The Design of Two Phase Chopping Regulation Voltage Soft Starter

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Abstract. As for the complexity of the trigger pulse control method for the generally-used thyristor soft starter, The poverty of the continuity of the stator current, the shortage of the waveform distortion and the higher harmonic content. A type with IGBT to realize AC chopping regulation voltage soft starter has been designed, using the two-phase AC power control to achieve the aim of three-phase AC power control, ensuring the effect and saving the costs. The paper makes use of the MATLAB to analyze of the two phase chopping regulating all control type soft starter start performance with simulation, and designs the soft starter of the hardware circuit and the software programs.

Keywords: IGBT, Two phase chopping, Asynchronous motor, Soft starter

1. Introductiong

In the application of the motor, the starting of the motor problem is particularly important. When the asynchronous motor starts, transient current shock is large, generally up to 4~8 times than the motor rated current, and even larger. Too large starting impact current will cause adverse effect on the motor itself, the normal operation of the other electrical equipment and power grid.

Because of the half control of thyristor, the discontinuous current, currently used thyristor voltage regulation of the soft starter will produce a lot of low harmonic, causing harmonic pollution, making the output voltage waveform distort serious and influencing the dynamic characteristics of the motor[1-3]. Because of using all control devices, the two phase chopping regulating all control type soft starter can be shut off by self and can achieve the stator voltage stepless regulation by changing duty ratios of the trigger pulse. Its advantage is that IGBT trigger pulse does not need to link the phase of the three-phase BUS voltage, and has no need to test the zero crossing point. It regulates voltage by adjusting the duty ratios of trigger pulse without calculating the firing angle; the control algorithm and the implementation method are relatively simple. In the use of the freewheeling circuit, The motor current and voltage waveform become much closer to the sine wave, and the waveform distortion rate becomes low [4-5].

2. The main circuit of two phase chopping regulating soft starter

The two phase chopping regulating all control type soft starter is by controlling the duty ratio of all control devices IGBT trigger pulse to adjust the input voltage of stator from power grid, so as to adjust the size of the starting electromagnetic torque. Specifically it's adjusting the three-phase output voltage size by controlling the output voltage of the two phase. The main circuit topology structure is shown in

Fig.1 The specific voltage regulation methods are as follows:

The main circuit structure adopts four power diodes, an insulated gate bipolar transistor and its corresponding protection circuit, to form two groups of basic single-phase ac voltage regulation circuit (1), (2), respectively concatenated in the power supply phase A and phase B of the three-phase ac asynchronous motor. In addition, it adopts six power diodes, an insulated gate bipolar transistor and its corresponding protection circuit, to form a three-phase freewheel bridge (3). The three-phase freewheel bridge connects ac voltage regulation circuit to three-phase ac asynchronous motor stator winding. In order to detect and control the starting current, set up current transformer (12), (13), (14) to A, B, C phase power line of the three-phase ac asynchronous motor respectively. Then the current signal tested by the current transformer will be send to the microprocessor control system (5).

On the main circuit control, the control pulse generated by the microprocessor control system has two ways, one triggers the insulated gate bipolar transistor (8), (7) of two sets of ac voltage regulation (1), (2) shown in diagram, the other triggers the insulated gate bipolar transistor (6) of the three-phase freewheel bridge dc side. The positive and negative of these two pulses are exactly opposite, and they are complementary pulse. Therefore, when (8), (7) trigger on, (6) shuts off , then three-phase ac power supplies to three-phase ac asynchronous motor; when the (8), (7) shut off, (6) triggers on, then three-phase ac asynchronous motor stator current follow current by three-phase freewheel bridge.

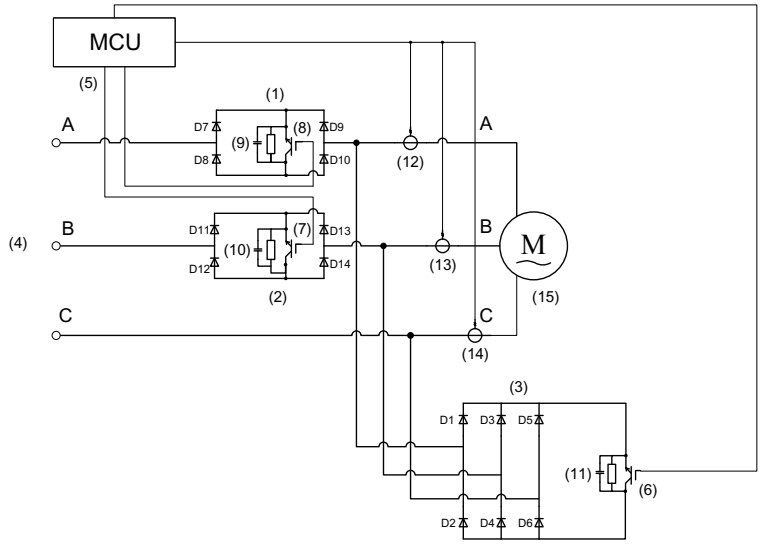

Figure.1 The main circuit structure of two phase chopping regulating soft starter

3. Start modes

The soft starter has a variety of start modes: voltage ramp start, voltage ramp start with pulse kick, current-limiting start, dual ramp start, etc. The maximum allowable time during start process can be set as starting time parameter, and starting time limit range is: 10-120 s, the default value is 60s. The start-up way is as follows:

For voltage ramp start, the user can set up an initial starting torque, and this initial starting torque corresponds to an initial starting voltage. The voltage of the motor increases at a fixed growth rate from the initial starting voltage by a constant speed, until up to the rated voltage. And the growth rate of voltage can be adjusted to adapt to different starting times.

Voltage ramp start with pulse kick is the mode that gives the motor with a higher starting voltage for a short period of time in the motor starting moment, making the motor produce a large instantaneous torque to overcome the static friction torque under the static state, and making the motor turn up. Its main application is on overloading starting motor.

Current-limiting start provides the motor decompression start with a fixed current, used to limit the maximum starting current, which is mainly used in the occasion of the need to limit the impact current when starting[6-8]. Current-limiting start needs to cooperate with the effective value of current detection circuit. The program contains the PID current limit control algorithm, fuzzy control algorithm or combining fuzzy and PID control algorithm, etc. [4], which makes the motor current won't exceed the maximum value during the process of start, as the voltage ramp starts without a maximum value range, providing a kick torque start. The current-limiting start current limit value can be set in 2 ~ 4 times of the rated current.

Dual ramp start, similar to voltage ramp start, corresponds to two different rates of voltage rise. These two start solutions are set in advance. According to their practical application , users could store two commonest start modes in the soft starter, in order to set the starting parameters quickly to start motor. Slope 1 starts from 50% of the full voltage, lasts 100s, and linear increases to full voltage. Slope 2 starts from 70% of the full voltage, lasts 120s, and linear increases to full voltage. The motor can also firstly start by the slope 2. The initial torque is higher, but the voltage rise slowly, which makes the current of the motor change not severe. When the motor speeds up, the current will be reduced, making the motor rise to full voltage rapidly, and completing the start.

4. The Simulation Analysis of Two Phase Chopping Regulating All Control Type Soft Start

Based on the main circuit of two phase chopping regulating all control type soft starter shown in the figure.1, the simulation model shown in Fig.2 is built. Simulation parameter settings are as follows: IGBT switching frequency is 1KHz, trigger pulse duty ratio 0.5, three-phase ac power source 380V, 50 Hz, asynchronous motor rated power 15kw , rated voltage 400V, rated frequency 50Hz,and the load torque 85N · m.

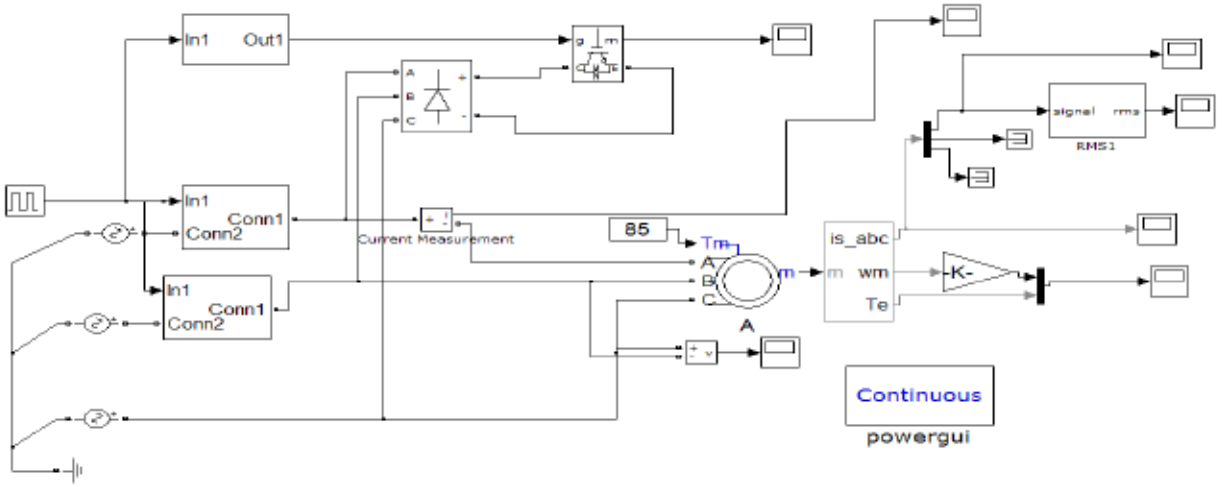

Figure.2 The main circuit model of two phase chopping regulating soft starter

The stator current simulation result of two phase chopping regulating all control type soft starter is shown in Fig.3, it can be shown from the diagram that the stator current fluctuation is significantly decreased than that of thyristor regulating soft start, and the biggest stator current is about 2 times than that of stable operation when starts [9-10] .

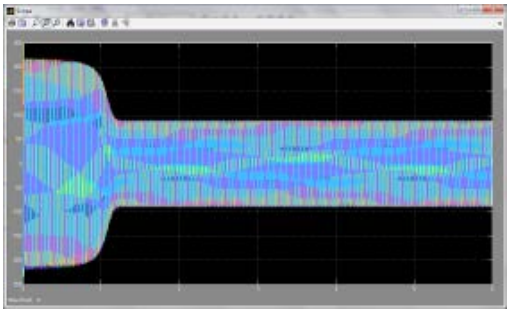

Figure.3 The stator current simulation result of two phase chopping regulating soft starter

Fig.4 is the speed and torque simulation results of two phase chopping regulating all control type soft starter. It can be reflected: the revolving speed of two phase chopping regulating all control type soft starter rises faster, and the rising process is smoother. The time to stabilization is also ahead of thyristor regulating soft starter. The starting torque of two phase chopping regulating all control type soft starter is smoother, there' s no peak impact torque.

Fig.5 is the stator current local amplification figure of two phase chopping regulating all control type soft starter. It can indicated from the picture that as IGBT works under the high switch frequency, the stator current waveform is very close to the sine wave, and the stator current is continuous. Discontinuous phenomenon hardly appears for a while near zero.

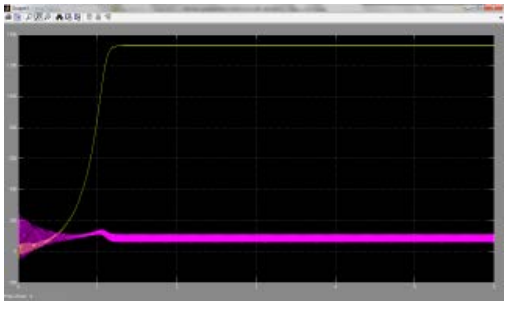

Figure.4 The speed and torque simulation results of two phase chopping regulating soft starter

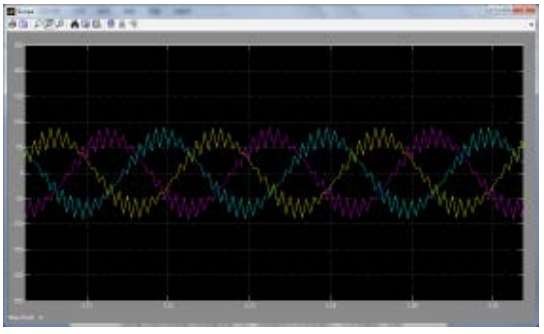

Figure.5 The stator current local amplification figure of two phase chopping regulating soft starter

Fig.6 is the FFT analysis of two phase chopping regulating soft starter A phase stator current simulation results. It can be presented that the main harmonic frequency is 19, 21, 59, 61, and the total harmonic factor is only 6.15%, compared with thyristor regulating soft start. The total harmonic factor has fallen by half. The harmonic content of 19 and 21 is higher, and they belong to higher harmonic, easy to be filtered through the filter circuit.

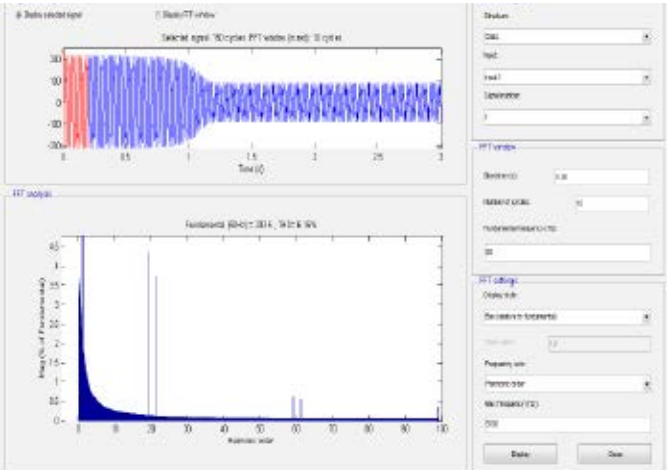

Figure.6 the FFT analysis of two phase chopping regulating soft starter A phase stator current

Through the analysis of simulation results, it confirms that the two phase chopping regulating all control type soft starter has the advantages: small starting current, smooth starting torque, low total harmonic content, and low harmonic content, compared with thyristor regulating soft starter.

5. The Hardware Circuit Design of Two Phase Chopping Regulating All Control Type Soft Starter

The hardware schematic diagram of two phase chopping regulating soft starter is shown in Fig.7. It mainly includes several main parts: the main control chip STM32[5], communication circuit, current detection circuit, USB to serial communication circuit, the CPLD circuit, voltage detection circuit, drive circuit, power circuit. Every subcircuit needs to be connected with the corresponding power supply circuit, without showing the specific connection in the picture.

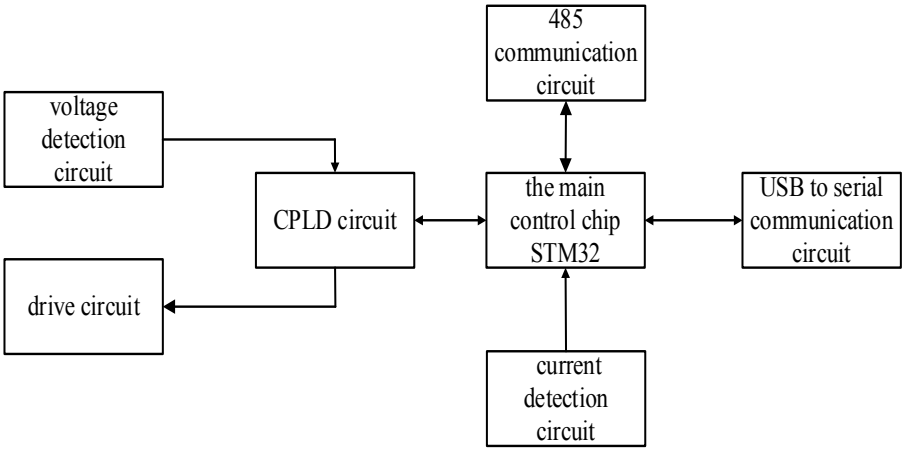

Figure.7 The schematic diagram of two phase chopping regulating soft starter

6. The Software Design of Two Phase Chopping Regulating All Control Type Soft Start System

6.1 The design of main program

As the central control system, two phase chopping regulating soft start main program, has command and deployment effects to the behavior of each program of the control system .The main program flow chart of control system is shown in Fig.8. Simple its structure is, it is the soul of the whole control system, and has irreplaceable importance. The detailed working process is displayed below.

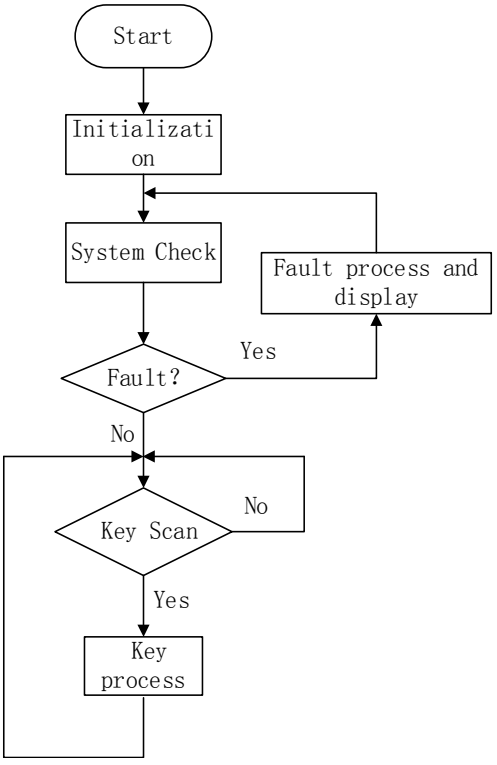

Figure.8 The main program flow chart of control system

First of all, the control system must initialize the main control chip internal various registers and each external pin operation after power-on. Then run a series of system detection subroutines by reading the corresponding parameters of pin, to judge whether the current environment of the motor could start. The operation of the main subroutines on the stage includes phase sequence detection, lack of phase detection, temperature detection. If the detect results conform to the motor starting, it will enter to scan key link. This link uses to monitor whether the control signals are input by the human through the keyboard. If so, the process enters the key processing steps, then the relevant subroutines process the control of the input signal, and wait for starting. If the output of detection subroutines does not conform to the motor starting, the system will enter the fault process which will be displayed. After the fault processed, test whether it conforms to the motor starting conditions.

6.2 The design of main program

Current-limiting starting mode is a more detailed starting mode, which highlights the current size

control in the process of motor starting. It needs to feedback the real-time current to the main control system in the process of motor starting , then by the comparing the value of the real-time current with the set current, the main control system generates control signal, adjusts the IGBT trigger pulse duty ratio, and then makes the motor starting current near the set value within a range. This way of starting is relatively complex.

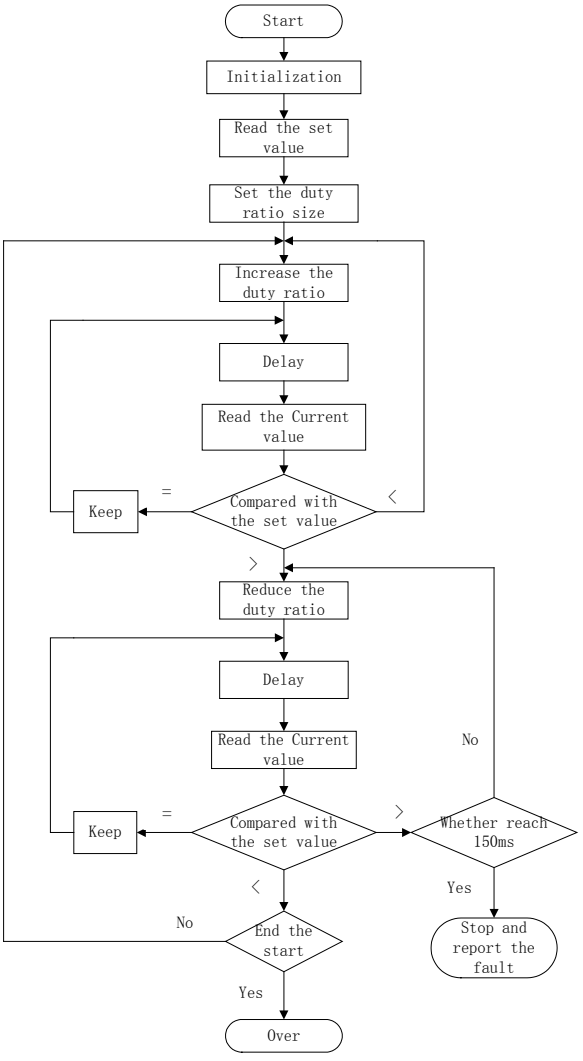

Figure.9 Flow chart of current limiting soft start

The biggest starting current of the current-limiting starting is generally no more than four times of the electric motor rated current. Usually the current limit control algorithm has PID method, fuzzy control method, the combination of PID and fuzzy control method, and so on. This article uses the fuzzy control method. Flow chart of current limiting soft start is shown in Fig.9.

7. Conclusion

This paper proposes the two phase chopping regulating all control type soft starter. Its starting current, starting torque, total harmonic content and the stator current waveform, are all superior to the thyristor voltage regulating soft starter. The paper proposed the hardware circuit and the software program of the two phase chopping regulating all control type soft starter. The harmonic content of the two phase chopping regulating all control type soft starter is lower. Compared with thyristor regulating soft starter, the starting current is closer to the sine wave, and with good continuity, Control algorithm is simple, the protection circuit is complete, the system has high stability and easy maintenance, and Large starting

torque is continuous adjustable. With use less of power electronic devices, the equipment controls the two phase to achieve the purpose of control three phase, saving costs. It's a method of ac asynchronous motor soft start worth promoting.

Acknowledgment

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