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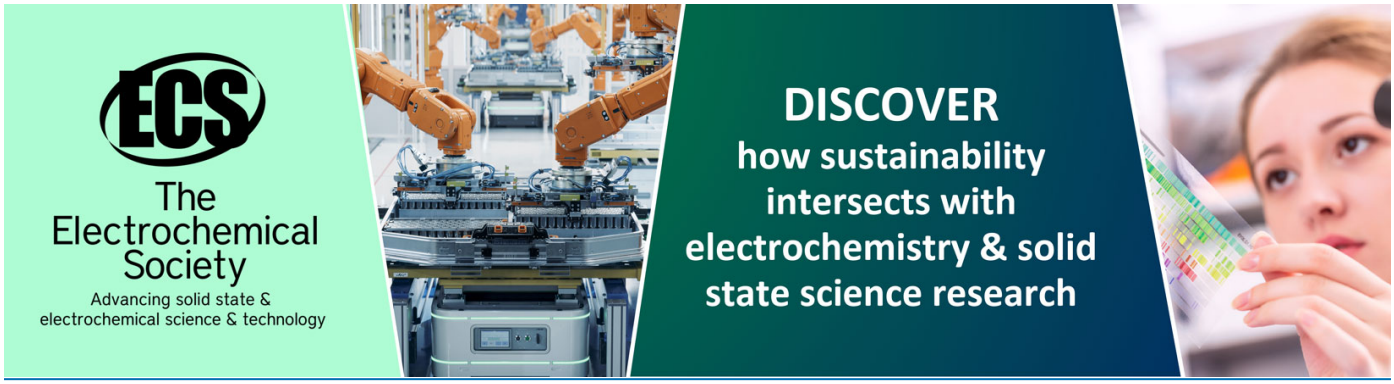

Research on Fuzzy Control System for Constant Current Soft Start of Motor

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Abstract. The soft starter is widely used in the starting of three-phase cage asynchronous motors. Because of its small starting current and reduced damage to the grid and motor during the traditional start-up of the motor it is applied in industrial, agricultural and transportation. The starting current of the motor is controlled by intelligently controlling the firing angle of the thyristor to achieve soft start of the motor in this paper. Fuzzy control is added to the system to establish a control model, which enhances the error resistance of the entire system and enhances the robustness, thus continuously improving the entire system. Fuzzy control is applied in this system to control the constant current soft start of the motor, which greatly improves the intelligence of the motor. The system can reduce the starting current, improve its dynamic torque, can effectively suppress the influence of pure hysteresis. In a large number of experiments and practical production work, it can be proved that the fuzzy control system of motor based on PLC has very good stability, can effectively suppress the influence of pure lag, and indeed has very good control effect.
Keywords: Soft starting, fuzzy control; motor; intellectualization.

1. Introduction

In the past, most of the starting devices used contactors, which belonged to the contact system, which was prone to wear and caused malfunction, and the starting characteristics were not good. In order to achieve contactless control and obtain flexible and variable starting characteristics, the cage soft motor electronic soft starter[1] was born in the early 1980s. The soft start controller is a new type of energy-saving equipment that has been widely used in Europe and the United States. It uses thyristor AC voltage regulation technology to achieve step-down start-up, and later incorporates power factor control technology. In the research of control devices, it is improving the detection and self-diagnosis functions of improving starting torque, improving product reliability, improving manufacturing process, Efforts to reduce costs and other aspects.

On the basis of the traditional soft starter, combined with the characteristics of buck start and variable frequency start, the new start method is designed to have low current and high torque characteristics, which can greatly improve the application range of the soft starter. Motor is a time-varying, non-linear and complex system. It is difficult to describe its starting current accurately with mathematical model, which increases the difficulty of current control and makes the traditional control unable to achieve good results. According to the non-linear characteristics of motor soft start system, some control methods, such as trajectory optimization [2], fault tolerant control [3] magnetic control [4], have been applied to motor soft start control, which has a certain improvement effect.

At present, many research institutions and internationally renowned companies such as ABB, ROCKWELL, MOTORTRONICS, EMOTRON, AB, etc. are carrying out research work in this area, and have formed their own series of products, the price is generally more expensive[5,6]. Domestic research work started late, is not perfect, and has problems such as low reliability, poor stability, and vulnerability to the on-site environment.

Based on the above reasons, this paper studies a high-torque soft starter based on the grading frequency conversion theory, which adopts the grading frequency conversion theory to improve the starting torque and reduce the starting current, and the starting time is shorter than the traditional simple step-down starting. It fundamentally solves some of the problems in motor control, especially the problem of constant torque starting of large-capacity motors. It can be said to be a new technology to replace the traditional step-down starting method.

2. Soft Start of Asynchronous Motor

In order to study the relationship between the starting and stopping voltage, current, torque and other variables of asynchronous motor, it is necessary to study the mathematical model of motor. For variable-frequency speed regulation, the mathematical model based on equivalent circuit is generally adopted, as shown in the Figure 1.

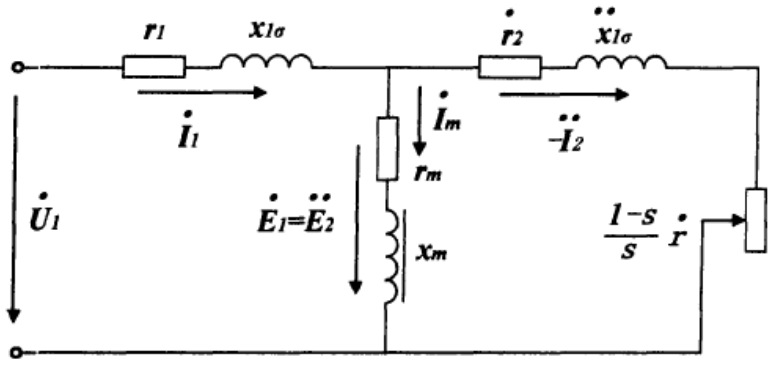

Figure 1. Equivalent circuit diagram of asynchronous motor.

The load terminal voltage can be changed by connecting the thyristor voltage regulator between the AC power supply and the load. There are two ways to adjust the voltage with thyristor: one is to adjust the voltage by phase control, that is, to change the amplitude of the output voltage by using the change of the pulse phase of the gate pole; the other is to adjust the voltage by chopping, that is, to change the effective value of the output voltage by changing the duty cycle of the element. However, when chopping is used at the stator end of the motor, the frequency of on-off alternation cannot be too low, otherwise, on the one hand, it will cause electric drive On the other hand, every time the current is connected, it is equivalent to a reclosing process of asynchronous motor.

When the power supply is cut off, the magnetic field in the air gap of the motor will be maintained by the transient current in the rotor, and will rotate with the rotor. The frequency of the electromotive force induced by the air gap magnetic field in the stator winding will change. When the time interval of the cut-off is long, the electromotive force induced by the rotating magnetic field in the stator and the power supply voltage when it is reconnected may have a large phase difference, so it will come out. The large impact current may endanger the safety of thyristor. However, the working frequency of thyristors is generally not high, and there is no self closing function. If we adopt chopper voltage regulation technology, we need to add chopper circuit or replace thyristor with self closing device, which will make the device complex and high cost.

The main circuit of soft starter adopts three-phase AC voltage regulating circuit of thyristor. Three bidirectional thyristors can be used when the power is small, and three pairs of anti parallel thyristors can be used when the power is large. The equivalent circuit is shown in Figure 1. The output voltage is determined by the conduction angle of the thyristor, and the conduction angle of the thyristor is related to its trigger angle. The smaller the trigger angle is, the larger the output is. Therefore it is only necessary to control the trigger angle of thyristor during the starting process of motor, so that the stator terminal

voltage and starting current of motor can be changed according to the rules set in the working requirements. In this way, the starting voltage and starting current of the motor can be adjusted and set arbitrarily, so that it is in the best starting process. Its essence is the step-down start, which is different from the traditional step-down start in that there is no mechanical contact, and the starting voltage and starting current can be adjusted arbitrarily.

The soft start system adopts the thyristor voltage regulation principle, and realizes various functions of the soft start by adjusting the input voltage and phase of the motor stator. The main circuit is as shown in Figure 2. Six anti parallel thyristors are connected in series on the three-phase stator coils of the motor. The stator windings can be star connected or triangle connected.

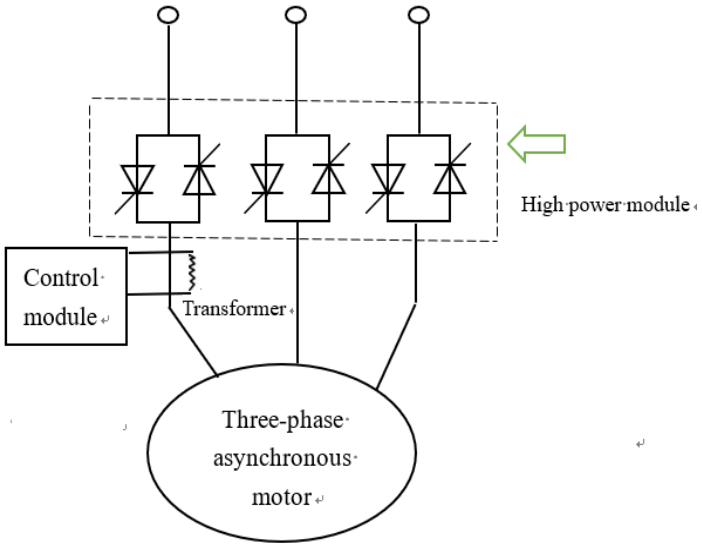

Figure 2. Schematic diagram of soft starter.

In the voltage regulation control of asynchronous motor, phase control technology is generally used in the voltage regulation of thyristor. In phase-shifting voltage regulation, the output voltage waveform is not sine wave. Through analysis, it can be seen that the output voltage does not contain even harmonics, but takes the third harmonic in odd harmonics as the main component. Harmonic in asynchronous motor will cause additional loss, torque ripple and other adverse effects. In addition, since the motor is inductive load, it can be seen from the power electronics that when the thyristor AC voltage regulating circuit has inductive load. The voltage regulating function can only be played when the phase shift angle α is greater than the power factor Φ of the inductive load, because when $\alpha \leq \Phi$, the current conduction time will always be 180°. In this case, as in the case of $\alpha = 0$, the phase control does not play any role in voltage regulation. Even when the trigger pulse of the thyristor is not wide enough, there will be only one direction of the thyristor in operation, and the DC component may appear on the load. Therefore, the lower limit amplitude of α is taken as Φ value under rated operation, while the upper limit amplitude of α is taken as 180°.

In the thyristor AC voltage regulating system, the thyristor can adopt the mode of power supply commutation (both resistive load and inductive load), without additional commutation circuit. Therefore, its main advantages are simple circuit, small volume of voltage regulating device, low price, convenient use and maintenance.

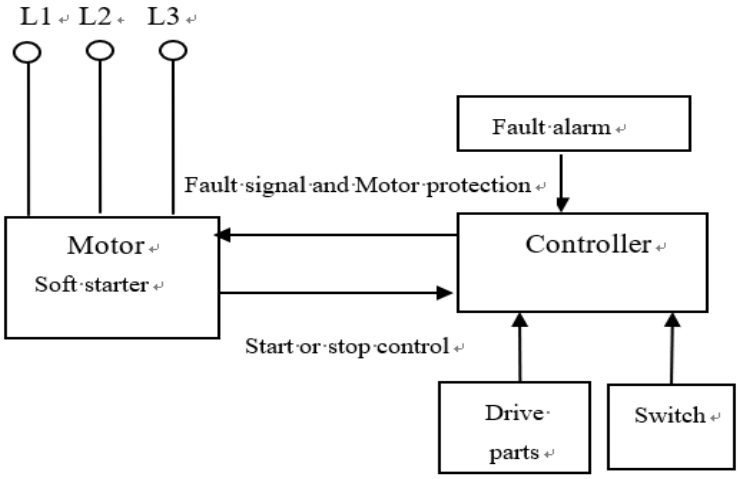

Figure 3. System hardware diagram.

3. Fuzzy Control of Soft Starter

Fuzzy control, as a kind of language controller, is not very sensitive to the change of process parameters, can overcome the influence of nonlinear factors, does not require the controlled object to have accurate mathematical model, only needs to store the fuzzy control table in the computer for control call, using this kind of good adaptability and flexibility, can get good start-up characteristics.

In this paper, the fuzzy control method used in the motor soft start control system is shown in Figure 4. The difference between the motor output current, the expected value and its change rate Δ are taken as the input variable, and the change of the thyristor trigger angle Δ are used as the output variable. The fuzzy controller fuzzizes, infers, decides and de fuzzizes the input information. To the control quantity, it is applied to the controlled object motor to realize soft start. The schematic diagram is as Figure.4.

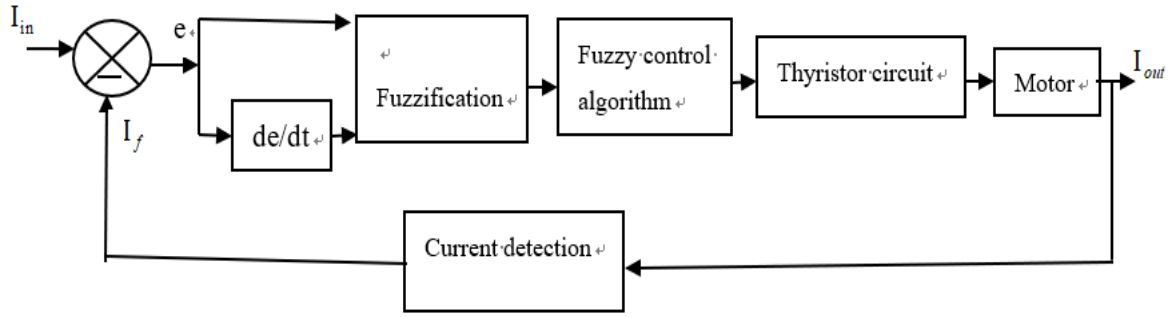

Figure 4. Fuzzy control of soft start control system.

The input value is the deviation and deviation change rate between the given starting current value and the starting current signal f of the detected induction motor. The output value is the starting current I_{out} of the induction motor. The output of the fuzzy controller is the given value of the trigger angle α of the bidirectional thyristor trigger circuit. The input variable of the fuzzy control system is the error between the current value and the expected value and the change rate Δ I; the output variable is the theory domain a of the trigger angle change rate α of the thyristor.

Current deviation refers to the deviation between the given value of current and the starting current value of induction motor. The control range bounded by the current deviation value ± 1.3A is defined as the fuzzy control area. In the fuzzy control area, the current deviation is divided into 10 Fuzzy States. The range of current deviation ± 1.3A is divided into 13 points, and their membership values corresponding to 10 fuzzy states are given by using triangle membership function.

The current change rate is defined as the change in a sampling period, and the fuzzy control area is within ± 0.5A. It is divided into 10 Fuzzy States. The output states of the fuzzy controller are defined as 16, which correspond to the given values of the output pulse trigger angle a of the bidirectional thyristor

trigger circuit. The 16 output states are divided into 8 Fuzzy States, and each specific output state corresponds to the membership value of the 8 Fuzzy States.

Current deviation refers to the deviation between the given value of current and the starting current value of induction motor. The control range bounded by ± 2.4a current deviation is defined as fuzzy control area. It is divided into 13 points, and the triangle membership function is used to give the membership values corresponding to 8 Fuzzy States, as shown in the table1 below:

Table 1. Fuzzy control table.

	-0.6	-0.5	-0.4	-0.3	-0.2	-0.1	0.0	0.1	0.2	0.3	0.4	0.5	0.6
-2.4	7	6	7	6	7	7	7	4	4	2	0	0	0
-2.0	6	6	6	6	6	6	6	4	4	2	0	0	0
-1.6	7	6	7	6	7	7	7	4	4	2	0	0	0
-1.2	6	6	6	6	6	6	6	3	2	0	-1	-1	-1
-0.8	4	4	4	5	4	4	4	1	0	0	-1	-1	-1
-0.4	4	4	4	5	4	4	1	0	0	0	-3	-2	-1
0.0	4	4	4	5	1	1	0	-1	-1	-1	-4	-4	-4
0.4	2	2	2	2	0	0	-1	-4	-4	-1	-4	-4	-4
0.8	1	1	1	-2	-3	-3	-4	-4	-4	-3	-4	-4	-4
1.2	0	0	0	0	-3	-3	-6	-6	-6	-3	-6	-6	-6
1.6	0	0	0	-2	-4	-7	-7	-7	-7	-6	-6	-7	-6
2.0	0	0	0	-2	-4	-6	-6	-6	-6	-6	-6	-6	-6
2.4	0	0	0	-2	-4	-7	-7	-7	-7	-6	-7	-6	-7

The system is mainly composed of four modules: interrupt module, sampling module, fuzzy control module, motor operation module. Among them, the fuzzy control module consists of three subprograms: the domain transformation subprogram carries out the domain transformation of the input quantity, changes the accurate analog quantity obtained by the sensor through the domain to the discrete value; the table lookup subprogram finds out the corresponding output value according to the discrete value; the solution of the fuzzy subprogram is to convert the corresponding domain value in the table into the actual output current value. The design method of the system is simple and clear, the response speed is fast, and it has a good control effect.

4. Conclusion

In this paper, the design of constant current soft start fuzzy control system is studied. In this paper, the soft start mode of motor is to control the on-off angle of thyristor at different speed, so that the motor terminal voltage increases gradually, so as to solve the problem of over current and other start-up problems in traditional start-up mode. In the system, the fuzzy control is used to improve the control effect of the soft start of the motor, and the constant current soft start of the motor is controlled. On the basis of the fuzzy model of the controlled object, the approximate reasoning method of the fuzzy controller is used to realize a method of the system control, and the higher reliability is gained by its simplicity. With its parallel operation, the response speed of the control is speeded up. With the uniqueness of its single rule, the response error of the individual rule is counteracted to the degree of influence on the whole, and the anti error ability and robustness of the whole system are enhanced. In a large number of experiments and practical production work, it can be proved that the stability of the motor constant current soft start fuzzy control system is very good, it can effectively suppress the influence of pure lag, and indeed has a good control effect, so the motor constant current soft start fuzzy control system has great research significance and development prospects. There are also inevitable errors in the system, which lead to errors in the system demonstration results. If the errors are to be eliminated, the system is needed to further be studied.

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