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PERFORMANCE ANALYSIS OF SENSORLESS BLDC MOTOR USING PI AND ANFIS CONTROLLER

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Abstract

The development of power electronics the converters are widely used in motor drive application. Industrial Applications make use of variable speed drives, because of its efficient performance. With the different PWM techniques projected for voltage fed inverters. , there is an increasing trend of using space vector PWM (SVPWM. It is easier digital realization, low level harmonics, concentrated switching losses. It is better DC bus utilization which is used here. In usual control and other sensing techniques there is a necessity to measure the speed and position of rotor by using sensors. It is because the inverter phases acting at any time, must be commutated depending on the rotor position whereas in sensor less control. The performance and reliability of BLDC motor drives have been increased much greater. BLDC Motor involves the estimation of parameters of drive system using Adaptive Neuro Fuzzy Inference system (ANFIS) algorithm which makes use of both adaptive neural networks and fuzzy logic for the estimation of rotor position and aims at minimization of error. This method is like a fuzzy inference system using a back propagation output layer. Therefore, the combination of least squares estimation and back propagation for membership function is used in ANFIS which tries to provide a faster and good dynamic response thereby speed control of BLDC motor. The torque ripple reduction is carried out. The results obtained by using MATLAB/Simulink.

Keywords: BLDC Motor, Sensor less Control, FOC, PI Controller, ANFIS Controller, Dynamic stability of motor.

1. Introduction

Household appliances are one of the fastest growing markets for BLDC (2), (4).The Common household appliances which use electric motors. These appliances have relied on traditional electric motors such as single phase AC motors including capacitor- start, capacitor- run motors, and universal motors. Now consumers demand better performance. They expect reduced acoustic noise. Hence, BLDC (7) have been introduced in order to fulfil these requirements. The BLDC (5) are usually small horsepower control motors. It provides a range of advantages such as quiet operation, high reliability, high efficiency, low maintenance and, compact form. The advantages of listed below: (i) High efficiency: The machine does not require separate field winding slip ring or brushes. The field copper losses and brush contact losses are absent, resulting in increased efficiency of the motor. (ii) The gain of the brushless DC motor in which the rotor is within the stator. The cross sectional area is presented for the armature winding, the equal time the conduction heat is improved through the frame. An increase in electrical load is achievable, provided that a greater exact torque.

2. Field Oriented Control

In BLDC motor have a permanent magnet rotor and the intelligence the rotor position which can be achieved by an external device or internally. The rotor position is essential for the operation motor. In the same way to the indirect and direct back EMF techniques are used. The Field Oriented Control (FOC) is a control method used to sense the rotor position without the help of sensors. Also known as vector control, FOC (11) provide healthier efficiency at upper speeds than sinusoidal control. It is also guarantee optimized effectiveness even in transient process by absolutely maintaining the rotor and stator fluxes. It gives healthier performance on dynamic load changes. While compared to all other provides and techniques improved performance, over the torque range than the Back EMF methods.

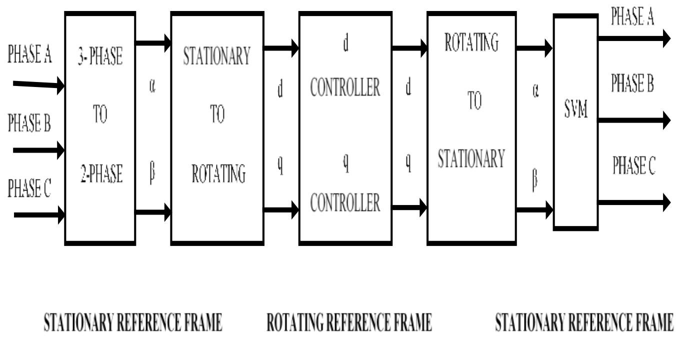

Figure 1 Transformations in FOC

3. Stator Voltage & Current Transformation

For BLDM, the performance characteristics as well as all the transient response is controlled by the voltage and the initial value of the lag angle of the rotor during the first switching ON. This angle represents the lag of the rotor d- axis with respect to the phase- A axis. It is also assumed that during the first switching ON the resultant space voltage vector was pointing along the phase- A axis. At that instant the lag angle of the rotor has been taken as –α as shown in figure2.

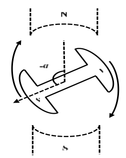

Figure2. The rotor moves from –α to (-α+60°) when the next switching takes place and the lag angle falls back to – α and the cycle repeats.

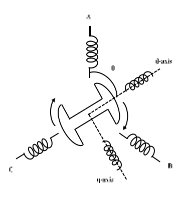

Figure 3. d-q axis transformation of BLDC Motor

This lag angle has a direct linear relation with the so called torque angle normally referred to in synchronous machines. At first the stator voltages and stator current are engaged to do the abc to dq (reference frame rotating with the rotor) transformation. This is because the permanent magnet(3) has distinct d and q axis. d-axis is taken along the axis of the PM flux and q-axis leads d-axis by 90°(electrical) as shown in figure4

$V_d = \frac{2}{3}\left[\mathrm{Va}\cos\theta + \mathrm{Vb}\cos\left(\theta - \frac{2\pi}{3}\right) + \mathrm{Vc}\cos\left(\theta - \frac{2\pi}{3}\right)\right]$

(5)

$V_q = \frac{2}{3}\left[\mathrm{Va}\sin\theta + \mathrm{Vb}\sin\left(\theta - \frac{2\pi}{3}\right) + \mathrm{Vc}\sin\left(\theta - \frac{2\pi}{3}\right)\right]$

(1)

Where θ is the angle between the d-axis of the rotor and the phase A axis at any instant of time. θ is measured in CW direction from phase A as shown in figure3.

4. Reactive And Active Estimation

This step is done to calculate the reference current with motor terminal parameter values alone.

$I_d^* = \int \frac{\mathrm{Vd}}{\mathrm{Ld}} - I_d^*\left(\frac{\mathrm{Rs}}{\mathrm{Ld}}\right) + \omega e \times I_q^*$

(2)

$I_q^* = \int \frac{\mathrm{Vd}}{\mathrm{Lq}} - I_q^*\left(\frac{\mathrm{Rs}}{\mathrm{Ld}}\right) - \omega e \times I_d^* - \omega_e\left(\frac{\mathrm{flux}}{\mathrm{Lq}}\right)$

(3)

Where, I_d^* - Ref current

ω_m- approximate speed

5. Space Vector Transformation

A three phase inverter (9) provides a three phase ac supply which could be given to a three phase motor. The switches must be controlled so that at no time are both switches in same leg turned ON or else supply would be shorted. It has 6 active states and 2 zero states totally 8 sectors which is shown in figure 4. The rotating reference voltage is sampled at high sampling frequency which has its own limits.

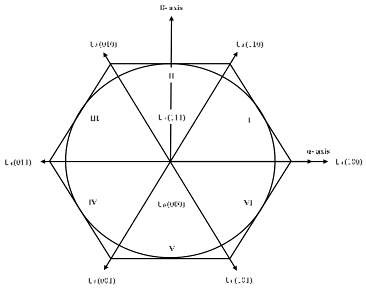

Figure4. Sector diagram of SVPWM

Each switch have the specified time period of conduction when the sector number is selected using the voltage values obtained from above step and voltage vectors is shown in table1

Table2.Voltage Vector for SVPWMN

VOLTAGE VECTORS	SWITCHING VECTORS			LINE TO NEUTRAL VOLTAGE (x Vdc)			LINE TO LINE VOLTAGE (x Vdc)		
	a	b	c	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
V_0	zero	zero	zero	zero	zero	zero	zero	zero	zero
V_1	one	zero	zero	2/3	-1/3	-1/3	one	zero	-1
V_2	one	one	zero	1/3	1/3	-2/3	zero	one	-1
V_3	zero	one	zero	-1/3	2/3	-1/3	-1	one	zero
V_4	zero	one	one	-2/3	1/3	1/3	-1	zero	one
V_5	zero	zero	one	-1/3	-1/3	2/3	zero	-1	one
V_6	one	zero	one	1/3	-2/3	1/3	one	-1	zero
V_7	one	one	one	zero	zero	zero	zero	zero	zero

$$=[0.5V\alpha] + \left[\left(\sqrt{3}\frac{V\beta}{2} - 0.5V\alpha\right) \times 2\right] + \left[\left(\sqrt{3}\frac{V\beta}{2} - \quad 0.5V\alpha\right) \times 4\right] \quad (4)$$

Where N denotes the sector number

Only positive values of V_α, V_β are taken. Each sector has two fixed time periods using that ON and OFF period are calculated.

ANFIS

The basic structure of ANFIS coordination is to control the speed of the BLDC Motor. It consists of four important parts knowledge base, neural network(12), the de-Fuzzification and Fuzzification (1) blocks. The Fuzzification unit change the crisp data into linguistic variables. It is specified as inputs to the law based block. The set of rules are written on the basis of earlier information and experiences.

6. Overall Block Diagram And Working

To perform sensorless (6) control the stator voltage and the stator current are the major parameters which are taken to perform control process. The overall block diagram in controlling the motor speed is shown below in figure5. Taking the stator voltage and current value whole control process is carried out.

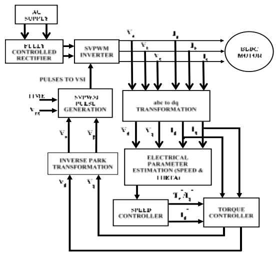

Figure5. Overall block diagram

7. Simulation Output

Dynamic speed stability curve, torque ripple reduction curve, stator current and voltage waveform are shown below. By applying the above mentioned procedures there is reduction in torque ripple while the dynamic stability(13) of the motor is attained as soon as possible whose simulation results are shown below,

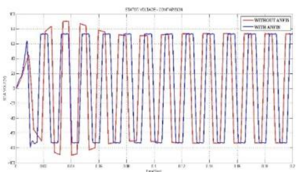

Figure6. Comparison of Stator Voltage curve using PI and ANFIS Controller

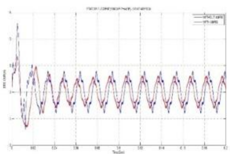

Figure 7. Comparison of stator current curve using PI and ANFIS Controller

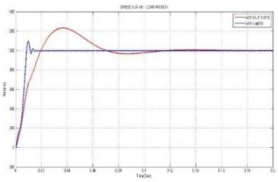

Figure 8. Comparison of Speed regulation response with PI controller and ANFIS Controller

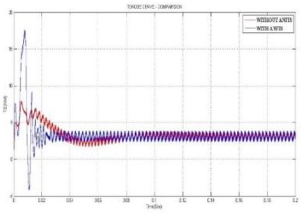

Figure 9. Comparison on Torque curve using PI and ANFIS Controller

8. Comparision On Results

SPEED WAVEFORM (FOR 1000 RPM)

METHOD	PEAK OVERSHOOT	PEAK UNDERSHOOT	SETTLING TIME
WITHOUT ANFIS	232 rpm	45rpm	0.17sec
WITH ANFIS	95 rpm	35 rpm	0.025sec

TORQUE WAVEFORM

METHOD	UPPER RIPPLE	LOWER RIPPLE	TORQUE RIPPLE ERROR
WITHOUT ANFIS	3.689 Nm	2.487 Nm	1.193 Nm
WITH ANFIS	3.85 Nm	2.39 Nm	1.46 Nm

9. C ONCLUSION

Various sensorless control techniques are being introduced and researched in order to replace the use of sensor control techniques in a BLDC system. By doing this, the cost of the system can be reduced and BLDC can be more affordable. The important PWM technique for Three Phase VSI for the control of permanent magnet synchronous motors, switched reluctance, Brushless DC and AC Induction. The space vector pulse width modulation is presented in this analysis. The Modulation Index is higher for SVPWM as compared to SPWM. The current and torque harmonics produced are much less in case of SVPWM. In case of SVPWM the output voltage is about 15% more as compared to SPWM. The SVPWM method utilizes DC bus voltage more efficiently. It produces less harmonic distortion in a three-phase inverter output. In this paper, a hybrid Neuro-Fuzzy controller is proposed for a BLDC motor drive. The control of the drive system analysed at steady state conditions and transient state. From the experimental results, favourable control characteristics are obtained using the proposed hybrid neuro-fuzzy controller which is an alternative approach for PI control. The effectiveness of the proposed control system is shown experimentally under the parameter and load variations.

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