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SIX SECTORS DTC CONTROL OF IM DRIVES BASED ON ANN WITH REGULATION SPEED USING ANFIS CONTROLLER

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Abstract: In this paper, an adaptive neuro fuzzy inference (ANFIS) based neural direct torque control (DTC-ANN) controlling of an induction machine (IM) is proposed. In this method control the Artificial Neural Network (ANN) used to replace the switching table and the speed of the IM is controlled by using the ANFIS controller. The entire proposed system is implemented in MATLAB/SIMULINK environment. And simulation results are also presented to demonstrate the attractive performance of the proposed ANFIS based DTC-ANN speed control of the induction machine. The comparison between proposed scheme control and classical DTC, show the proposed control reduced the torque ripple, stator flux ripple and Total Harmonic Distortion value (THD) of stator current of IM drives.
Keywords: IM, DTC, ANFIS, ANN, THD

INTRODUCTION

Adaptive neuro-fuzzy inference system (ANFIS) is the grouping of artificial neural network (ANN) and fuzzy logic regulator (FLC). This mixture combination enables to decrease the difficulty of power intelligent structure [1]. In the designed ANFIS system, ANN techniques are used to choose a proper rule base, which is achieved by the back propagation algorithm.

This incorporated approach improves the classification performance. Cost-effectiveness, efficiency, dynamism, reliability of the designed regulator [2].

Since, the IM has been widely used in industry due to its relative cheapness, low maintenance and high reliability [3]. The apparition of the field oriented control (FOC) made IM drives a most important candidate in high performance motion command applications. However, the difficulty of FOC algorithms led to the development in recent years of many studies to find out diverse solutions for the IM command having the features of exact and rapid torque response. The DTC command proposed by I. Takahashi and M. Depenbrock in the mid-eighties has been standard to be a viable solution to attain these requirements [4].

DTC command is characterized by its simple realization and a quick dynamic response. In addition, the inverter is directly regulated by the algorithm, i.e. a modulation method for the inverter is not needed. The major advantages of DTC command are absence of coordinate conversion and current controller, absence of divide voltage modulation block [5]. Though, DTC has high dynamic performance, it has few drawbacks such as high undulation in torque, flux, current and variant in switching frequency of the inverter [6].

This paper is presented a neural direct torque command of IM using PI controller based on ANFIS regulator. ANFIS neural direct torque control is used to improve dynamic response performance and decrease the ripples of stator flux, torque and THD value of stator current.

DIRECT TORQUE CONTROL SCHEMA

It is well recognized that DTC command operators to command the stator flux and the torque directly by selecting the parallel inverter switching situation [7]. The DTC command consisted of torque and flux controllers (hysteresis controllers), electromagnetic torque and flux estimator and switching table. It is very much simpler than the vector command system due to the existence of synchronize conversion between immobile frame and synchronous frame and PI regulators [8]. Figure 1 shows a simple structure of the classical DTC for IM drives.

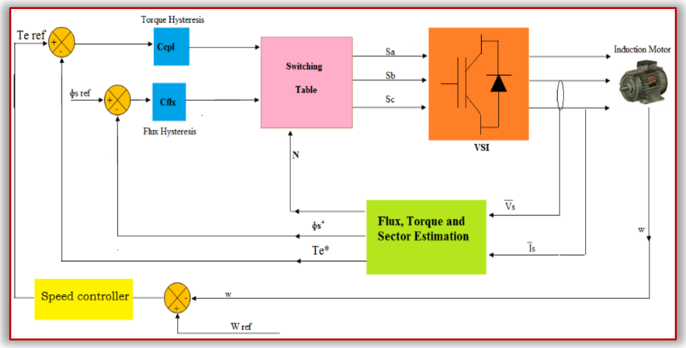


Figure 1. Basic DTC control scheme for IM.

The flux can be evaluated by integrating from the stator electrical energy equation [9]:

$$\Phi_S = \int_0^t (v_S - R_S i_S)dt \tag{1}$$

The electromagnetic torque is expected from the stator flux and stator current information as:

$$Te = \frac{3}{2} p\left[\Phi_{S\alpha} i_{S\beta} - \Phi_{S\beta} i_{S\alpha}\right] \tag{2}$$

The flux angle θs is calculated by:

$$\theta_S = \mathrm{arctg}\left(\frac{\Phi_{\beta s}}{\Phi_{\alpha s}}\right) \tag{3}$$

A two-level conventional electrical energy inverter can attain 7 divide positions in the phase corresponding to the 8 sequences of the electrical energy inverter. These positions are illustrated in Figure 2. In the accumulation, Table. 1 shows the sequences for each situation, such as: Si= 1,…,6, Si are the areas of localization of stator flux vector [10].

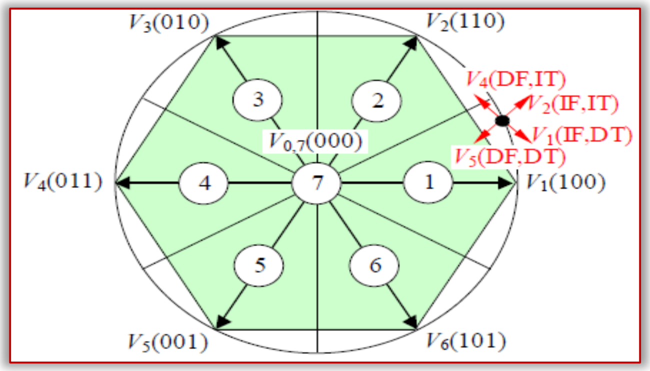


Figure 2. Different vectors of stator voltages provided by a two levels inverter, (100): (1: inverter switch is ON, 0: for OFF) I(D) F: increase (decrease) of flux magnitude, I(D) T: increase (decrease) of torque

TABLE 1. SWITCHING TABLE FOR CLASSICAL DTC WITH ZERO VOLTAGE

Cflx	Ccpl \ N	1	2	3	4	5	6
1	1	2	3	4	5	6	1
	0	7	0	7	0	7	0
	-1	6	1	2	3	4	5
0	1	3	4	5	6	1	2
	0	0	7	0	7	0	7
	-1	5	6	1	2	3	4

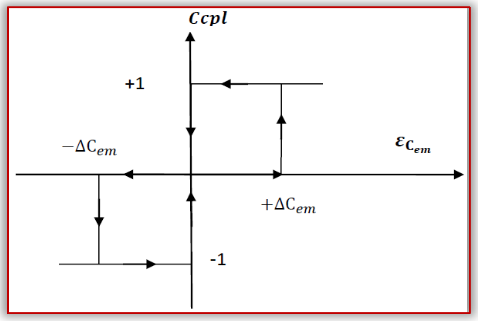


Figure 3. Torque hysteresis comparator

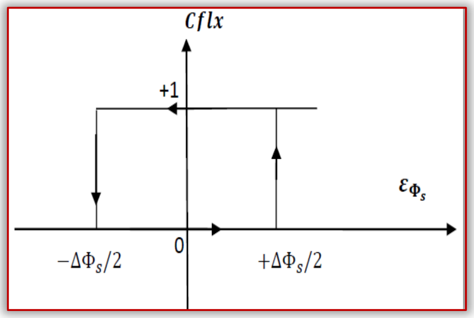


Figure 4. Flux hysteresis comparator.

Figures 3 and 4 illustrate the torque and stator flux controllers, respectively. The output of torque hysteresis comparator are (-1, 0, 1) and the output of stator flux hysteresis comparator are (0, 1).

DTC-ANN CONTROL WITH ANFIS SPEED CONTROLLER

The essential of DTC-ANN command with ANFIS speed regulator for IM drives is shown in Figure 5. ANN have self-adapting compatibilities which makes them well suited to handle non-linarites, uncertainness and parameter modifications. A multilayer feed forward ANN constructs a global expertises to non- linear input-output mapping. ANN are capable of generalization in regions of the input space, where little or no training data are available [11]. The principle of ANN techniques DTC command is similar to traditional DTC command. However, the switching table is replaced by the ANN controller.

The structure ANN has three layers. Input layer has 3 neuron, output layer has only 3 neuron and hidden layer has 30 neurons.

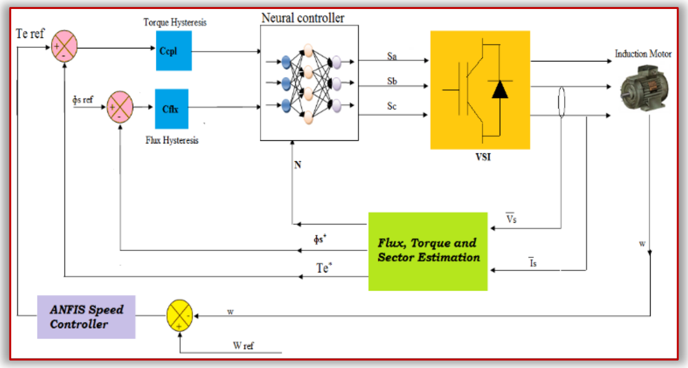


Figure 5. DTC-ANN with ANFIS speed controller.

The construction of the proposed ANN used in this command, is shown in Figure 6.

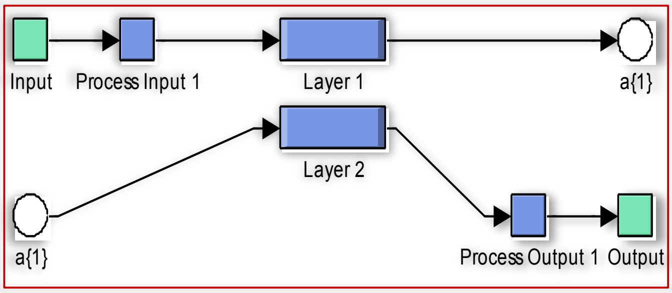


Figure 6. Structure of proposed artificial neural networks

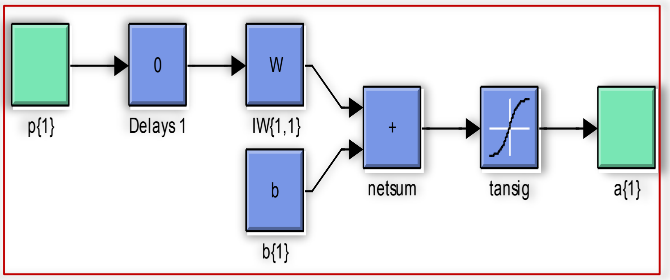


Figure 7. Structure of layer 1

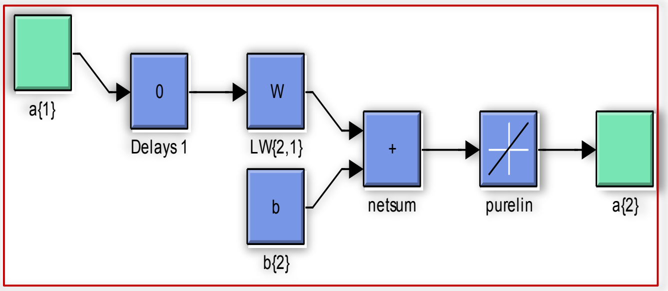


Figure 8. Structure of layer 2

In this paper, the PI controller of speed is replaced by the ANFIS regulator. The Adaptive Neuro-Fuzzy Inference System (ANFIS) controller is one of the popular neuro-fuzzy techniques that is the mixture combination of ANN and is based on Takagi–Sugeno fuzzy inference system (FIS) [12]. The ANFIS is urbanized using Matlab ANFIS editor [13]. The block diagram for ANFIS based PI regulator is shown in Figure 9.

Then the designed ANFIS has 2 inputs namely, the reference speed (w ref) and speed of motor (w) while the output is the Cem ref. The construction of ANFIS PI regulator is shown in Figure 10.

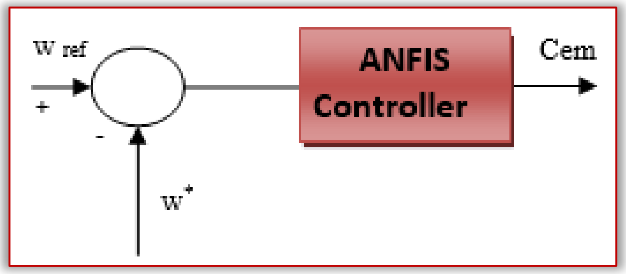


Figure 9. ANFIS control of PI regulator

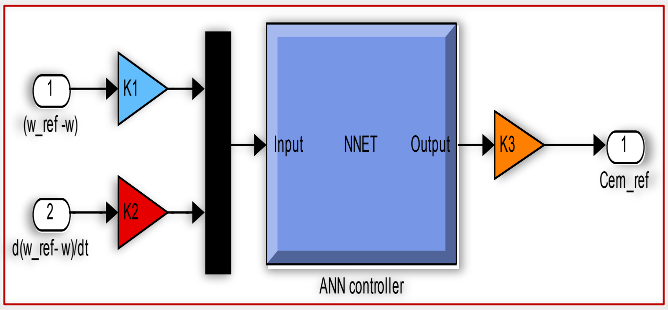


Figure 10. ANFIS construction for PI regulator.

Table 2. Fuzzy rules of speed regulator

e / Δe	NL	NM	NP	EZ	PS	PM	PL
NL	NL	NL	NL	NL	NM	NP	EZ
NM	NL	NL	NL	NM	NP	EZ	PS
NP	NL	NL	NM	NP	EZ	PS	PM
EZ	NL	NM	NP	EZ	PS	PM	PL
PS	NM	NP	EZ	PS	PM	PL	PL
PM	NP	EZ	PS	PM	PL	PL	PL
PL	EZ	PS	PM	PL	PL	PL	PL

The fuzzy regulator design is based on connaissance and simulation. These values compose a training set which is used to obtain the table rules [14]. On possible initial rule base, that can be used in drive systems for a fuzzy regulator, consist of 49 linguistic rules, as shown in Table 2 [15, 16], and gives the change of the produit of fuzzy regulator in borne of two input: the error (e= w_{ref} – w) and change of error (Δe).

SIMULATION RESULTS

The simulations of the neural DTC with ANFIS regulator of IM drive are compared with classical DTC command. A 3-phase, 1MW, 3 pole, IM with parameters of Rs=0.228Ω, Rr=0.332Ω, Ls=0.0084H, Lr=0.0082H, Lm=0.0078H, J=20 Kg.m2 are considered.

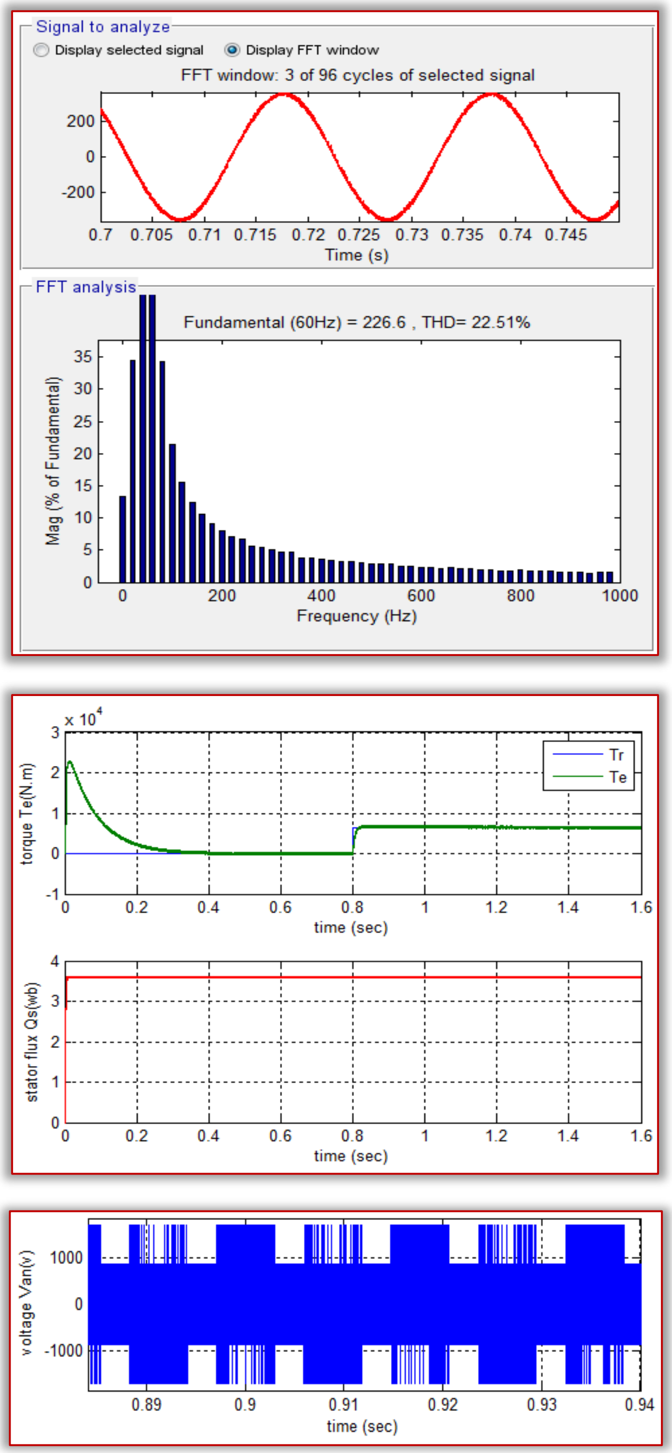


Figure 11. Performances of classical DTC command

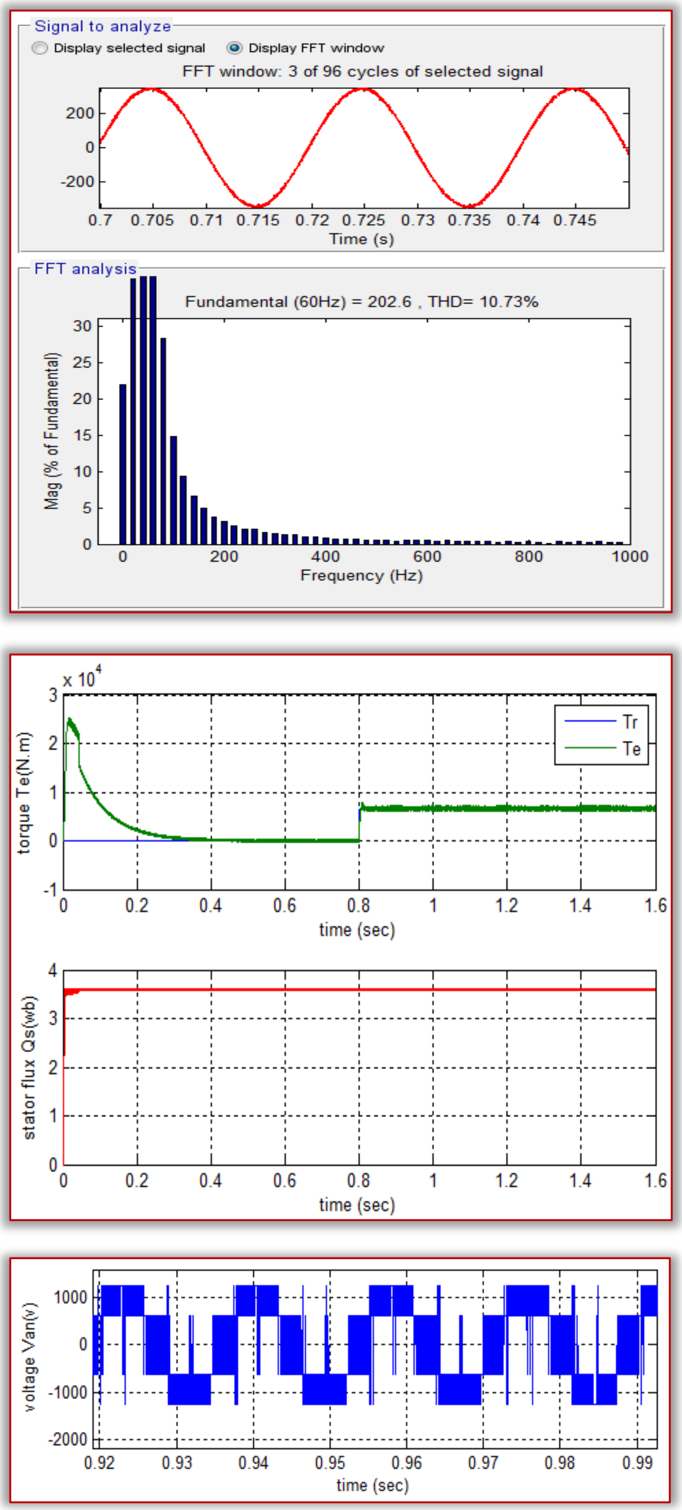
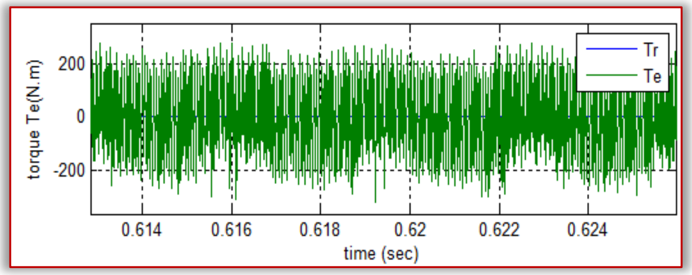


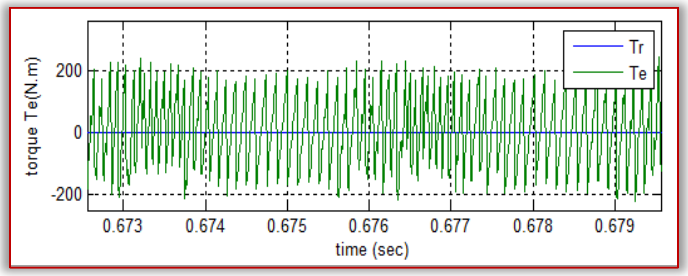
Figure 12. Performances of classical DTC-ANN with ANFIS speed controller

Figures 11-12 shows the harmonic spectrum of one phase stator current (Ias) of the IM obtained using FFT technique for classical DTC command and DTC-ANN with ANFIS regulator one respectively. It can be clear observed that the THD is reduced for DTC-ANN with ANFIS regulator (THD=10.73 %) when compared to the classical DTC command one (THD = 22.51 %). In the other hand, the dynamics of the components of the stator flux are not affected by the application of these load guidelines.

Electromagnetic torque response comparing curves are shown in Figure 13. See figure the electromagnetic torque ripple is significantly reduced when the intelligent techniques is in use.



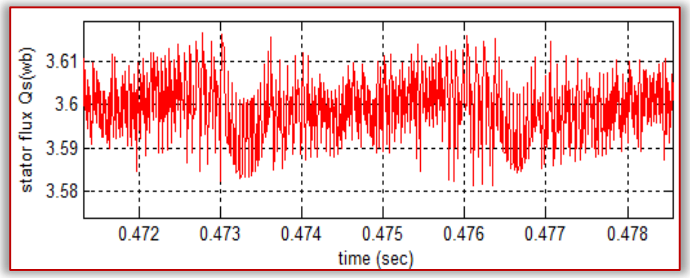
a) Classical DTC



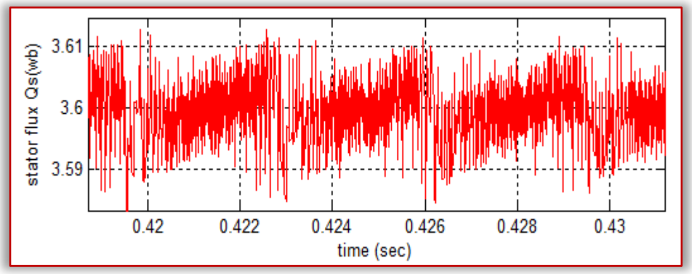
b) Neural DTC with ANFIS speed controller

Figure 13 Zoom in the torque.

Figure 14 shows that the DTC-ANN with the ANFIS PI regulator significantly reduces the ripple of the stator flux compared to that of the classical DTC command.



a) Classical DTC command



b) DTC-ANN with ANFIS speed regulator

Figure 14 Zoom in the stator flux.

CONCLUSION

In this paper, the DTC command of IM drives using intelligent techniques is presented. This intelligent technique (ANN and ANFIS) determinates the desired amplitude of switching table and classical PI regulator of speed.

The proposed DTC command schemes improve considerably the drive performance in terms of reduced electromagnetic torque, stator flux pulsations and THD value of stator current.

Therefore, proposed DTC command is an excellent solution for general purpose IM drives.

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ACTA TECHNICA CORVINIENSIS BULLETIN OF ENGINEERING
ISSN: 2067-3809