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Simulation Research of Brushless Direct Current Motor Speed System Based on Neuro-PID Position Controller

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Abstract

A new speed control strategy is presented for high performance control of a Brushless Direct Current Motor (BLDCM). A self-tuning Neuro-PID controller is developed for speed control. The PID gains are tuned automatically by the neural network in an on-line way. In recent years, the re-searches on the control of electrical machines based on Neuro-PID Position Controller are increased.It offers inherent advantages over conventional PID controller for BLDCM, Such as reduction of the effects of motor parameter variations, improvement of controller time response and improvement of drive robustness. The BLDCM drive system was simulated by using MATLAB 7.0/Simulink software package. The performance of the proposed method is compared with the conventional PID methods. At the result, the control based on self-tuning Neuro-PID control has better performance than the conventional PID controller.

Keywords: BLDCM, Neuro-PID, Self-tunning, Speed servo system

1. Introduction

Recent advances in power semiconductor devices, microprocessor, converter design technology and control theory have enabled ac servo drives to satisfy the high performance requirements in many industrial application. Current-regulated Brushless Direct Current Motor (BLDCM) are used in many applications that require rapid torque response and high-performance operation such as robotics, vehicle propulsion, heat pumps, actuators, computer numerically machine tools and ship propulsion.

The control performance of the BLDCM servo drive is still influenced by uncertain-ties, which usually are composed of unpredictable plant parameter variations, external load disturbance, and unmodeled and nonlinear dynamics of the plant. In the past decade, many modern control theories, such as nonlinear control, variable structure system control, adaptive control, optimal control, and the robust control have been developed for the BLDCM drive to deal with uncertainties. In the application of such techniques, development of mathematical models is a prior necessity. However, such mathematical modelling which is largely based on the assumption of linearization of system might not reflect the true physical properties of the system.

The complex mathematical models which do reflect precise input-output physically relation of the system can be build, but the sensivity of parameters should be low in order to make the control system useful. And, if some changes in the plant occur, the model must be re-build and the new control law must be determined. Therefore, these control theory is difficult to apply for real world problem.

The purpose of this paper is to develop a self tuning Neuro-PID position control drive system for BLDCM. The analysis, design and simulation of the purposed controller are described. Good and robust control performance, both in command tracking and the load regulating characteristics of the rotor position, is achieved.

2. System Description and Machine Model

The Fig shows the total configuration of a field-oriented Permanent Magnet Synchronous Motor drive system investigated in this work. The system consists of a BLDCM and load, a hysteresis current controlled voltage source inverters, a field-orientation mechanism and a coordinate translator, a position control loop and a self-tuning Neuro-PID speed controller. The torque in BLDCM's is usually controlled by controlling armature current. In high-performance drives, pulse-width modulated (PWM) inverters are used to provide effective current control. Various techniques and control algorithm of current control of PWM inverters have been studied and reported in the literature. In one of these control schemes called hysteresis on-off current control, the motor currents are compared to their reference currents and the switching instants for the inverter power switches are determined using hysteresis control strategy. In this work, the hysteresis control strategy is used for current control of PWM inverter and the reference currents are produced by self-tuning PID-neuro controller.

2.1 Introduction of the Model of Brushless Direct Current Motor

The machine model is developed for the simulation work. At the developed machine model, magnetic saturation is neglected, all parameters of the motor are not assumed to be constant and dependent operation condition. All harmonic torques resulting from supply harmonics and operation temperature are neglected. The inverter is assumed to be ideal and the machine has damper windings. The machine model is shown Figure 2.

The BLDCM used in this drive is three-phase, wye-connected stator windings, six pole, 2500W, 5.75A and 5000 r/min type. The stator windings are identical, sinusoidal distributed and displaced 120°.

2.2 The Mathematical Model BLDCM

The voltage equations of the wye-connected permanent magnet synchronous machine, which is shown Figure 2, are given by,

$$V_{as} = r_s i_{as} + L_{ss}\frac{di_{as}}{dt} + \omega_r \lambda_m Cos(\theta_r)$$

$$V_{bs} = r_s i_{bs} + L_{ss}\frac{di_{bs}}{dt} + \omega_r \lambda_m Cos(\theta_r - \frac{2\pi}{3}) \qquad \text{Eq.(1)}$$

$$V_{cs} = r_s i_{cs} + L_{ss}\frac{di_{cs}}{dt} + \omega_r \lambda_m Cos(\theta_r + \frac{2\pi}{3})$$

Where r_s , L_{ss} , θ_r , ω_r ,and λ_m denote the stator resistance, stator self inductance, the position of the rotor, angular shaft speed and the flux linkage due to permanent magnet, respectively. The voltage equation of the BLDCM is established using reference frame theory to express the variables in the rotor reference frame.

This transform is:

$$f^r qdo = K_s^r f_{abcs} \qquad \text{Eq. (2)}$$

Where f may represent voltage, current or flux linkage. K_s^r , which is matrix, are as follows,

$$K_s^r = \begin{pmatrix} Cos(\theta_r) & Cos(\theta_r - \frac{2\pi}{3}) & Cos(\theta_r + \frac{2\pi}{3}) \\ Sin(\theta_r) & Sin(\theta_r - \frac{2\pi}{3}) & Sin(\theta_r + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{pmatrix} \qquad \text{Eq.(3)}$$

The voltage equations of BLDCM are transformed from abc variable to qdo variable using Eq.(3). A circuit model of a BLDCM, which is used predicting its transient behaviour, can be obtained using either of two equivalent circuits representation of BLDCM.

3. Design of the Self-tuning PID-Neuro Controller

This approach direct applications for many traditional control techniques which include adaptive control methods. Many adaptive control methods have a number of parameters or user defined polynomials that are needed to be selected or tuned in prior. These are usually by trial and error. By integrating a neural network into the control scheme, it can than tune the these parameters in on-line way. Thus this self-tuning neuro-control strategy has possible application in many traditional control approaches. The neural network is used to tune the parameters of the PID controller. The neural network is minimized error function by adjusting the PID gain, such as, KP, KI, KD. There are many artificial neural network architectures that have been proposed. One of these architecture is the feed-forward neural network (FFNN). A typical multi input, multi output two layer FNN structure is illustrated in Figure 3.

4. Simulation of the Drive System

The dynamic performance of the BLDCM drive is evaluated by using computer simulation. The control system is shown in Figure 4.

The MATLAB 7.0/Simulink software package was used to analyze the position con-troller. The simulation was run three different times for each specified reference trajectory. The first run was to demonstrate position response with nominal machine parameters. PID and Neuro-PID position controller responses are shown in Fig.5. The a–position response with only PID controller, b- position response with neuro-PID controller, c-electrical torque with Neuro-PID controller d- phase current of PMSM with Neuro-PID controller.The load torque is increased to 5 Nm at 0.3s.

The electrical time constant is increased to 1.5 times the nominal value for PID and neuro-PID controllers. The simulation results are shown in Figure 6.

5. Conclusion

A robust BLDCM drive system, which is based on self-tuning PID neuro-control structure , has been presented in this paper. A PI position controller was described first. Next self-tuning Neuro-PID speed controller is designed with three layer and three output neural network. The Neural Network is tuned PID gains on-line. Then, the self-tuning Neuro-PID controller was on line designed to match the time domain reference tracking specification under the parameter variation. In this work, the mathematical basis of the proposed controller was derived and the drive system simulated. The simulation result showed that this self-tuning Neuro-PID control strategy effectively achieved the desired dynamic performance of BLDCM.

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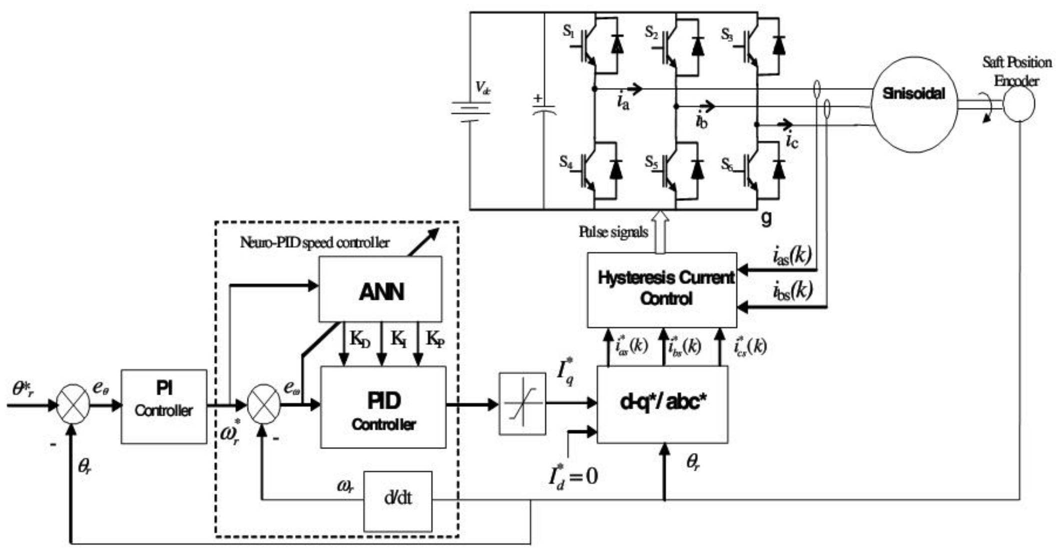
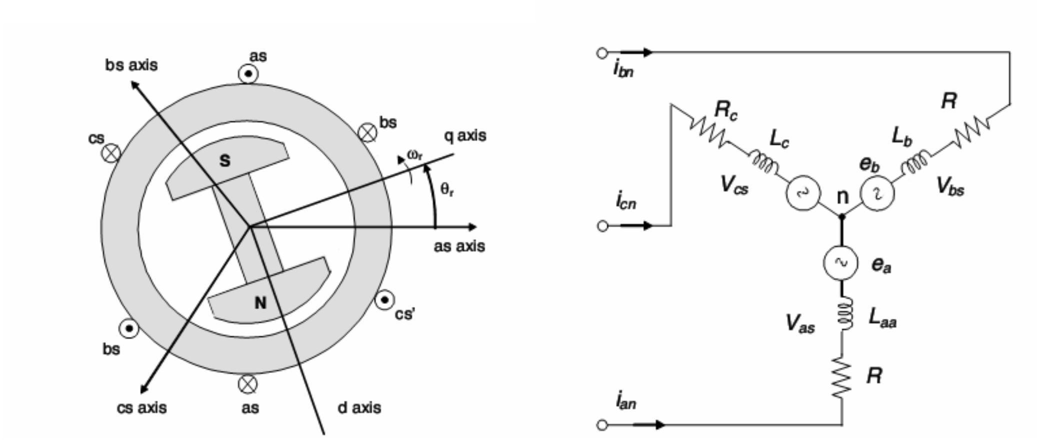


Figure 1. The block diagram of proposed BLDCM motor drive system



(a) (b)

Figure 2. Model of Brushless Direct Current Motor

(a) A BLDCM, (b) the stator windings of the machine

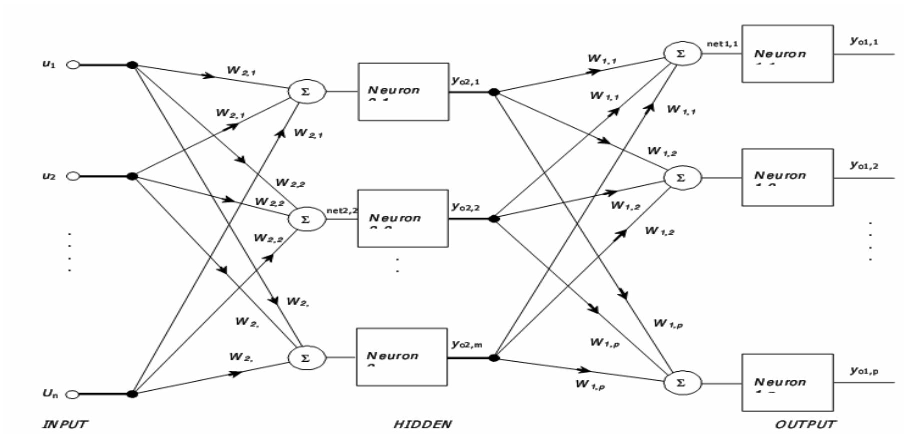


Figure 3. Topology of multi input ,multi output 2 layer feed-forward neural network

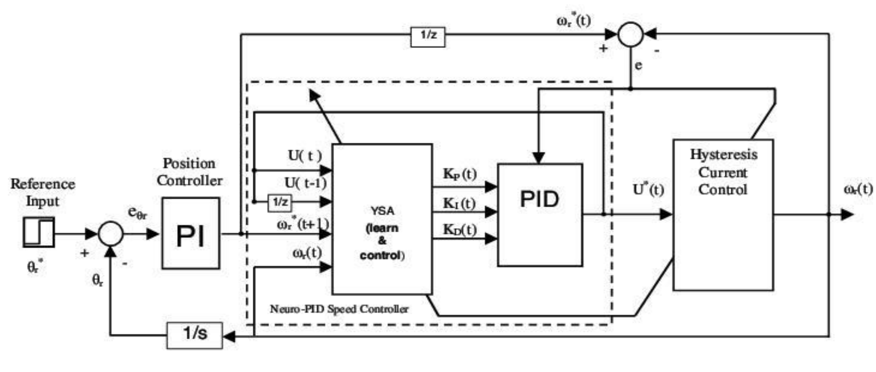


Figure 4. The block diagram of the self tuning neuro-PID control system

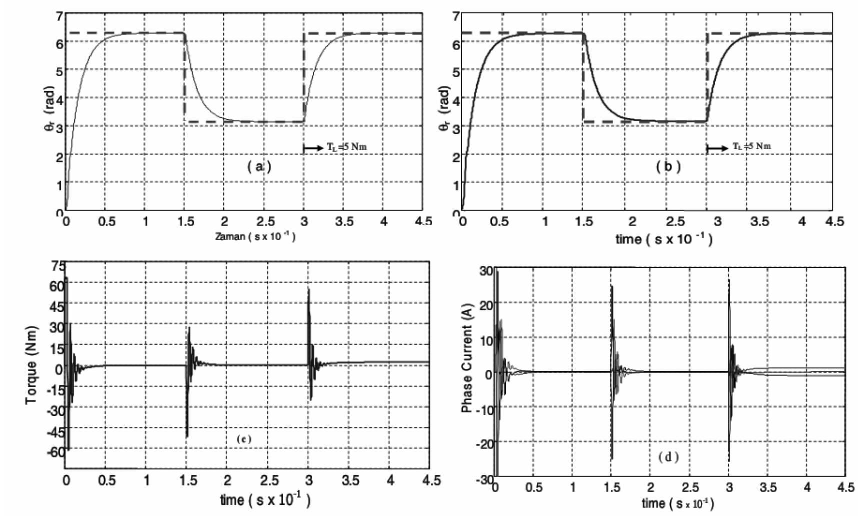


Figure 5. The simulation results with nominal parameters.

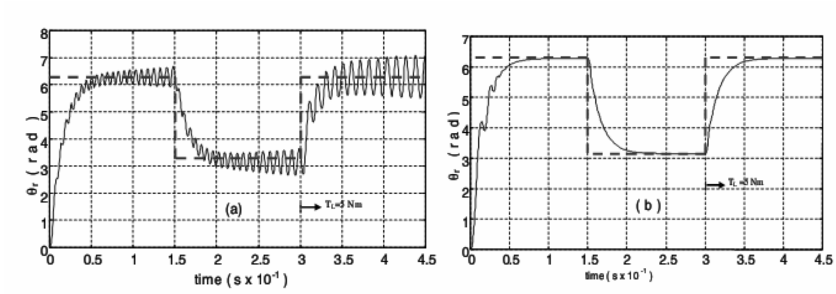


Figure 6. Simulation results with variation, a- PID, b- proposed Neuro-PID control