IOP Conf. Series: Earth and Environmental Science **446** (2020) 042047 doi:10.1088/1755-1315/446/4/042047

The Design of Controller for BLDC Based on STM32

Fengcan Zhang[1], Xiangyu Kong[2], Fang Li[3] and Yulin Zhang[1*]

[1] School of Information Science and Engineering, University of Jinan, Jinan, ShanDong Province, 250022, China

[2] School of Information Science and Engineering, University of Jinan, Jinan, ShanDong Province, 250022, China

[3] Students' Affairs Division, Shandong medical college, Jinan, ShanDong Province, 250002, China

[*]Corresponding author's e-mail: ise_zhangyl@ujn.edu.cn

Abstract. According to the characteristics and operation principle of brushless DC motor (BLDC), a drive controller of brushless DC motor is designed from the aspects of hardware and software. The control system uses STM32F103RBT6 as the control chip, including power supply circuit, drive circuit and detection circuit. According to the structure and characteristics of the brushless DC motor, the control system adopts the FOC vector control strategy and the double closed loop control strategy of the PI speed loop and the current loop. The experimental results show that the control system can control the motor to run stably and fast, and the control effect is good and the response speed is fast.

1. Introduction
With the rapid development of social economy, green sustainable development is becoming more and more important, so we must accelerate the development and utilization of green energy. The DC brushless motor is mainly driven by electric energy, which is harmless to nature and can be fully utilized. DC brushless motors do not use mechanical commutation, but use electronic commutation, which not only reduces noise, but also improves efficiency and reduces losses[1-2]. DC brushless motors have the advantages of small size, long life, high efficiency, safety and reliability, and low noise[3], so they are widely used in home appliances, automobiles, industrial and other industries.

The control chip of this control system uses STM32F103RBT6 chip, the control chip has 64-pin, 128KB program storage capacity, the maximum frequency can be multiplied to 72MHz, with 16-channel 12-bit resolution ADC and advanced timer with PWM complementary output. Resources enough for this system to use. The control system adopts the chip as the main control chip, designs the circuit schematic diagram, then builds the hardware platform, and adopts the foc double closed-loop control strategy, which is implemented by software programming and successfully debugged.

2. BLDC structure and control principle
The basic structure of the brushless DC motor is mainly composed of a stator and a rotor, the stator is generally a winding, and the rotor is generally a permanent magnet[4]. The stator is generally wound into a multi-phase, mostly connected by a three-phase star. The DC brushless motor control system is mainly composed of a BLDC motor, a three-phase inverter, a position sensor and a main control chip. The main control chip is mainly responsible for receiving and transmitting signals; the position sensor

is mainly responsible for detecting the position of the rotor in real time; the three-phase inverter mainly changes the state of the internal power switch tube according to the rotor signal transmitted from the position sensor, thereby realizing commutation[5].

The operating principle of the brushless DC motor is that when one of the phase stator windings is energized, the generated magnetic field interacts with the magnetic field generated by the rotor permanent magnet, so that the rotor can be rotated. At the same time, the position sensor continuously detects the position of the rotor and transmits the position signal of the rotor to the controller, thereby controlling the power switch tube of the three-phase inverter to turn on or off in a certain order to drive The motor rotates. The schematic diagram of the DC brushless motor operation is shown in Figure 1.

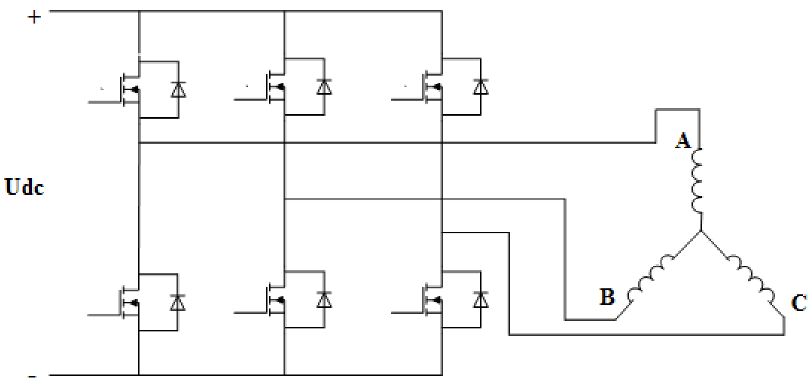

Figure 1. BLDC running schematic

3. Hardware design

3.1STM32 control circuit

The system control design includes a DC power supply circuit, a three-phase inverter, a stm32 peripheral interface circuit, a current detection circuit, a position detection circuit, and a protection circuit. The control system uses a three-phase inverter to drive the motor, the PWM mode controls the motor speed, and the quadrature encoder measures the motor speed to drive the motor to work normally. The control system structure is shown in Figure 2 .

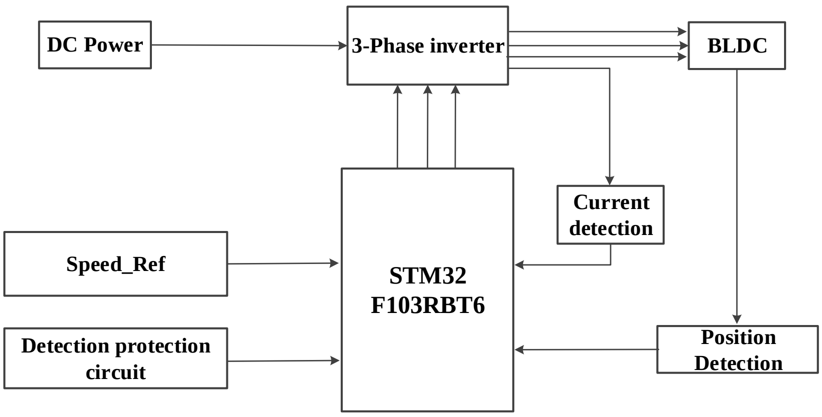

Figure 2. Control system structure diagram

3.1.1Power circuit. The power circuit includes a motor drive power supply and a system control board power supply. The motor drive power supply is a high voltage area, which requires 5V and 15V power supply. 5V supplies power to the op amp and encoder circuit, and 15V supplies power to the drive module IRAM136. Through the input of AC220V, the DC300V is converted by the GBJ2510 rectifier bridge. The DC300V outputs 15V through the VIPER12A voltage chip, and the 15V output 5V through the LM7805 step-down chip. The system control board power supply is a low voltage area, which requires 3.3V power supply and 3.3V power supply for the STM32 chip. AC220V output 12V through the buck module, 12V through the TPS54331 voltage chip output 5V, 5V through the LM1117 three-terminal linear regulator chip output 3.3V. The circuit conversion is shown in Figures 3 and Figures 4.

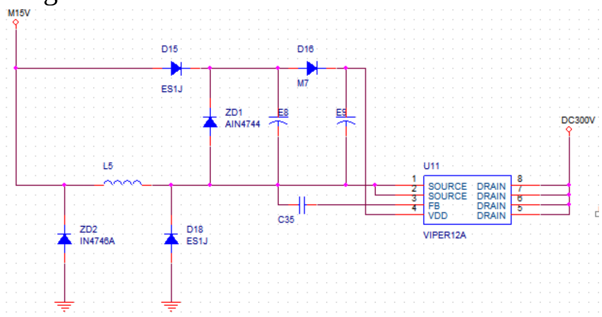

Figure 3. DC 300V to DC 15V circuit

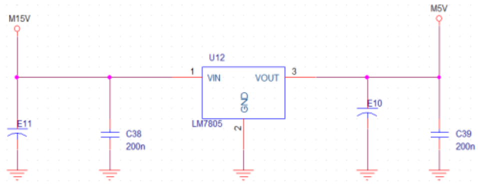

Figure 4. DC 15V to DC 5V circuit

3.1.2Motor drive circuit. The drive circuit of this control system uses IRAM136-1061A drive module. IRAM136-1061A is an intelligent power module with high integration and protection. It integrates six high-power and low-power IGBT and has its own protection function, including excessive temperature, excessive current, low voltage and fault protection[6]. In the industry, it is mainly used for the control of motors, such as washing machines, air conditioners and other drives.

The IRAM136-1061A2 has 29 pins, including power, U, V, W three-phase output signals, PWM six input signals, and current protection pins, fault output/enable pins, and temperature feedback pins. The STM32 control chip outputs six PWM signals to the IRAM136-1061A2 to drive the three-phase inverter, control the turn-on and turn-off of the IGBT, and realize the control of the motor. And, when the FLT/EN fault enable pin outputs a low level, the six-way inverter switch will be turned off, the PWM output is disabled, and the protection module function is realized. And the module has a bootstrap circuit, which is composed of an internal diode and an external bootstrap capacitor to form a bootstrap boost circuit to supply power to the upper arm of the three-phase inverter. The PWM frequency of the IRAM module is up to 20KHZ, and the size of the bootstrap capacitor is selected according to the frequency of the switch. The IRAM136 drive circuit is shown in Figure 5.

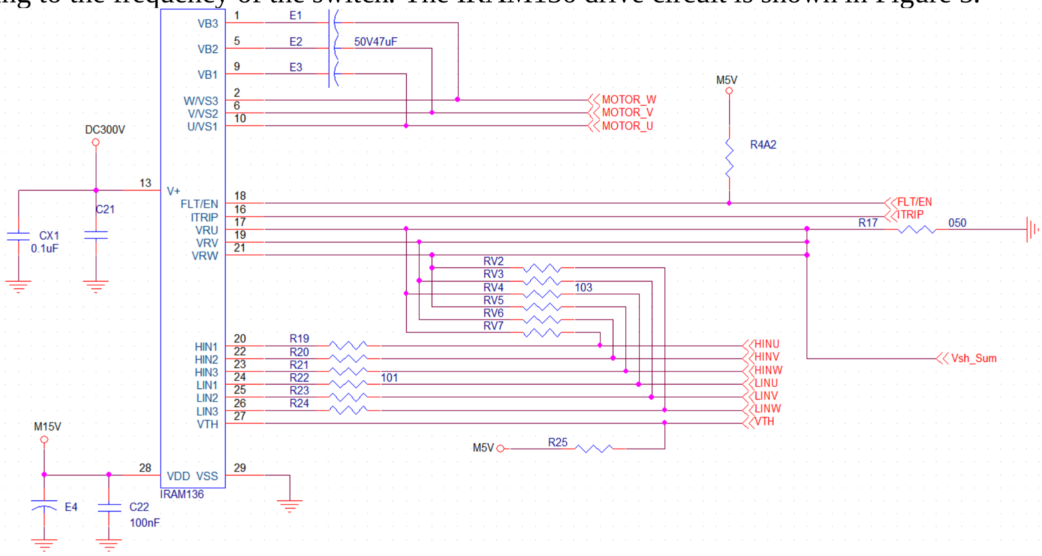

Figure 5. IRAM-136 drive circuit

3.1.3Current detection circuit. The current detecting circuit adopts the resistance sampling method, and the sampling arm is connected in series with the lower arm of the three-phase inverter to detect the

IOP Conf. Series: Earth and Environmental Science **446** (2020) 042047 doi:10.1088/1755-1315/446/4/042047

sampling current, and then the sampling voltage is obtained through the operational amplifier, and then the sampling voltage is input to the AD module of the STM32 for sampling. This control circuit design uses the LM358 operational amplifier to achieve current sampling amplification, as shown in Figure 6.

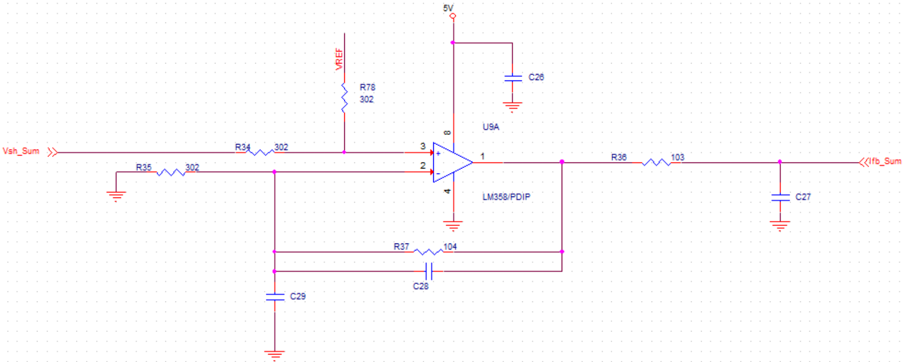

Figure 6. Current detection circuit

3.1.4Protect the circuit. In circuit design, in order to ensure the stability and reliability of the circuit, the protection circuit is indispensable. During the operation of the motor, excessive current, over-temperature and under-voltage may occur. At this time, the protection circuit can function to protect the circuit and the module. This paper samples the amplified voltage of the LM358 op amp by AD, then compares the sampled voltage with the threshold voltage through the voltage comparator LM393, and then inputs the output value to the AD module of the controller. After receiving the signal, the controller turns off the three-phase. Inverter switch tube, disable PWM output, realize current protection, drive module protection.

3.1.5Position detection circuit. In the control of DC brushless motor, position detection is the basis of normal operation of the motor. Therefore, it is necessary to detect the position and rotation speed of the motor rotor in real time, and use the position sensor to detect the position signal and speed signal feedback to the STM32 control core to obtain the rotor. The position and calculation of the speed[7]. The control system adopts a quadrature encoder. By outputting a pulse signal with phase difference of 90 degrees between A and B to the timer encoder module of STM32 chip, the system can obtain the rotation direction of the motor according to the advance sequence of the two-phase signal of AB.

3.2Printed circuit board design

After the system completes the design of the schematic, the next step is to implement PCB plate making. This design is produced by Candence. The PCB design is shown in Figure 7.

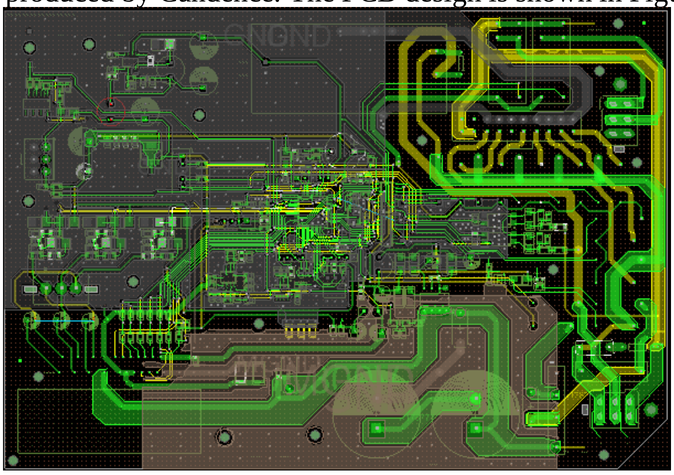

Figure 7. PCB design

4. Control strategy

In the control strategy of DC brushless motor, square wave control and sine wave control are commonly used. The control system adopts vector control and uses PI current loop and speed loop double closed loop. Vector control, also known as FOC, controls the motor by decoupling the voltage vector. The FOC controlled bldc control system has small torque ripple and speed pulsation, and has good control performance[8]. PI control is mainly to adjust the deviation between the target value and the actual value through proportional and integral, and realize the algorithm of control automation. The PI double closed-loop control strategy not only ensures system control accuracy but also improves response speed.

5. Analysis of experimental results

The control system adopts DC brushless motor with rated voltage of 310V and rated power of 145W. It adopts foc vector control and PI double closed loop strategy. The STM32 controller outputs six pwm signals to the three-phase inverter to drive the motor to run stably. The hardware platform built is shown in Figure 8. Then download the code to the chip via KEIL software, measure and observe the output of the driving signal through the oscilloscope. Take the U phase as an example, and open the upper and lower bridge arms at the same time, the waveform output is as shown in Figure 9.

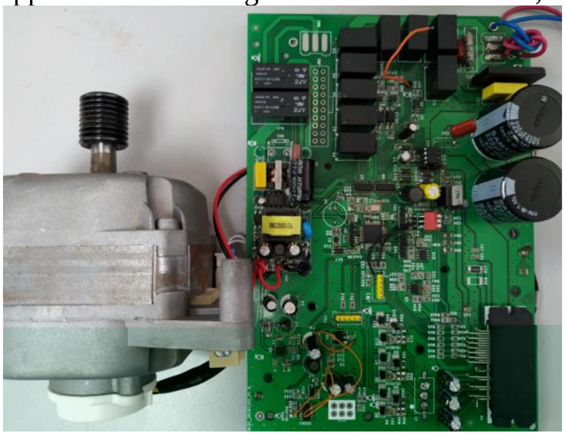

Figure 8. Hardware platform

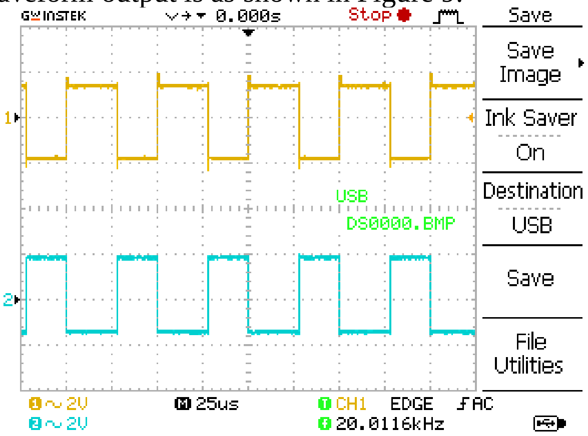

Figure 9. U phase output waveform

6. Conclusion

This paper designs a STM32-based DC brushless motor hardware system. The software part of the system is completed by Keil Vision5, and the hardware part is realized by Candence software. Through the control of 300V, 145W bldc motor, it is verified that the bldc motor adopting foc double closed-loop control strategy can operate well and stably. The system improves the stability and reliability of the system through reasonable combination of software and hardware.

Acknowledgments

This work was supported by the Research and practice of professional ability of key scientific research projects in Colleges and universities of Shandong Province (2018VC12007).

References

[1] Barata F A, Quadrado J C, Silva J F, et al. (2005) Brushless DC Motor: Position Linear Control Simulation. J. Wseas Transactions on Systems, 44(June):207.

[2] Xitai W X W, Xuexiu Z X Z, Lifeng L L L, et al. (2009) Brushless DC Motor Speed Control System of the Walking Aids Machine[C] // Second International Conference on Intelligent Networks & Intelligent Systems. IEEE Computer Society.

[3] Jiao H N , Liu X P , Yang J .(2014) Design of Controller of Permanent Magnet Brushless DC Motor for Electric Vehicle. J. Advanced Materials Research, 986-987:1063-1066.

[4] Salah W, Ishak D, Hammadi K. (2011) PWM Switching Strategy for Torque Ripple Minimization in BLDC Motor[J]. Journal of Electrical Engineering, 62(3).
[5] Lai Y S , Lin Y K . (2008) Novel Back-EMF Detection Technique of Brushless DC Motor Drives for Wide Range Control Without Using Current and Position Sensors. J. IEEE Transactions on Power Electronics, 23(2):934-940.
[6] Saleh S A, Rahman M A. (2009) The development and testing of a scalar double-loop controller for a 3Φ WM inverter-fed IPM motor. C. // IEEE Power & Energy Society General Meeting.
[7] Buchnik Y, Rabinovici R. (2004) Speed and position estimation of brushless DC motor in very low speeds. C. // Electrical and Electronics Engineers in Israel, 2004. Proceedings. 2004 23rd IEEE Convention of. IEEE.
[8] Lei Z, Fei-Hui Z, Min O, et al. (2012) BLDC motor field orientation control system based on LPIDBP neural network. C. // IET International Conference on Information Science and Control Engineering 2012 (ICISCE 2012). IET.