A Digital Thyristor Trigger Control System based on DSP

Zhen Guo [a], Jun Liu [b], Shunxing Hu [c], Yuyang Li [d]

Department of Electrical and Electronic Engineering, Hubei University of Technology, Wuhan 430068, China

[a]244078120@qq.com, [b]283525350@qq.com, [c]954707735@qq.com, [d]963292146@qq.com

Abstract. A digital trigger for three-phase fully-bridge thermistor, using a high performance DSP, is mainly introduced in this paper. This circuit can generate appropriate pulse triggering signals according to the control angle which is supplied by keyboard of DSP. Three- phase bridge rectifier circuit is driven by the amplified power and triggering angle can be controlled. The hardware circuit and programmable software are designed and the control accuracy is analyzed in the paper. This system is valuable and can be used to develop new devices.

Keywords: DSP, thyristor, triggering circuit.

1. Introduction

With the development of power electronics and power supply technology, higher request to the thyristor trigger control must be put forward to adjust to the diversified applications. In some specific experiment, debugging is very difficult. Many shortcomings is hard to solve such as low control precision, poor degree of symmetry, influence of temperature etc. In order to overcome these, the special chip MCU trigger circuit and other forms of CPLD/FPGA have appeared. Three-phase full-controlled bridge, using DSP (digital signal processor) as the trigger controller, has the advantages of high speed data processing ability. Thus we design three-phase thyristor trigger circuit based on F2812 DSP.

2. Operation scheme of the system

Simplified block diagram of the system is shown in Figure 1, the main circuit of three-phase AC power grid goes through the main transformer to supply the power of the three-phase bridge rectifier circuit. In the control circuit, three-phase synchronous power comes from auxiliary winding of the three-phase synchronous power, and it is filtered, phase shifted, amplitude limited in order to align zero-crossing and the six natural commutation point.

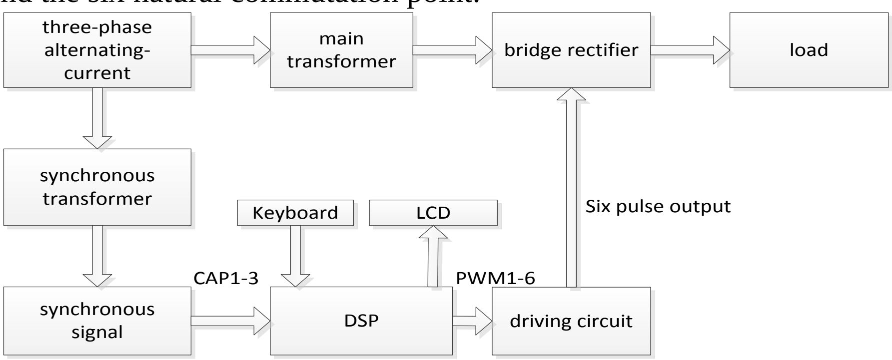


Fig.1 Simplified block diagram of the system

3. Principle of voltage rectifier and system circuit

3.1 Principle of voltage rectifier

The power circuit and its operation principle should be understood first. Three-phase alternating current flows through the main transformer and the three-phase bridge rectifier circuit which is formed by VT1~ VT6.The control circuit provide an appropriate angle to drive the gate of VT1~ VT6 and then we can use this method to control the output voltage of main circuit.

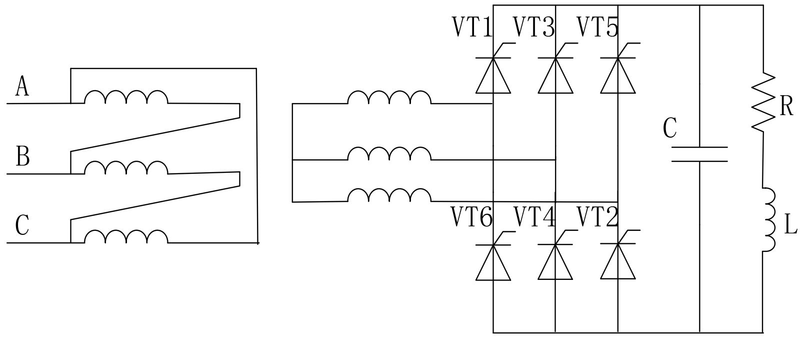


Fig.2 Three-phase full-bridge thyristor rectifier

3.2 The proposed scheme based on DSP

The core of this system is TMS320F2812 digital signal processor, it is a high performance fixed-point chip based on F24X and particularly suitable for motor and other motion control applications. Its code and instructions fully compatible with F24Xdsp and run F24x's program. But F2812 using 32bit operation, can greatly improve computation accuracy and capacity. Its main characteristics is:

High-Performance Static CMOS Technology

-150 MHz (6.67-ns Cycle Time)

-Low-Power (1.8-V Core @135 MHz, 1.9-VCore @150 MHz, 3.3-V I/O) Design

On-Chip Memory: 20K x 16 Total Single-Access RAM (SARAM)

Serial Peripheral Interface (SPI)

-Two Serial Communications Interfaces (SCIs),

-Standard UART Enhanced Controller Area Network (eCAN)

-Multichannel Buffered Serial Port (McBSP)

Clock and system control peripherals can change the PLL frequency and a watchdog timer module

Three 32bit CPU timer

Two event manager module (EVA, EVB) can control signal output

Serial port communication peripherals can conveniently realize equipment's connection with network

56 individually configurable I/O pin

The proposed scheme is showed in figure 3.

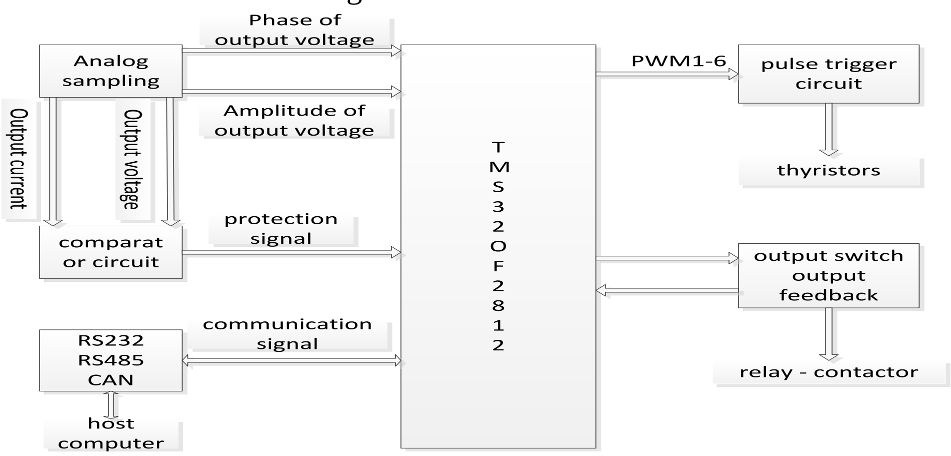


Fig.3 Thyristor controlled AC voltage regulator circuit schematic

3.3 Synchronous signal circuit

Synchronization's generation is the first problem of the thyristor triggered by DSP. Because natural commutation point of trigger pulse has been aligned with the zero-crossing of three-phase power line voltage, synchronous signal of Uac phase's generating circuit is as shown in Figure 4, as well as the other two phases. When AC voltage has been stepped-down, LM339 (zero crossing comparator) start to work for zero-cross detection. Then the photoelectric isolation circuit is used here to output pulse signal and it is send to DSP after filtering alternatively. In each zero-crossing of the power cycle, this circuit output two synchronous pulses. In other words, three-phase power supply output six synchronous pulse in one period, and six synchronous pulse is shifted 60 °in phase.

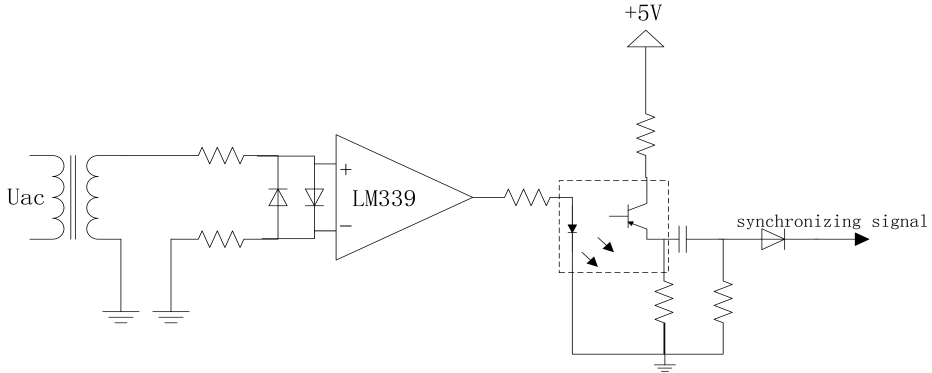


Fig.4 Circuit of synchronous signal

3.4 Thyristor trigger pulse

Pulse signal from the control circuit output is not enough to drive the thyristor gate. One channel of trigger pulse driving circuit is showed in figure 5.Signals from DSP control system goes through photoelectric isolation, a crystal triode driving amplifier, a KCB trigger transformer, and then send to the thyristor's gate.

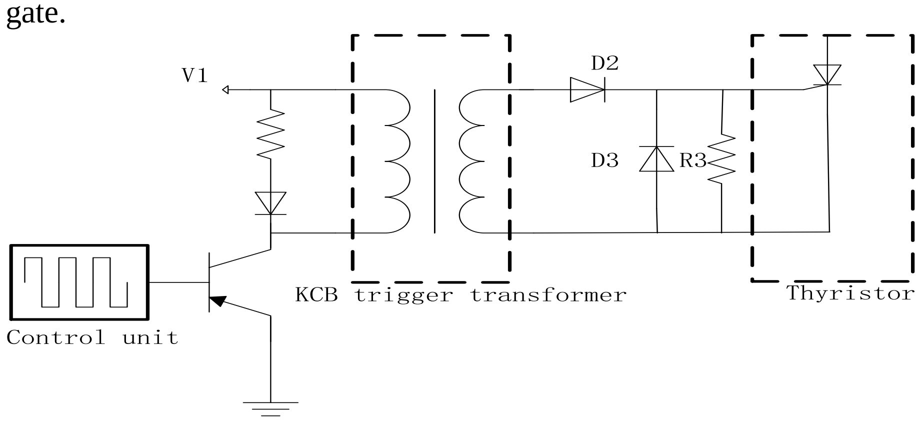


Fig.5 Driving circuit of trigger pulse signal

3.5 Amplitude limited and over-current protection

We set α=90 °to when the software is initialized, the control angle decreases when the given signal Ug increases gradually. Six thyristor of the rectifier bridge turns on successively under the triggering pulse. The control angle can be displayed in LCD and regulated from αmin to α max thus voltage amplitude can be limited. The over-current protection circuit is shown in figure 6, when current signal generated by the control cabinet exceeds the reference voltage Uref, the comparator output low level and trigger PDPINTA and the trigger pulse output port is in high impedance state in order to block the trigger pulse and prevent the accident.

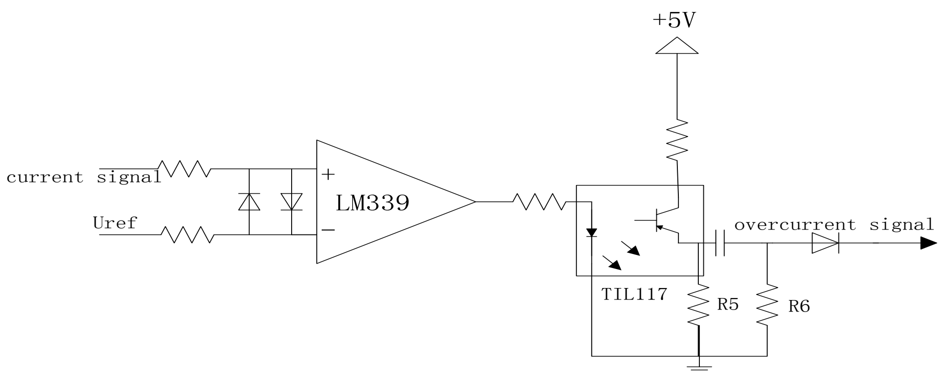


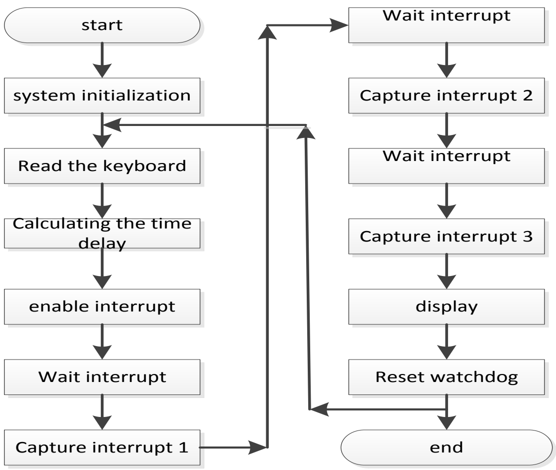
Fig.6 Over-current protection circuit

4. Calculation of control angle

α is the control angle of which the trigger pulse to lag behind the natural commutation point. For alternating current at power frequency of 50hz, the relationship between α and the corresponding delay time t is: $t = \frac{\alpha}{360} \times T = \frac{\alpha}{360} \times 20 = \frac{\alpha}{18}(\mathrm{ms})$, T is the cycle of alternating current, which equals to 20ms.For three-phase bridge rectifier / inverter circuit, α= 0°~150°; When system clock frequency is 150 MHz, the timer value shall be set to 0 ~ 1250000 and the highest resolution of the triggering angle φ=150°/1250000= 0. 00012°.Keyboard is set to change 5° every single time in order to avoid too much operation under the situation of laboratory experimentation. The keyboard uses row scanning instead of interrupt type, so as not to affect the operation of the system.

5. Control algorithm of software design

The system software consists of main program and interrupt subprogram. The main program includes system initialization (system status register, event management, interrupt etc.), synchronous signal capture, display program; the main program flow chart is showed in Figure 7.When Captrue1, 2, 3 of DSP pin read the rising edge, we use the initial value and keyboard number to calculate delay time from the zero crossing to trigger pulse and generate trigger pulse. The interrupt program flow chart of Capture 1 is showed in Figure 8, and Capture 2, 3 have the similar flow diagram, and the only difference is that the PWM output value.



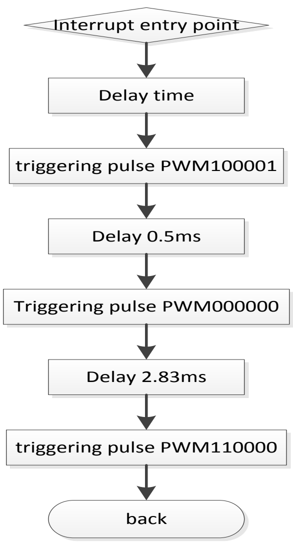


Fig.6 Control algorithm of main program Fig.7 Control algorithm of capture 1

6. Experimental results

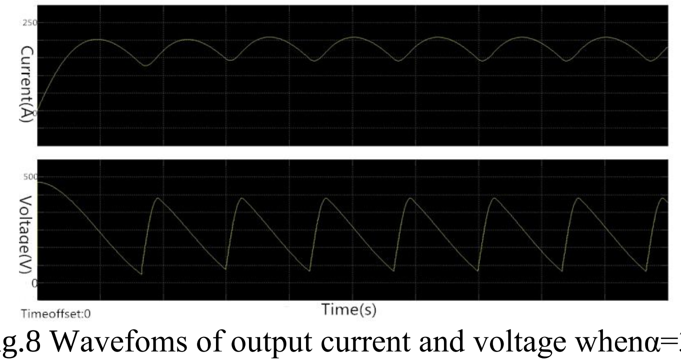


Fig.8 Wavefoms of output current and voltage whenα=30°

Time base: 0.02s/div Current scale: 50A/div Voltage scale: 100V/div

We use matlab/ simulink to get experiment waveforms.Figure8 shows the current and voltage of output after bridge rectifier accepting six pulses form DSP , the control angle α=30°with RL load. The output current will be close to a straight line when inductance is big enough.

7. Conclusion

This article focuses on the design and implementation about the digital thyristor trigger control system of three-phase AC voltage. Theory and simulation show that the DSP-based digital thyristor trigger control mode is feasible for the integrated control of the three-phase AC voltage circuit. Software achieved adaptive phase sequence, instead of hardware which was used to determine the phase sequence in the past. It not only reduces the external components but also improves the reliability of the control system. Using DSP unit to capture the synchronous sinusoidal voltage is useful to find natural commutation point, because we can use the keyboard to change the corresponding delay time, so as to ensure the accuracy of the trigger angle. In the simulation experiment, the thyristor phase shift control and pulse distribution functions adopt modular design, and its control algorithm have achieved better control effect. So this device can be applied to actual production, and has its value of popularization.

References

[1] Y. Suh and C. Kim, A study on high-current rectifier systems with mitigated time-varying magnetic field generation at AC input and DC output bus bars, IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1212–1219.

[2] F. P. Dawson and R. Bonert, High performance single-chip gating circuit for a phase-controlled bridge, IEEE Trans. Ind. Electron.,vol. 41, no. 4, pp. 467-470, Aug. 1994.

[3] Mar. 2012.P. C. Tang, S. S. Lu, and Y. C. Wu, Microprocessor-based design ofa firing circuit for three-phase full-wave thyristor dual converter, IEEE Trans. Ind. Electron. vol. 29, no. 1, pp. 67-73, Feb. 1982.

[4] R. Simard and V. Rajagopolan, Economical equidistant pulse firing scheme for thyristorized DC drives, IEEE Trans. Ind. Electron. And Control Instrum, vol. IECI-22, pp. 425-459, Aug. 1975.

[5] Zhaoan Wang, Jun Huang. Power Electronics, 4rd ed. Machinery Industry Press, Beijing (in Chinese). p. 113-118. 2007

[6] Shu-pu Sun, Ming Li, Xiao-jie Wu. Power Electronics, 1rd ed. China University of Mining &Technology Press, Xuzhou (in Chinese). p. 215-226˛July 2000

[7] B. Wu, J. Pontt, J. Rodriguez, S. Bernet, and S. Kouro, Current-source converter and cycle converter topologies for industrial medium-voltage drives, IEEE Trans. Ind. Electron., vol. 55, no. 7, pp. 2786–2797,Jul. 2008.

[8] H. Inaba, A. Ueda, T. Ando, T. Kurosava, S. Sakai, and S. Shima, A new speed control system for dc motor using GTO converter and its application to elevators, IEEE Tran. Ind. Appl., Vol.IA-21, pp.391-397, March/April 1985.

[9] M. Nedeljkovi and Z. Stojiljkovi, Fast current control for thyristor rectifiers, Proc. Inst. Elect. Eng. Elect. Power Appl., vol. 150, no. 6, p. 636–638, Nov. 2003.

[10] Information on: http://www.alldatasheet.com/view.jsp?Searchword=TMS32OF.