Analysis of Two-Phase Spindle Motor Driven by Sensorless BLDC Mode

Chao BI, *Member, IEEE,* Quan JIANG, *Member, IEEE,* and Taile WEI

***Abstract*--The performance of two-phase spindle motor is analyzed, which is driven by constant voltage sensorless BLDC mode. In the motoring operation, the rotor positions are estimated by back EMF detecting and a digital filter is used to realize BLDC sensorless control. The two-phase BLDC motor is more robust in the starting and low speed operation, and can realize accurate speed control. Both the simulations and experiments show that the proposed drive mode is effective in driving spindle motors.**

***Index Terms* -- BLDC motor, sensorless control, two-phase motor.**

I. INTRODUCTION

HARD disk drive (HDD) is the most effective mass data storage device in computer nowadays. The spindle motor is one of the key components used in HDD, and its performance has a direct impact on the HDD performance. Usually, the spindle motors are made of three-phase, outer rotor, surface mounted permanent magnet (PM), and concentrated armature winding.

Currently, the three phase spindle motors with sensorless BLDC drive mode are employed and many researches have been done in their performance analysis and improvements [1, 2]. However, the development of HDD products trends to high areal data recording density and high spin speed. The former requires the accurate rotational speed, and the latter makes the speed higher than 10,000 rpm, and some of them even higher than 15,000 rpm. One major concern for three-phase sensorless high-speed spindle motor is that its starting ability is poor as the phase back-EMF is too low to be detected at the low speeds. Many methods are being developed to solve this problem and using two-phase EM structure is one of the potential solutions. Comparing with the mature three-phase spindle motor, how can we drive the two-phase motor effectively? In this paper, we will introduce a sensorless BLDC drive system to drive the two-phase spindle motors used in HDDs. The simulations and experiential results are used to analyze the features of the drive system.

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II. TWO-PHASE SENSORLESS BLDC DRIVE SYSTEM

A. The structure of two-phase spindle motor

From point of view of armature winding, if the concentrated windings are used, every 4 slots can form one electrical cycle of the two-phase motor. Fig. 1 shows the structure of a two-phase motor. For this kind of armature winding, the EM field produced by the armature winding contains rich third harmonics. Therefore, if we utilize the third harmonic, every 4 stator slots can realize 3 pole-pairs of the field, which is shown in Fig. 1.

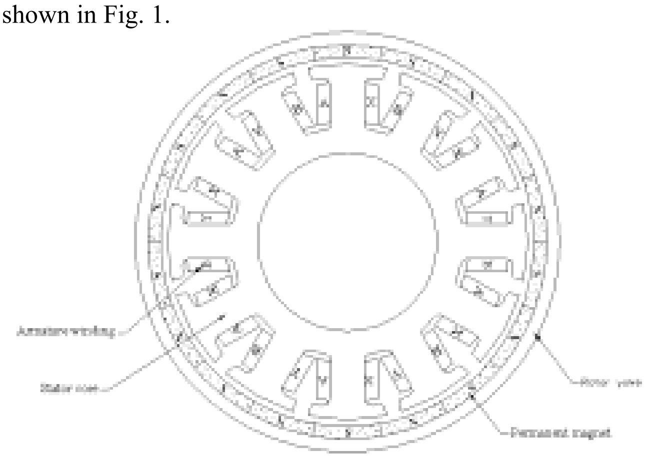

Fig. 1. The structure of the 18-pole/12-slot two-phase spindle motor.

B. The system implementation

In our research, we built up a two-phase spindle motor and its sensorless BLDC drive system. Fig. 2 shows the block diagram of two-phase sensorless BLDC motor drive system. The drive system contains a two-phase spindle motor, an adjustable DC supply, a two-phase inverter, a back-EMF detector and a DSP ADMC401.

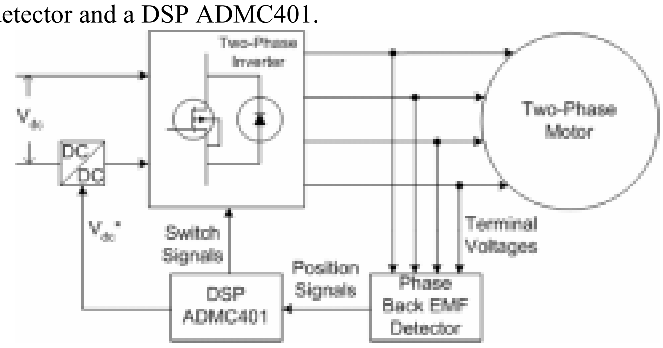

Fig. 2. The block diagram of two-phase sensorless BLDC motor drive system.

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Fig. 3 shows a typical two-phase inverter, which realizes the BLDC control for two-phase spindle motors. In sensorless BLDC control, the exciting status of a phase winding produces the effective motoring torque and the silent status of the phase is used to detect its back-EMF [3].

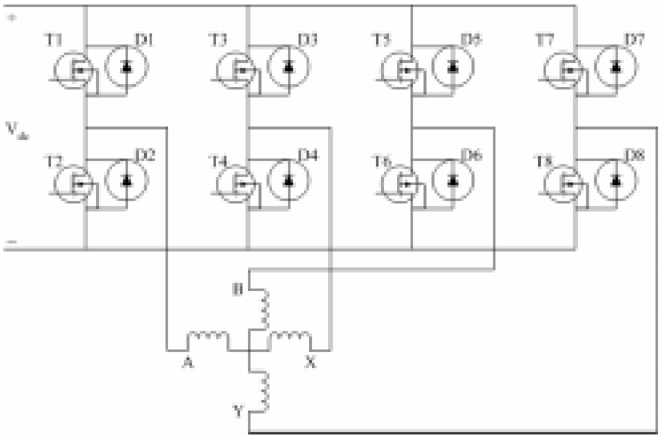


Fig. 3. Two-phase inverter configuration.

The back-EMF detector uses a compact programmable logic device (CPLD) to obtain the zero crossing signals of phase back EMF from the differential terminal voltages. The zero crossing signals are used as the rotor position signals and inputted to the DSP for further processing.

DSP ADMC401 is employed to control the two-phase motor drive in sensorless BLDC mode based on the above zero crossing signals. After recognizing the true zero crossing signals, the DSP shifts the zero crossing signals by 45° as the commutation signals for two-phase inverter. Then the two-phase spindle motor runs in BLDC mode. Also, the zero crossing signals are utilized to detect the rotor speed. According to the speed, the PI controller and DC-link voltage adjustment are used to implement the close-loop speed control of the two-phase spindle motor.

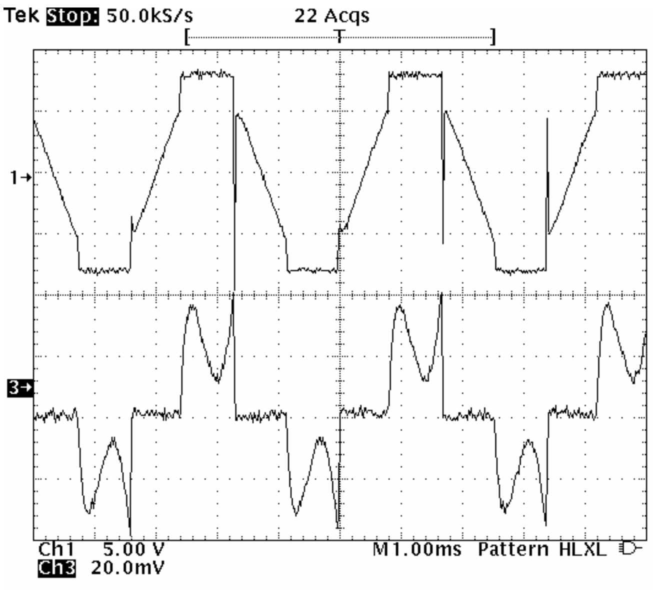
III. Simulation And Experiment Results

The model of the two-phase sensorless BLDC motor has been built and is used to simulate the motor performances. Fig. 4 shows both the simulation and experimental results of one phase voltage and current. And the testing results match well with the simulation ones.

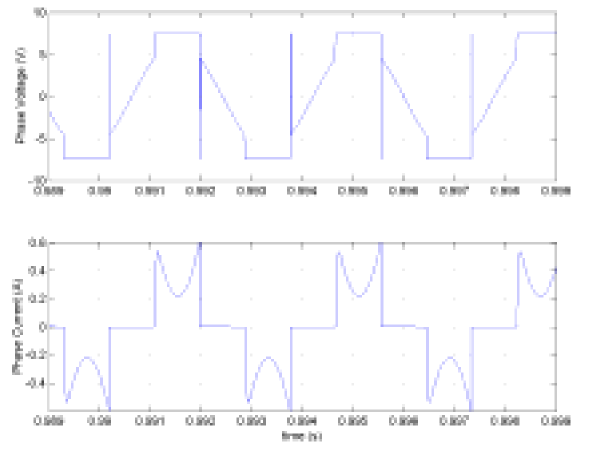
VI. Conclusions

When the motor with high rated speed spins up from a low speed, the phase back-EMF coefficient of the three-phase spindle motor is low and it makes the starting mode be difficult to be changed to BLDC mode at low speed. But, for the two-phase spindle motor, which is shown in Fig. 1, its phase back EMF is about $\sqrt{3}$ times of the three phase motor. Therefore, the drive system can be switched to BLDC mode at lower speed. This means that the motor starting time can be shorten and starting torque can be increased. All these are important to the HDDs with high spin speed.

In this paper, the sensorless drive mode for the two-phase BLDC motor is discussed, and the simulation and experimental results show that the sensorless drive mode presented is effective to the two-phase BLDC motors.



(a)



(b)

Fig. 4. Waveforms of the phase voltage and phase current in BLDC mode. (a) Experimental results. (b) Simulation results.

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