Journal of Theoretical and Applied Information Technology
15th January 2012. Vol. 35 No.1

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

NEURO DIRECT TORQUE CONTROL OF PERMANENT MAGNET SYNCHRONOUS MOTOR WITH GENETIC ALGORITHM SPEED CONTROLLER

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ABSTRACT

In recent years, permanent magnet synchronous motors (PMSM) have gained variety industrial applications, because of simple structures, high efficiency and ease of maintenance. But these motors have a nonlinear mathematical model. To resolve this problem several studies have suggested the application of vector control (VC) and direct torque control (DTC) with soft-computing (SC) technique. This paper presents neuro direct torque control (NDTC) of PMSM using genetic algorithm (GA) speed controller. The proposed method effectiveness has been verified by computer simulations using Matlab/Simulink®. These results are compared with the ones obtained with a classical DTC using PI speed controller.

Keywords: *Permanent Magnet Synchronous Motor, Neuro Direct Torque Control, Genetic Algorithm.*

1. INTRODUCTION

In the past, DC motors were used extensively in areas where variable speed operation was required, since their flux and torque could be controlled easily by the field and armature current. However, DC motors have certain disadvantages, which are due to the existence of the commutator and the brushes, that is, they require periodic maintenance, and they have limited commutator capability under high-speed, high-voltage operational conditions. These problems can be overcome by the combination of rapid development of semiconductors, microprocessors and control technology of alternative current (AC) motor. Now PMSM has become a leading in the industrials applications because it has simple and rugged structure, high maintainability and economy, it is also robust and immune to heavy overloading, etc [1]. Its small dimension compared with DC motors allows PMSM motor to be used widely in industrials applications.

Direct torque control method is one of the newest control systems for PMSM based on vector control of electric motors [2]. This method was invented originally for induction motor (IM) by Takahashi [3] and Depenbrock [4] in 1986 and 1988 respectively, and then a lot of improvements over their proposed method have been made by other researchers for PMSM. The DTC of a PMSM motor involves the direct and independent control of the flux linkage and electromagnetic torque, by applying optimum current or voltage switching vectors to the converter.

Recently, intelligent control, acts better than conventional adaptive controls. Artificial intelligent (AI) which is generally regarded as the aggregation of fuzzy logic control, neural network control, genetic algorithm and expert system, has exhibited particular superiorities and used widely in electrical drives [5][6]. [7] implemented a neural-network based space-vector PWM controller for three-level voltage fed inerter induction motor drive, where [8] presents excitation control of synchronous machine using polynomial neural networks, also the neural network controller for synchronous machine is presented in [9] and a fuzzy logic controller for synchronous machine and induction motor are presented in [10][11] while [12] presents a neuro-fuzzy controller for speed control of a permanent magnet synchronous motor drive. Others studies have suggested the application of the techniques of artificial intelligence (AI) to control speed loop of AC motors as one of them PMSM [13][14].

This paper proposes NDTC of PMSM with GA speed controller simulations. The performance of

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this method investigated with different PMSM parameters in simulation. In order to prove the superiority of the proposed GA controller with neuro selector, its performances are compared to those obtained by a conventional PI [3]. The proposed method based PMSM drive is found to be more robust as compared to the conventional PI based drive and hence found suitable for high performance industrial applications.

The contents of this paper are organized as follows. In section 2, the proposed method control of PMSM is implemented, analytic model of PMSM is developed in section 3, the principal of neuro selector and GA controller are treated in sections 4 and 5, motor parameters and comparisons between simulation results are given and show the validity and the limits of the proposed method in sections 6. Finely section 7 concludes the paper

2. PROPOSED METHOD CONTROL OF PMSM

Based on the theoretical statements and GA controller with neuro selector, the intelligent control structure of a PMSM drive system with DTC shall now be looked at in some more detail in figure 1.

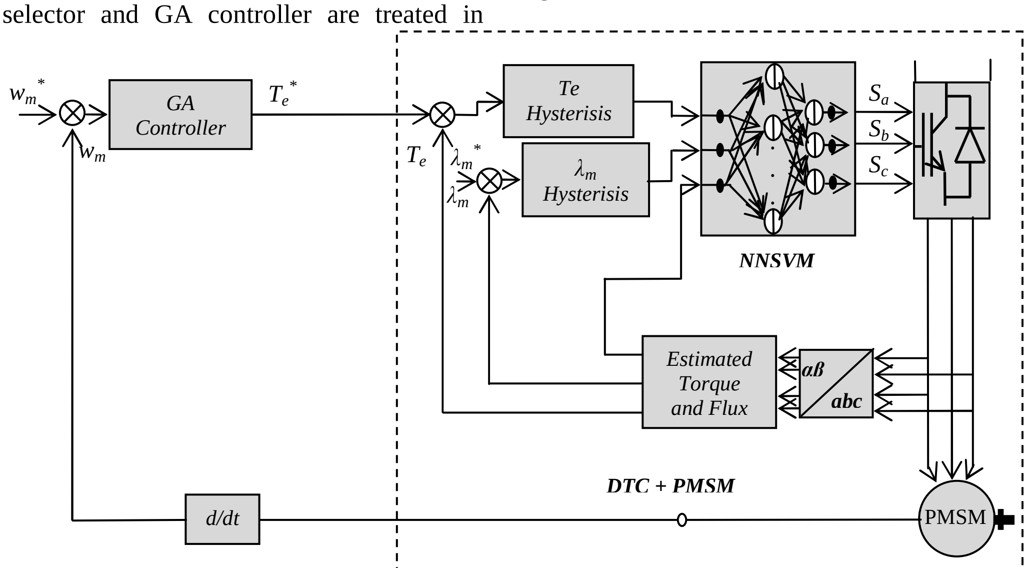


Figure 1 Structure of NDTC for PMSM based on GA speed controller

The rotor speed wm is compared with the reference speed. The resulting error is processed in the GA speed controller for each sampling interval. The output of this is considered to be the reference torque

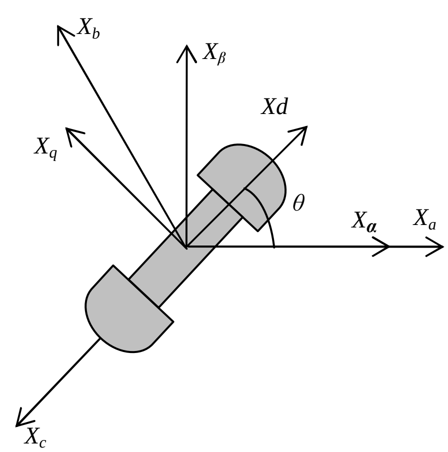
The neuro selector calculates the Sa, Sb and Sc from the outputs of hysteresis comparators HT, Hf and Si. After processing the well known of inverter, the stator voltage is finally applied on the motor terminals with respect to amplitude and phase

3. ANALYTIC MODEL OF PMSM

By developing the coupled three-phase mathematical model of PMSM, the (dq) axis current, voltage and flux will be obtained from two transformations.

The first part transfers the three phases (abc) to two phases (αβ) .The second part is the quantities at stationary to rotational frame (dq) Fig 2. Where θ represents the rotor position, X_i represents the stator currents, voltage vector and flux at several reference frames.

i: is a, b, c, d, q, α and β



Vector diagram of PMSM

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Then electromechanical behavior of the PMSM in the (dq) frame is expressed with the following equations:

$$V_d = Ri_d - \omega_r \lambda_q + \frac{d\lambda_d}{dt} \quad (1)$$

$$V_q = Ri_q + \omega_r \lambda_d + \frac{d\lambda_q}{dt} \quad (2)$$

$$\lambda_d = L_d i_d + \lambda_m \quad (3)$$

$$\lambda_q = L_q i_q \quad (4)$$

$$T_e = \frac{3}{2} p\left(\lambda_m i_q + \left(L_d - L_q\right) i_d i_q\right) \quad (5)$$

$$\frac{d\omega_r}{dt} = \frac{p}{J}\left(T_e - B\omega_r - T_m\right) \quad (6)$$

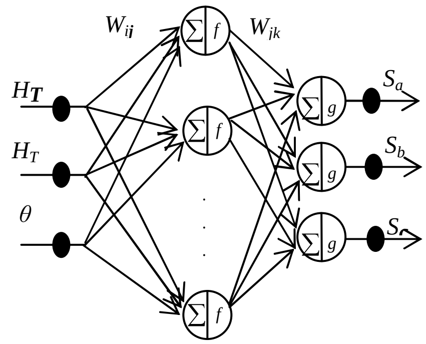
$$\omega_r = p\omega_m \quad (7)$$

Where R represents stator resistance, V_d and V_q represent stator voltage at rotational reference frame, w_r, w_m represent electrical and mechanical rotor speed, λ_d and λ_q represent stator flux at rotational reference frame, λ_m represents stator flux linkages due to the permanent magnet, T_e represent electrical torque, p represents the number of pole pairs, J represents rotor inertia, B represents friction T_m represents mechanical load torque, and L_d, L_q represent stator inductance.

4. NEURO SPACE VECTOR MODULATION

The Neural network (NN) is the most generic form of Artificial Intelligence (AI) for emulating the human thinking process, is particularly suitable for solving many important problems as SVM. The NN uses a dense inter connection of computing nodes to approximate nonlinear function. The neural network selector inputs proposed are the position of stator flux vector represented by the number of the corresponding sector, the error between its estimated value and the reference value and the difference between the estimated electromagnetic torque and the torque reference that is to say three neurons of the input layer Fig 4 [17].

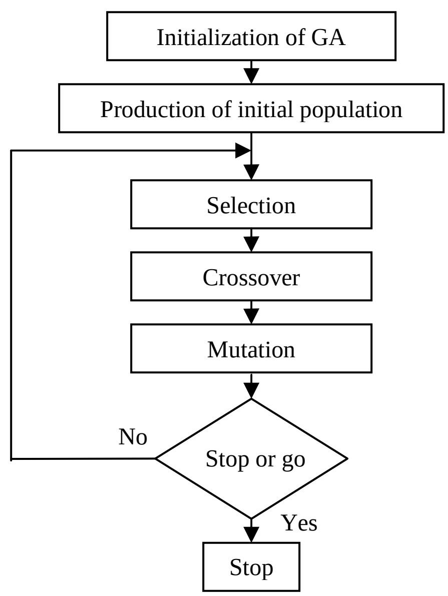
Using a general flowchart for neural network with backpropagation (BP) training algorithm, and after several tests the architecture 3-17-3 with tansig hidden layer and purelin output layer is established to illustrate the neural network voltage selector Fig 3.



Neural network voltage selector

5. GA CONTROLLER

GA is based on an analogy to the genetic code in our own deoxyribonucleic acid (DNA) structure, where its coded chromosome is composed of many genes. GA approach involves a population of individuals represented by strings of characters or digits. Each string is, however, coded with a search point in the hyper search-space. From the evolutionary theory, only the most suited individuals in the population are likely to survive and generate offspring that passes their genetic material to the next generation. Fig 4 shows the flowchart of GA [15][16].



GA flowchart

In order to design A PI controller with the transfer function (KpS+KI)/S a genetic algorithm is employed to optimize Kp and KI of control process. The configuration of genetic algorithm parameters in this paper used is given in Tab 1[17].

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Parameters	Value
Crossover probability	0,9
Mutation probability	0,001
Generation number Population	100
Population	80
Chromosome length	16 bit

Table : 1

The fitness function of each individual of this study is expressed by the equation (8):

$$fitness = 1/MO + 2*ST + 1 \quad (8)$$

Where:
MO: represents the overshot and
ST: is the settling time

6. PARAMETERS OF PMSM AND SIMULATION RESULT

The following table represents the parameters of PMSM:

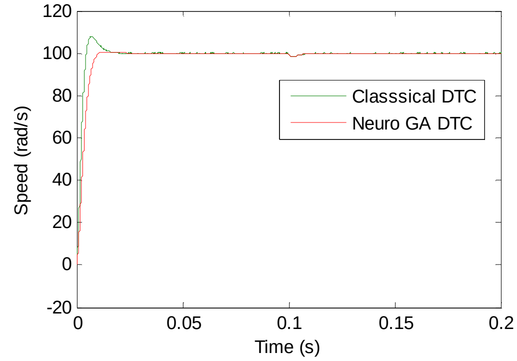
Parameter	Value	Unit
Stator resistance. R	1.4	Ω
d-axis inductance.	6.6	mH
q-axis inductance.	5.8	mH
Magnetic flux constant	0.1546	Wb
Friction coefficient.	0.00038	$N \cdot m \cdot rad^{-1} \cdot s^{-1}$
Motor inertia.	0.00176	$Kg \cdot m^2$

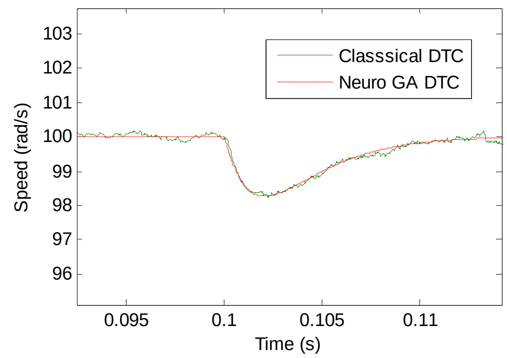
Table : 2

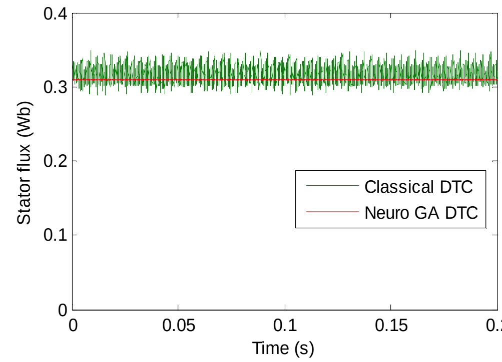
The neuro DTC of PMSM with GA speed controller is done using Matlab/Simulink®. And results are discussed and compared with classical DTC.

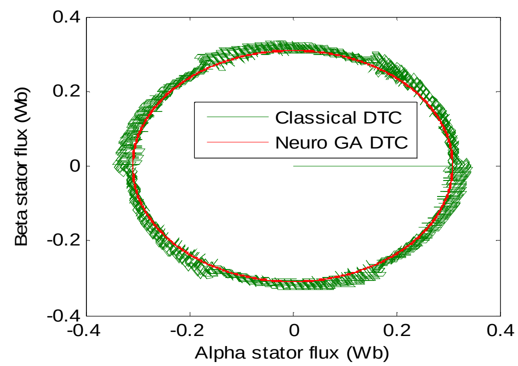
Figure 5 illustrates the simulation results of both technical command, classical DTC and the proposed Neuro GA DTC, where a reference speed equal to +100 rad /s and stator flux equal to 0.3128 Wb. It is noted that the classical DTC presents a large overshoot speed with harmonic ripples, and we can see that the proposed DTC has a high dynamic without overshoot, start-up, the response time are reduced compared to the classical DTC and the harmonic ripples is reduced also.

At the moment t=0.1s we have applied 4N.m load torque to PMSM, the results of simulation are satisfactory and the robustness of this neuro GA DTC is guaranteed more than the conventional DTC. We always see that the control suggested more powerful than the classical method.









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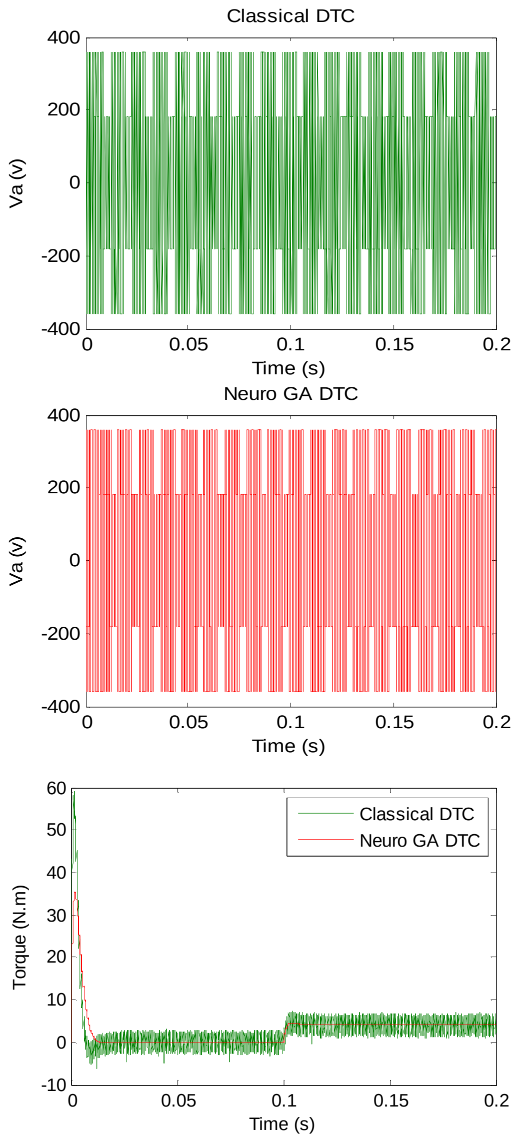

Simulated speed, flux, voltage and torque responses of the PMSM drive with Neuro GA DTC for a 100 speed reference with a fixed charge of 4N.m.

7. CONCLUSIONS

The simulation results shown with Matlab/Simulink® in this proposed study prove the superiority of soft computing to control non linear systems. In contrast to classical control we show that the soft computing control is designed without mathematical model.

Our future research work is to develop and improve other intelligent techniques such as the fusion of neural network with fuzzy logic by using the genetic algorithms to reduce more the torque ripple of the PMSM.

Integrate the training algorithm of neural network by resolving the local minima problem of backpropagation

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