Error Correction Control of Commutation Signal in Brushless DC Motor

Bingbing CHEN [1] , Zhongxiang ZHANG [1], yuanyuan ZHOU [1] and Weiwei MEI [2]

[1]*School of Electronics and Information Engineering,* Hefei Normal University, Anhui, Hefei 230000, P.R. China
[2]HeFei Softec Auto-Electronic Co.,LTD

***Abstract* — Aiming at the lack phase of permanent magnet brushless dc motor (bldcm) control system, which can not run normally. According to the motor back emf, which contains rotor position information, the allow hall error control system proposed for brushless dc motor. After analyzing the various error commutation with brushless dc motor which under operating conditions, used fft computation for the motor back emf signal, analysis of the power spectrum, according to the appropriate rules to identify errors commutation signals, and output the correct commutation signals, the system is simple and does not require external circuitry. Finally, used matlab/ simulink software to verify the proposed method, the experimental results show that the algorithm can get the motor's correct commutation signals in the wrong position, significantly improved the performance of the motor controller.**

Keywords - BLDCM*; *MATLAB/SIMULINK*; *FFT

I. INTRODUCTION

In recent years, brushless DC motor with good dynamic performance has been WIDELY USED IN OFFICE AUTOMATION, INSTRUMENTATION, model aircraft and appliances, and other fields[1].Because of the motor with brushless, correct commutation signals which relies on the position sensor are exported, combined with the corresponding signal conditioning circuits. The signals are sent into the controller, and than controller output the correct commutation signals. Usually, position sensors contain encoder and Hall sensor[2], among them encoder applications commonly used in high-precision, but it has higher cost. The system used Hall sensor. In FIGURE 1, it shows a block diagram of brushless DC motor control system.

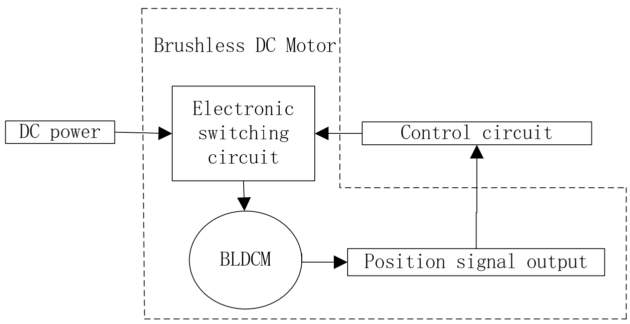

Figure 1. Brushless DC motor control system block diagram.

In order to reduce the position sensor work unreliability. Many scholars have studied the sensorless control strategy, which commonly used methods contains back-EMF detection method, inductance method , freewheeling diode method and the third harmonic method[3][4][5], among them back-EMF method is the most widely used. Since the counter electromotive force is proportional to motor speed, so the method depends on counter electromotive force of the motor is detected. Therefore, the counter electromotive force detection becomes difficult, when the motor work in lower speed. Also the method requires a complex algorithm program which makes sure the back-EMF signal converted to the correct commutation signals. These factors will make the performance of the controller system decreases[6]. The paper presents an efficient control strategy, on the one hand it solved the system not work which caused by the operating position sensor, on the other hand the system' s structure simple, reliable operation.

II. WORKING PRINCIPLE ANALYSIS OF BRUSHLESS DC MOTOR

The system used a three-phase brushless DC motor, assumed that the motor winding is star connection, and therefore the electrical angle between the three Hall sensors is 120° . Hall sensors output level, according to the rotor polarity output corresponding high and low, therefore, commutation signals shows 180° high level and 180° low level within one electrical cycle[7], ideally Hall sensor output correct commutation signal according to the rotor position picture as shown in Figure 2.

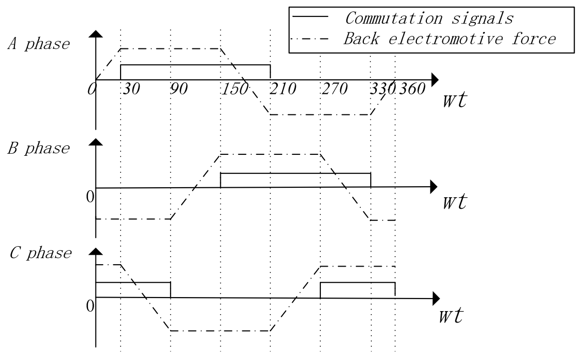

Figure 2. Motor back EMF and commutation signals in the ideal case

Hall sensor has two errors working condition during operation, one is correct commutation signal is high, but the actual produce low level, the paper mark Hall = 0 indicates this operation. Otherwise, when the correct commutation signal is low, but the actual commutation signal is high, this time in Hall = 1 indicates the error[8].

A commutation signal occur any error will affect the drive signal of one or two MOS tube, such as Hall sensor (HallA) produces the wrong commutation signals. Suppose HallA = 0 occurs, the correct opening sequence is: Q1Q2→Q1Q4 → Q3Q4, but because of the signal output from the Hall sensor A always 0, so the opening sequence becomes:Q5Q2→no MOS open →Q3Q0, which will seriously affect the operation efficiency of motor, which including motor torque, speed and line.

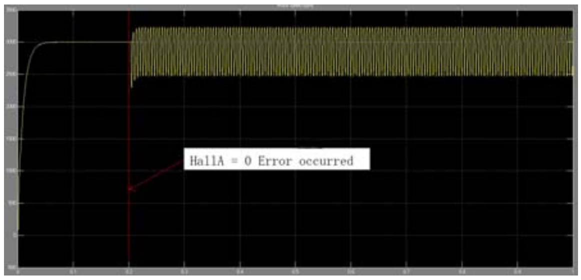

Figure 3. Velocity waveform of motor when one commutation error occur

Voltage and other parameters, In figure 3, it shows the speed comparison which occurs before and after HallA = 0 errors.

TABLE I. A PHASE HALL SENSOR OUTPUT IS ALWAYS ZERO

Electrical angle range	MOS switch situation	
	normal situation	*H_{allA}=0 situation*
30°- 90°	*Q1、Q2*	*Q5、Q2*
90°- 150°	*Q1、Q4*	*Non*
150°- 210°	*Q3、Q4*	*Q3、Q0*

III. ALLOW HALL ERROR CONTROL ALGORITHM

It can be obtained from the above analysis, three Hall sensor output commutation signal is unlikely to be 0 or 3 which is the sum of Hα、Hβ、Hχ at any time, and in addition the sum only can be 1 or 2, the following will use variable Hτοταλ to represent the sum.

$$H\tau o\tau\alpha\lambda = H\alpha + H\beta + H\chi \qquad (1)$$

Within a power cycle, Hτοταλ’s value is 1 or 2 under normally. If the value is 0 or 3, then directions a commutation signal error has occurred. When Hτοταλ = 0, indicating the output signal of a phase sensor has been zero, on the contrary, if Hτοταλ = 3, then the output signal of a phase sensor has one. Next we need to determine Hall sensor appear the problem in which phase, and the Hall sensor in which problem. We give an example still with phase A Hall sensor for analysis.

FFT is a fast algorithm for discrete Fourier transform. It can analyze a signal of frequency-domain information. Motor back EMF signal is difficult to see any features in the time domain, shown in Figure 4, The top of Fig. 4 shows the motor A phase EMF waveform, in the middle of Fig. 4 shows B phase EMF waveform, the last one for the C phase EMF waveform. The waveform is difficult to see what happens. But if transformed to the frequency domain, it is easy to see the features.

Each point corresponds to a frequency point after FFT transform, it is easy to see the features of the signal, that is, the frequency values of amplitude characteristic. Assumed that the signal peak is A0, the relationship between A0 and original signal is: the FFT modulus value of each point is N / 2 times of A0. Figure 4 shows the motor commutation error which occurs at 0.5s, the motor’s back EMF occurs significant changes in the magnitude. Therefore, the phase problems can be judged by the FFT method. Due to the symmetry of FFT results, usually we only use the results of the first half.

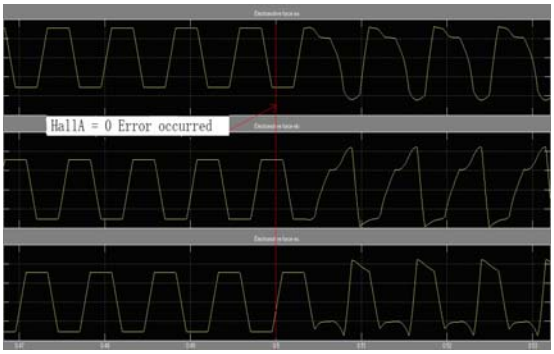

Figure 4. The Back-EMF signal waveform of motor when one commutation error occur

Brushless DC motor’s back EMF contains commutation information, so it can obtains three-phase motor back EMF’s spectrum to the use of the FFT, and then calculate the power spectrum. The first line’s two figures which in Figure 5 represents the power spectrum of A and B phases back EMF when the motor during normal operation; The second line of two figures respectively the power spectrum of A phase and B phase when occurs HallA = 0 error.

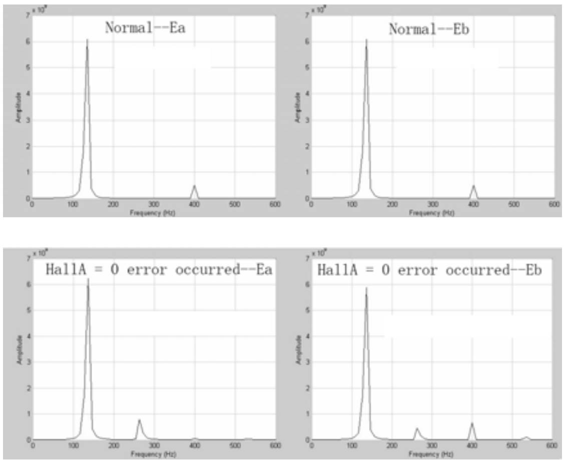

Figure 5. Back electromotive force waveform before and after error occurred

From the above figures shows, when HallA error occurs, the motor back EMF of the maximum difference compared with the normal operation is the size of the amplitude which frequency is 260Hz around. When HallB error occurs, B phase’s back electromotive force at frequency of about 260Hz have different the size of magnitude which show in Figure 6. Similarly, when HallC error occurs, the situation is the same. Therefore, the method can easily distinguish which phase commutation signal is an error occurred.

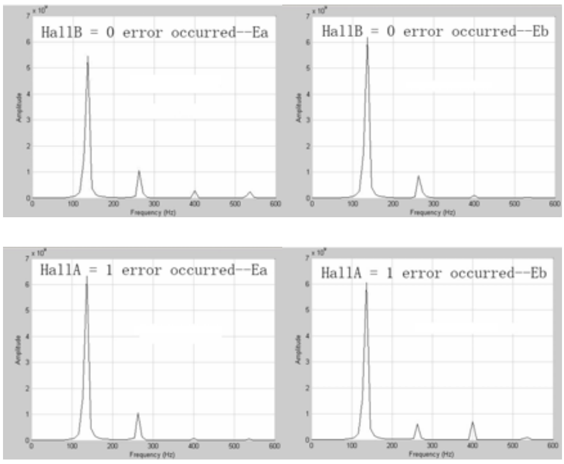

Figure 6. Back electromotive force waveform of HallA = 0 errors occurs and HallA = 1 error occur

When occurs HallA = 0 error or HallA = 1 error, the power spectrum are similar, but the size of magnitude are different which in a few key points. The magnitude of the power spectrum amplitude HallA = 1 error is significantly greater than HallA = 0 which in 136Hz, 264Hz, 400Hz and 530Hz. Table 2 lists the experimental test values.

TABLE II. POWER SPECTRAL AMPLITUDE WHEN OCCUR HALLA ERROR

Back electromotive force	Frequency (Hz)	amplitude in H_{allA}=0 (V)	amplitude in H_{allA}=1 (V)
Ea	*136*	*6234*	*6320*
	264	*787*	*1050*
	400	*51.5*	*66*
	530	*32*	*54*

When the controller did not get the right commutation signals, control system performance will be greatly reduced. First, the system by detecting three Hall sensor's sum, if the value is not equal to 1 or 2, which indicating the system does not get the right commutation signals; And secondly, by detecting By detecting three-phase back electromotive force of the power spectrum, in order to determine which specific phase sensor errors; Finally, by calculating the magnitude of corresponding to the power spectrum for distinguish HallA = 0 and HallA = 1 error.

IV. THE EXPERIMENTAL RESULTS

System conducts simulation for Allow Hall Error control by Matlab software. The simulation parameters are as follows,the motor load torque T_L = 3N· M, the stator resistance Rs = 1ohm, phase inductance Ls = 0.001H, moment of inertia J = 0.8 × 10^{-3} kg · m^2, motor pole pairs P = 4, the motor occurs H_{allA} = 0 errors at 0.2s, test motor running at 2000 rad / min, a power cycle of motor normal operation time t_{360} = 0.0075s.

Figure 7 shows, the method can output the correct commutation signals after HALL error occurs about 0.15s. After the correct output, the motor speed waveform remains smooth, correct the mistakes output for a short time. It can meet the daily applications. In addition, motor torque ripple is significantly reduced after correct output, consistent with the normal operation of the motor. It proved the feasibility of the method.

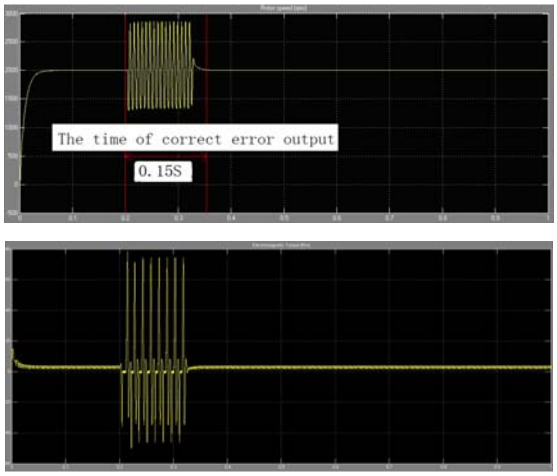

Figure 7. the motor 's speed and torque waveform in allows HALL error control system

V. CONCLUSIONS

The article describes the brushless DC motor allow Hall error control system, which can be achieved the motor still working properly when the position sensor is not properly output commutation signal. In the analysis of the motor get error commutation signal, and then explain in detail a kinds of simple handling errors commutation method. The method is by sampling the motor respectively three-phase back electromotive force, so we can get their power spectral density by FFT transforms. It can easily get specifically which phase occur error and what error has occurred through power spectral analysis. The method is simple, the motor running smoothly. It also can improve the overall performance of the control system.

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