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Simulation of Brushless DC Motor Drive System

Changfeng Guo
Logistics Engineering College, Shanghai Maritime University, Shanghai 201306, China.
guomar008@outlook.com

Abstract

Brushless DC motor has the operating characteristics of DC motors, and also has the advantages of brushless AC motor. It has the advantages of small size and light weight, so they are widely used in various industrial applications. In this paper, for brushless DC motor simulation, it introduces its working principle and mathematical model, using the six-step inverter to ensure the normal operation of the motor ,with closed-loop speed structure to ensure steady-state and dynamic performance, enhanced its reliability.

Keywords

Brushless DC Motor; Closed-Loop Speed System; Voltage Regulation Control; Power Electronics; AC Drive System.

1. Introduction

DC motors have the advantages of good speed regulation performance, large locked-rotor torque, etc., so they are widely used in various motion control systems[1]. However, due to their own structure, DC motors have brushes and commutator devices. At times, mechanical friction will be generated, which will affect the accuracy and reliability of the motor. Secondly, electrical sparks generated by mechanical friction can also cause radio interference and affect surrounding communication equipment. In addition, because the contact head of the brush is divided into carbon, continuous mechanical friction will wear the brush contact, so the brush needs to be replaced regularly. In view of the above factors, people have been looking for a structure that can replace brushes and commutators[2].

In recent years, with the continuous development and technological breakthrough of power electronic technology, computer technology and permanent magnet materials, a new motor mechanism was born-a brushless DC motor. This kind of motor is a product that combines mechanical technology and electronic technology[3]. It uses inverter circuits and Hall elements to replace point brushes and commutators. Therefore, it is easy to maintain in daily use, has high reliability, and does not need to be mechanically replaced. The speed limit can reach hundreds of thousands of revolutions per minute[4]. At present, brushless DC motors have been widely used in the textile industry, paper industry, automobiles, precision machine tools and other fields..

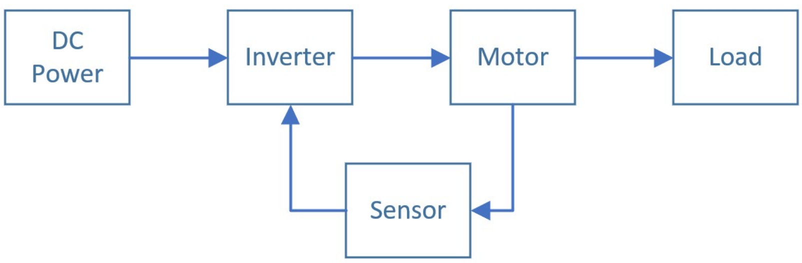

Fig. 1 Basic composition of brushless DC motor

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2. Brushless DC Motor Drive System

2.1 Configuration

The brushless DC motor system is mainly composed of the inverter circuit, the permanent magnet motor body and the sensor unit. Its structure is shown in Fig. 1. During the operation of the motor, the speed signal is obtained by the speed sensor, and the rotor position is obtained by the position sensor, so as to achieve correct position commutation and speed closed-loop control.

2.2 Principle of operation.

Different from the permanent magnet DC motor of ordinary structure, in the brushless DC motor, the armature winding is placed on the stator, and the permanent magnet is placed on the rotor. The position of the armature winding of each phase of the stator relative to the permanent magnet of the rotor is sensed by the rotor position sensor electronically or electromagnetically, and the output signal is used to drive the armature winding connected to the armature winding through the electronic switch circuit according to a certain procedure[5]. Power electronic switching devices conduct current to the corresponding armature winding. With the continuous rotation of the rotor, the position sensor continuously sends the rotor position signal, so that the armature windings are continuously energized in sequence, and the energization state is constantly changed, so that the direction of the current flowing in the armature conductors of the rotor is always unchanged.

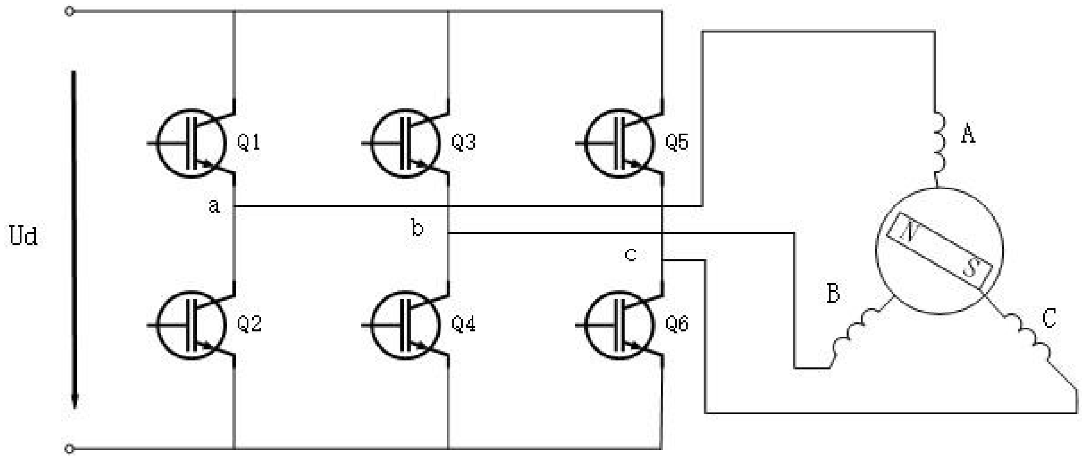

Fig. 2 Main circuit of brushless DC motor

Assuming that the power electronic switch of the three-phase bridge main circuit is a standard three-phase bridge structure, the upper bridge arm components Q1, Q2, and Q3 provide forward current to the windings of each phase to generate positive electromagnetic torque; the lower bridge arm components Q2, Q4, and Q6 provide reverse current to each phase winding to produce reverse electromagnetic torque. The circuit diagram is shown in Fig. 2.

Table 1 The relationship between position sensor signal and switch state

ha	hb	hc	Sa	Sb	Sc
0	0	0	0	0	0
0	0	1	0	-1	+1
0	1	0	-1	+1	0
0	1	1	-1	0	+1
1	0	0	+1	0	-1
1	0	1	+1	-1	0
1	1	0	0	+1	-1
1	1	1	0	0	0

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During the operation of the DC brushless motor, ha, hb, and hc are the signals of the internal position sensor of the motor, and the conduction state of the power switching device is determined by the sensor signal. When adopting the three-phase conduction working mode, the bridge arm working mode is 6 basic non-zero space vectors and 2 zero vectors. Sa, Sb, Sc represent the switching state of the three-phase bridge arm, +1 means the upper bridge arm is on, -1 means the lower bridge arm is on, and 0 means both the upper and lower bridge arms are off. The corresponding relationship between the position sensor signal and the switch state is shown in Table 1.

The sequence of the three-phase winding is A+B-, A+C-, B+C-, B+A-, C+A-, C+B-.

3. Simulation model

3.1 Control method of brushless DC motor

This simulation adopts the voltage regulation control method. In the voltage regulation control mode, the position sensor provides the rotor position, and through the function of the drive circuit, it provides the control signal to the H bridge to realize the motor synchronization. By comparing the given speed with the actual speed, the speed error is obtained; through the PI regulator, the reference voltage value is output; through the controlled source, the three-phase H-bridge circuit is provided with direct current; the output of the H-bridge circuit is provided to the motor stator three-phase winding Power supply drives the brushless DC motor to rotate[6]. The whole system constitutes a speed closed loop system, which has better steady-state performance and dynamic performance. Fig. 3 is a block diagram of the voltage regulation control mode.

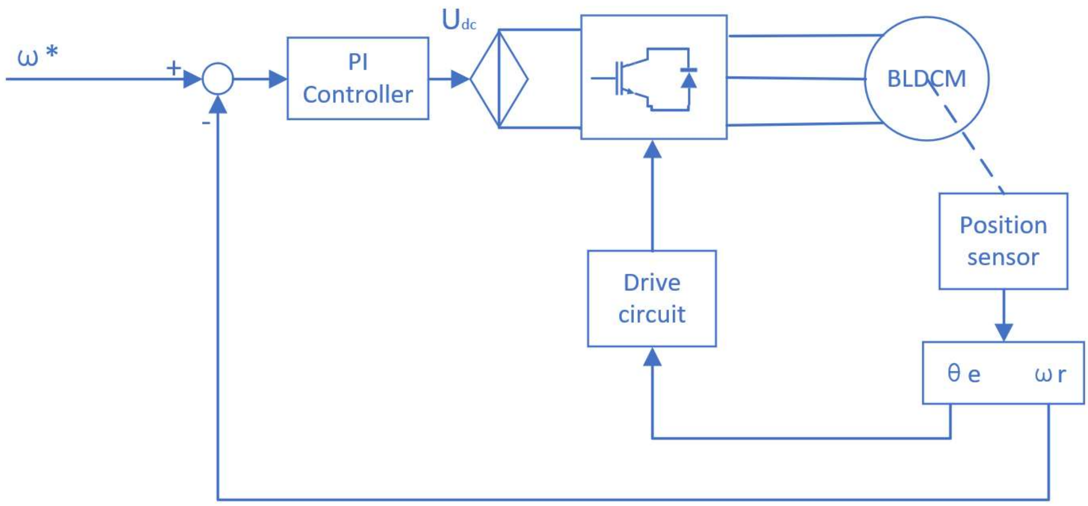

Fig. 3 Control block diagram of voltage regulation control mode

3.2 Simulation System of Brushless DC Motor

This simulation was performed in Simulink v8.8 of MATLAB R2016b. The SimPowerSystems library is used to establish a simulation model of the brushless DC motor control system. At t=0, the load is 0, t=0.1s, and the load is 3N·m. The simulation diagram is shown in Fig. 4. Among them, the parameters of the brushless DC motor are given in Table 2.

3.3 PI regulator

The brushless DC motor speed adjustment module is shown in Fig. 5, the target speed value (nref) minus the actual speed value of the motor (n), after the PI regulator calculation, output the reference voltage value (Us). The saturation limiting module is used to limit the output voltage value within a fixed range.

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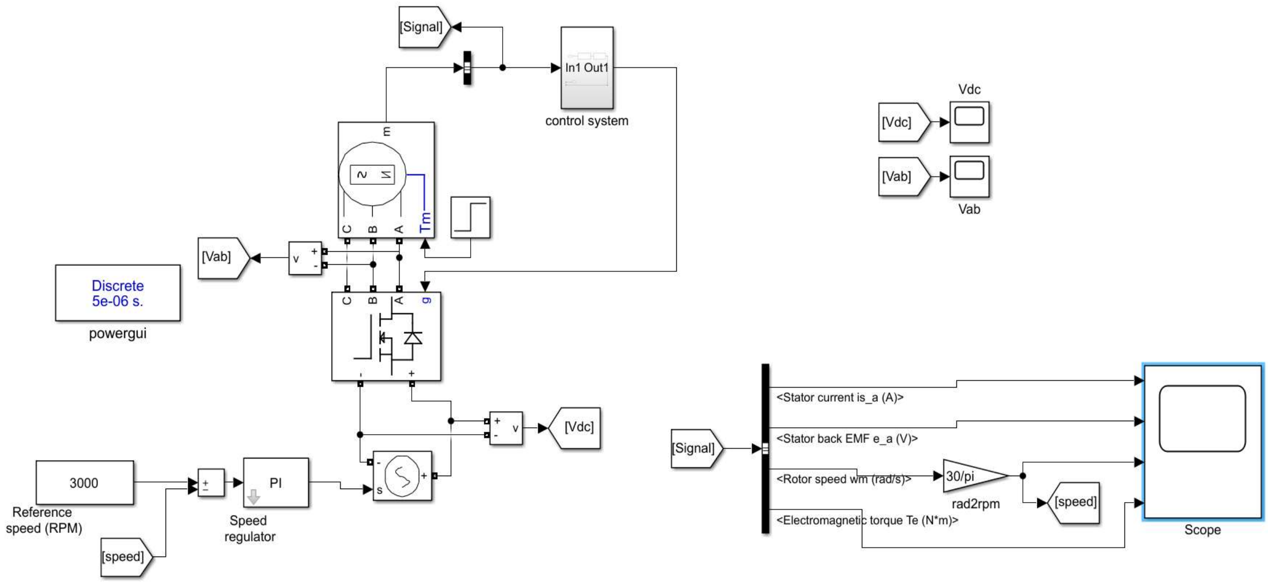

Fig. 4 The speed control simulation system of brushless DC motor

Table 2 Experimental Tests Parameters

Parameter	Value
Stator phase resistance Rs (ohm)	2.7650
Stator phase inductance Ls (H)	9.0e-3
Flux linkage	0.180
load inertia coefficient J (kg.m2)	0.75e-3
viscous damping F(N.m.s)	1e-3
pole pairs	4
static friction Tf(N.m)	0

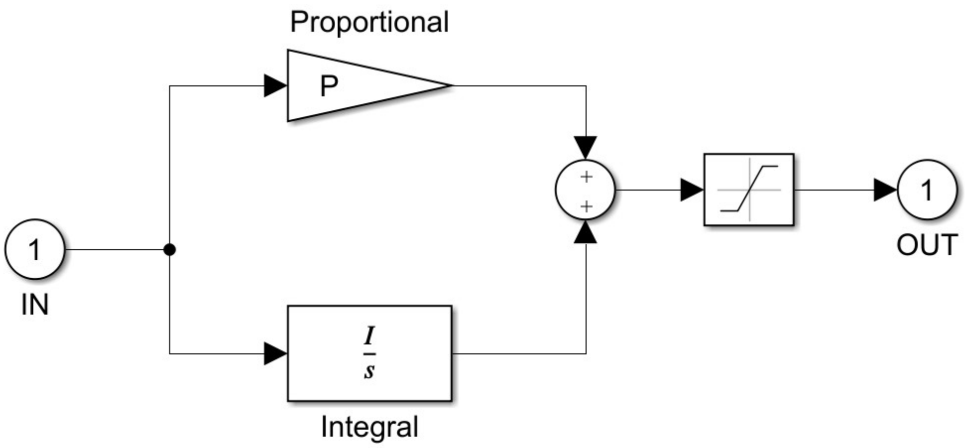

Fig. 5 PI regulator

3.4 Simulation results

In the initial stage, the motor changes from a stationary state to a moving state, and a certain load torque needs to be overcome. Therefore, at the initial position, the load torque is relatively large.

It can be seen from Fig. 7 that in the motor starting phase, there is a larger starting current. At t=0.04s, the motor state begins to stabilize. At t=0.1s, due to the increase of the load of 3N·m, the phase current first began to increase and then stabilized at 3A.

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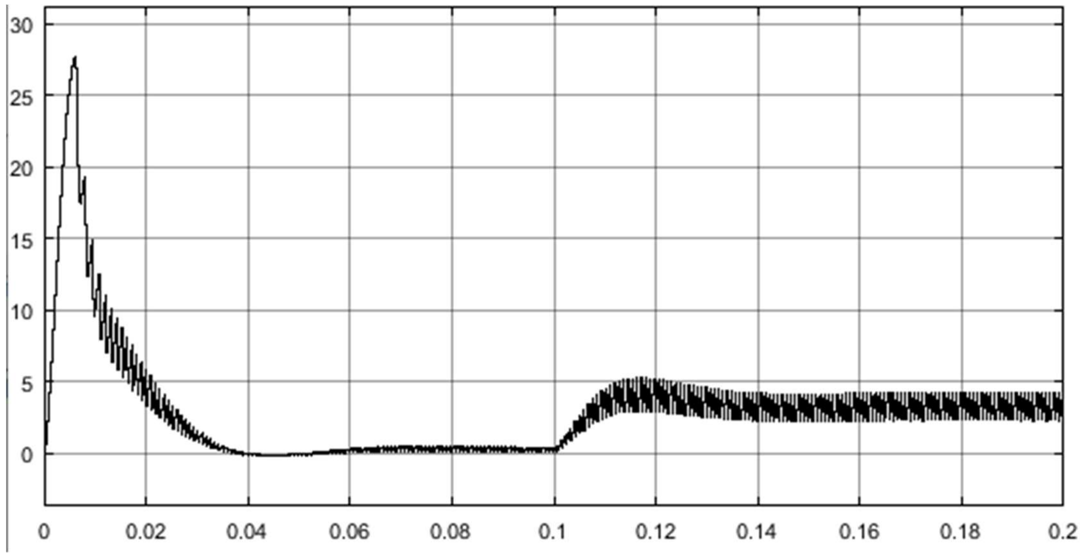

Fig. 6 Electromagnetic torque Te

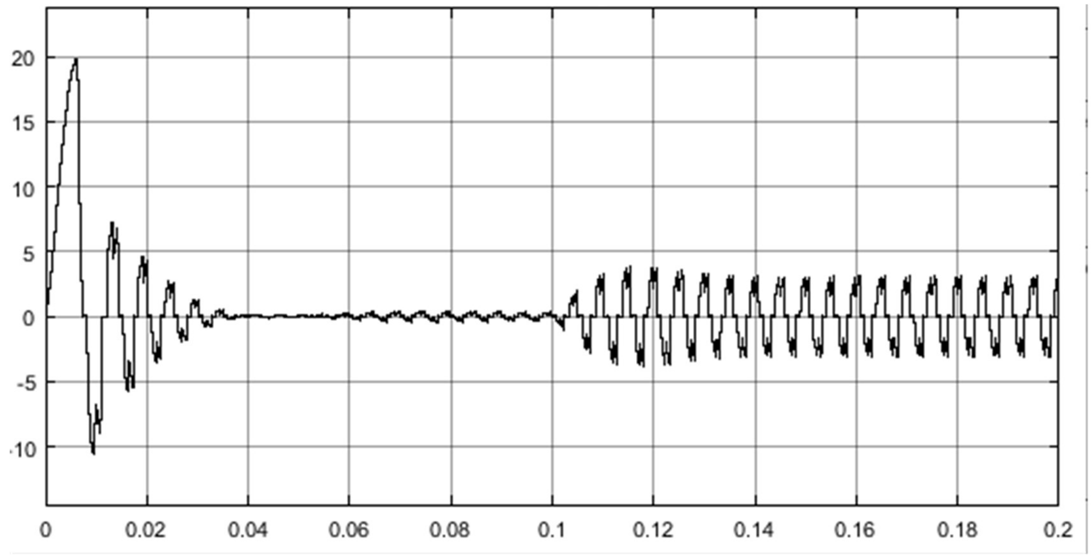

Fig. 7 Phase A Stator current (is_a)

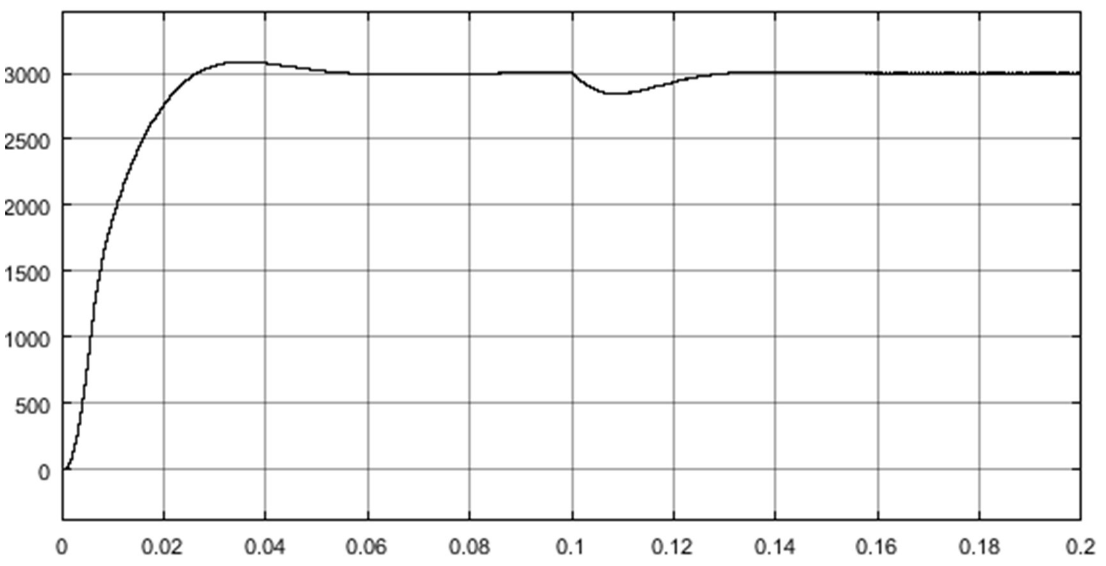

Fig. 8 Rotor speed

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The motor starts from a static state, and t=0.05s reaches the rated speed of 3000r/min, which reaches the given value. When t=0.1s, the speed fluctuates due to sudden load, but the whole system is a closed-loop speed system with good dynamic performance. After 0.02s adjustment time, the motor reaches the rated speed again.

4. Conclusion

In this paper, based on the working principle of the brushless DC motor, the BLDCM motor is simulated and analyzed based on Matlab/ Simulnik simulation tool. For the signal feedback from the position sensor, the motor signal is given according to the switch table, so that the motor runs stably. The motor is controlled by voltage regulation control, and good steady-state performance and dynamic performance are obtained. The simulation results show that the brushless DC motor has a short starting time and excellent performance.

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