

Fig. 2 Proposed ANN based DTC scheme

III. LITERATURE REVIEW

In past years this concept has been evolved over the years the first of its kind with advanced work was in JAN 2000, by C. Lascu, I. Boldea, F. Blaabjerg. Infrared technology was employed to track the position of the speaker in the video conference in year 2003, by Burak Ozpineci, L.M.Tolbertr [2],by Takahashi and Y. Ohmori in year 1989. 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 parts33 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.

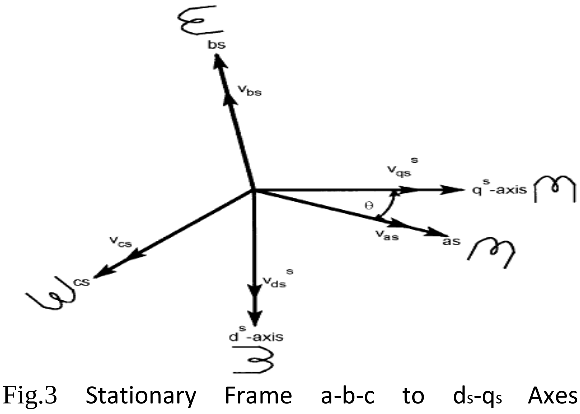

Fig.3 Stationary Frame a-b-c to d_s-q_s Axes Transformation

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

The corresponding inverse relation is

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

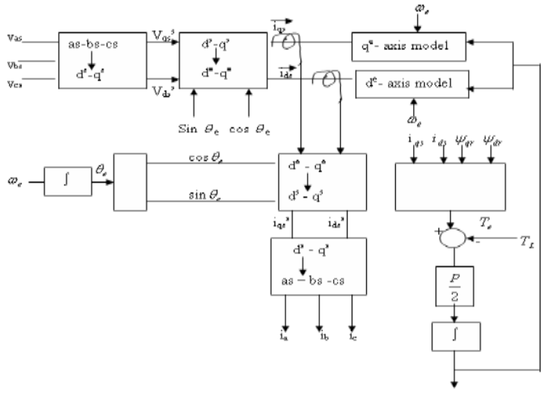

Fig.4 Synchronously Rotating Frame Machine Models with Input Voltage and Output Current Transformations

IV.CIRCUIT AND MAIN COMPONENTS

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.

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.

This method presents the following advantages:

- Absence of co-ordinate transforms.
- Minimal torque response time, even better than the vector controllers.

Although, some disadvantages are present:

- Possible problems during starting.
- Inherent torque and flux ripples.

B. 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 and torque 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.

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

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

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

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

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

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

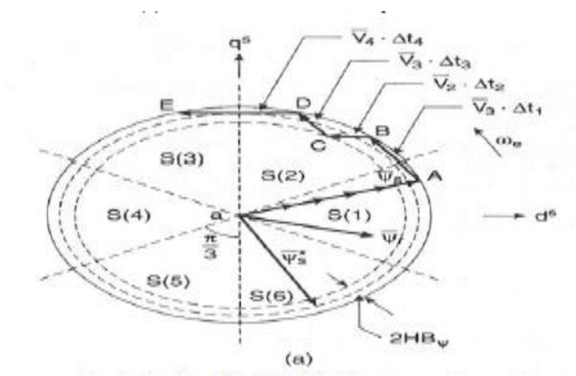

Fig.5 Flux Sector

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.

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

(or)

$$\Delta \overline{\psi}_s = \overline{V}_s \,.\Delta t \qquad (4.7)$$

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.

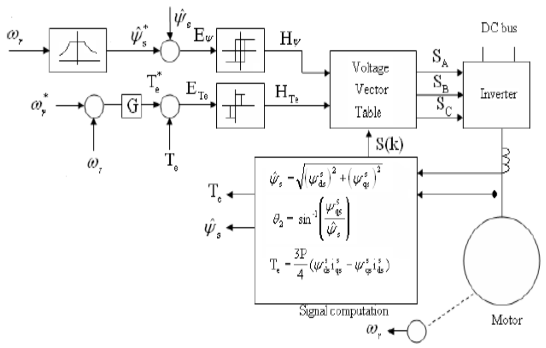

Fig.6 Direct Torque and Flux Control Block Diagram

H_ψ	H_T	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_7	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

Table I: Switching Table Of Inverter Voltage Vectors

Voltage Vector	V_1	V_2	V_3	V_4	V_5	V_6	V_0, V_7
Ψ_e	↑	↑	↓	↓	↓	↑	0
T_e	↓	↑	↑	↑	↓	↓	↓

Table 2 Flux And Torque Variations Due To Applied Volts

C. ARTIFICIAL NEURAL NETWORKS

Artificial Neural networks are relatively crude electronics models based on the neural structure of the human brain. 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. A neural net is based on layers of neurons. A unique property of a neural network is that it can still perform its overall function even if some of the neurons are not functioning. That is, they are very robust to error or failure. Here, neural network is used for compute the appropriate set of voltage and frequency to achieve the maximum efficiency for any value of operating torque and motor speed.

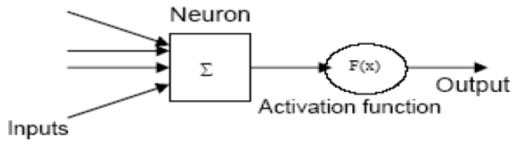

Fig.7 Simple Artificial Neuron

V. TESTING PROCEDURE

ANN PROGRAM USING MATLAB:

```
p=[330.51 344.22 359.02 0.082757 19.88 29.012 30.078 41.039 54.522 68.712 79.413 89.65 90.374 100.32 110.48
129.4 139.12 149.29 150.23 163.67 172.09 182.3 190.08 209.82 210.46 220.15 236.1 249.96 257.92 269.99 270.49
285.11 294.27 301.9 315.15 329.99];
%p=p';
o=[1 1 1 1 1 1 2 2 2 2 2 2 3 3 3 3 3 3 4 4 4 4 4 4 5 5 5 5 5 5 6 6 6 6 6 6];
net.numInputs=1;
net.numLayers=3;
net = newff([0 360],[36,1],{'tansig','poslin'},'traingdm');
net.trainparam.lr=0.002;
net.trainparam.epochs=5000;
net=train(net,p,o);
%net = newlind (p,o);
gensim (net,-1)
```

Simulation Block Machine parameters:

```
% Parameters of a typical induction machine.
rs=2.7; %Stator resistance
rr=2.23; %Rotor resistance
Ls=0.3562; %Stator inductance
Lr=0.3562; %Rotor inductance
M=0.3425; % Mutual inductance
P=2;   %Poles
J=0.00825; %Inertia
Vdc=2*155;%DC Link voltage
Vdc=Vdc;
tss=100e-6; % Sampling time
Tr=Lr/rr;
sigma=(Ls*Lr)-(M*M);
B=0.000;
Sls = sigma/Lr;
tr =Lr/rr;
sigma1=sigm (Ls*Lr);
c1= (Lr/M);
c2= (Ls*Lr)-(M*M);
lst=sigma/Lr;
t = 20; %N*m
t_1 = 0.8;
Vs = 220/sqrt (3);
```

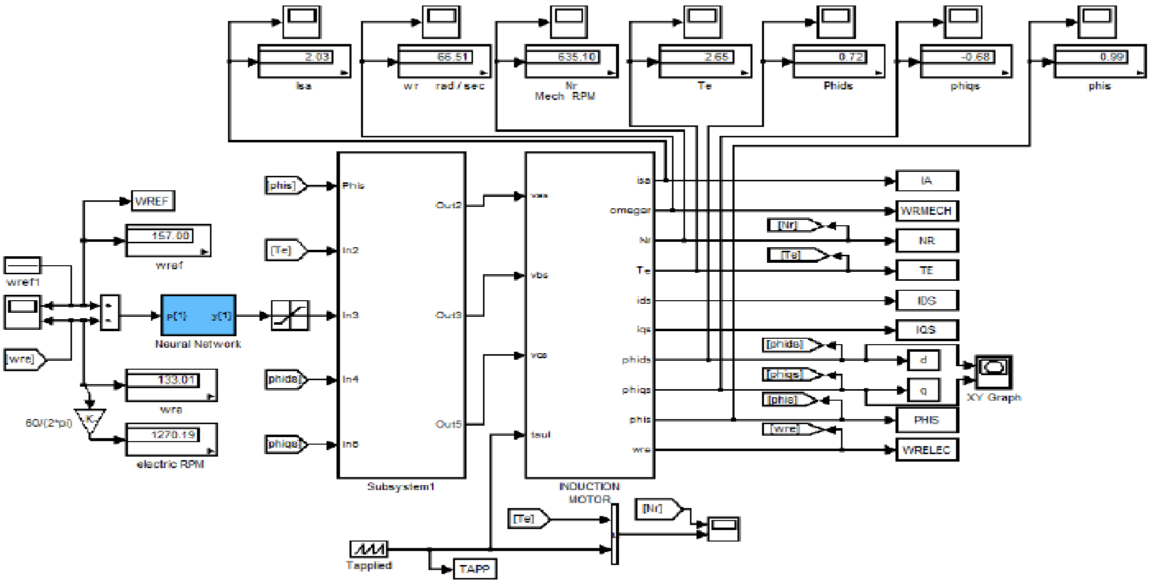

Fig.8 Simulation Block For DTC with ANN System

VI. Simulation results:

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.

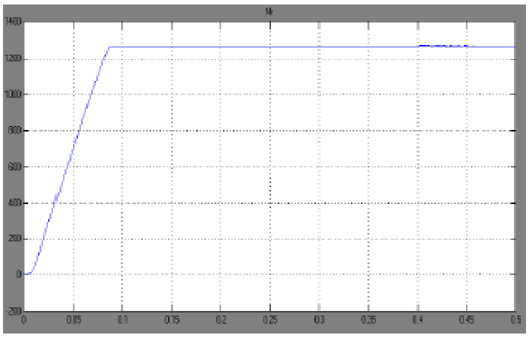

Fig.9 Speed of induction motor with ANN Based SVM

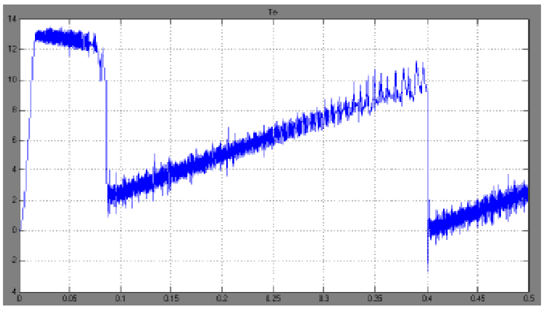

Fig.10 Electromagnetic Torque Response Waveform with ANN DTC

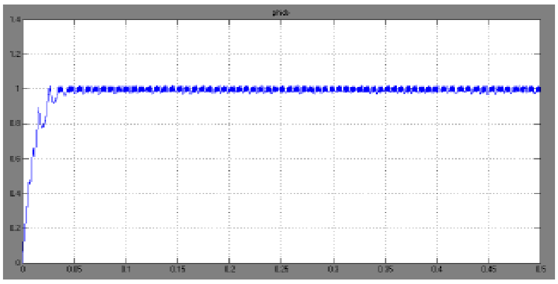

Fig.11 Stator Flux Magnitude of ANN Based DTC

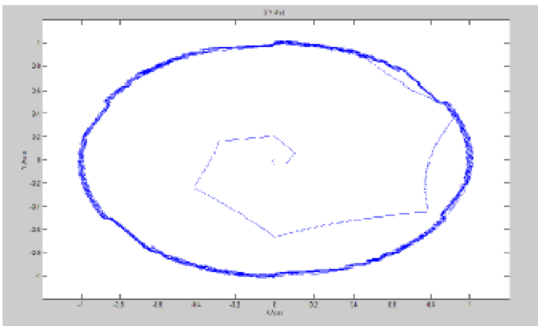

Fig.12 d-q axis Waveform With ANN Based DTC

VI. CONCLUSION

From the above the classical direct torque control technique is used for DTC control of Induction motor.In classical DTC, as the torque ripple is maintained within hysteresis band, switching frequency changes with speed. Moreover, the torque ripple is important problem at low speed. It has several other disadvantages like high current and torque ripple, 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 proposedfor conventional DTC scheme. The intelligenttechnique ANN is capable of learning the desired mapping between the input and output signals of the system without knowing the exact mathematical model of the system, so this technique is used forproper sector selection in DTC so that the rotor speed,
torque and flux performance of induction machine is improved.

FUTURE SCOPE:

The direct torque control drive for a squirrel cage induction motor can also be implementedby using a rule based fuzzy logic technique and current source inverter by which the transient torque ripples and the flux ripples are more likely to be reduced than a Direct torque control drive which employs artificial neural network technology.

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