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AC Motor Speed Control Method and Its Application in Automation System

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Abstract: *With the continuous improvement of the level of industrial automation and the development of manufacturing technology, AC motors are increasingly widely used in various automation systems. At present, the speed regulation requirements of the motor in industrial production are getting higher and higher, the traditional speed regulation method has been unable to meet the requirements of modern industry for high efficiency and high precision, AC motor as the most commonly used drive equipment in industrial production, plays a key role in production lines, mechanical equipment, transportation systems, etc. The AC motor speed control method realizes the precise control of the motor speed by adjusting the voltage, frequency or pole number of the motor, so as to improve the production efficiency and product quality. This paper provides technical support and theoretical guidance for the intelligent and fine development of industrial automation system by deeply studying the motor speed control method and its application strategy.*

Keywords: *AC Motor, Speed Control, Automated System, Apply*

1. Introduction

With the increasing prominence of global energy and environmental problems, energy conservation and emission reduction have become an important issue in industrial production. Ac motor as one of the main energy consumption equipment in the industry, through speed control and other means to achieve the effective use of energy and energy saving and consumption reduction is particularly key, in-depth study of AC motor speed control method in the automation system application strategy, not only can improve production efficiency and quality, but also can reduce energy consumption, to achieve sustainable development goals.

2. AC Motor Speed Control Method

2.1 Frequency Conversion Speed Control

Variable frequency speed control is a common method of AC motor speed regulation, by changing the input frequency of the motor to achieve speed regulation, the basic principle is to use the inverter to adjust the frequency of the power supply, so as to change the speed of the motor [1].

The core of variable frequency speed control is the frequency converter, which is an electronic device that can convert the alternating current of the power supply to the alternating current with adjustable frequency and adjustable amplitude. The frequency converter realizes the speed control of the motor by controlling the frequency and voltage of the output power supply. Its basic working principle is to use power semiconductor devices (such as IGBT, etc.) for high-frequency switching modulation, to convert direct current into controllable AC electrical signals, so as to control the motor speed. In addition, frequency conversion speed control can be used in open loop control and closed loop control. Open loop control refers to directly output to the motor according to the preset frequency and voltage value, which is suitable for some simple speed regulation scenarios; The closed-loop control is to obtain the current speed information of the motor through the feedback system, and adjust the output frequency and voltage according to the difference between the set value and the actual value, to achieve more accurate speed control [2]. In terms of control strategy, the common ones are constant frequency control, vector control and direct torque control. Constant frequency control is the most basic speed regulation mode, through adjusting the output frequency to achieve speed regulation; Vector control is to control the torque and speed of the motor by measuring and calculating the rotor position

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and speed accurately. Direct torque control is to control the torque output of the motor more precisely on the basis of vector control.

One of the advantages of variable frequency speed control is that it can achieve a smooth start and stop process, reduce the impact and mechanical stress of the motor when starting, and extend the service life of the motor [3]. At the same time, because the speed of the motor can be adjusted according to the actual needs, the appropriate power output can be provided under different working conditions, improving the flexibility and efficiency of the system.

2.2 Soft Start Control

Soft start control is a method used to reduce the shock when the motor starts, by gradually increasing the voltage and frequency of the motor to achieve smooth start. Compared with the traditional direct start mode, soft start control can reduce the peak current during the start process, reduce the pressure of the power grid and equipment, and help to improve the stability and reliability of the system.

The working principle of soft start control is to control the voltage and frequency in the start circuit, so that the motor gradually reaches the rated speed when starting. The traditional direct starting mode will cause the motor and equipment to bear a large current and torque impact when starting, which is easy to cause equipment damage and power grid load fluctuation. Soft start control, by gradually increasing the voltage and frequency, reduces the impact during the start process and protects the equipment and the power grid. Secondly, soft start control can be realized in many ways, such as voltage chopper control, frequency increment control, current limit control, etc. Voltage chopper control is to control the current and torque in the motor starting process by decreasing the voltage step by step. Frequency increment control is to gradually increase the frequency of power output, so that the motor gradually accelerates to the rated speed; Current limiting control is to reduce the impact during startup by limiting the size of the starting current [4]. In terms of application scenarios, soft start control is widely used in occasions where it is necessary to control and protect the motor starting process. For example, in the start-up process of large wind turbines, water pumps, compressors and other equipment, the soft start control can effectively reduce the start-up impact, extend the service life of the equipment, and reduce the load fluctuation of the power grid. In addition, in soft start control, a specific starter or soft starter is usually used to achieve a gradual increase in voltage and frequency. This control mode can effectively reduce the mechanical vibration and stress when the motor is started, extend the service life of the equipment, and reduce the maintenance cost and energy consumption of the equipment.

2.3 Vector Control

Vector control is a kind of advanced AC motor speed control method, through the motor current and magnetic field accurate control, the motor speed and torque accurate adjustment. Compared with the traditional voltage frequency modulation control mode, vector control can control the running state of the motor more precisely, and improve the dynamic response performance and control accuracy of the motor.

First of all, the traditional speed regulation method is to control the speed of the motor according to the voltage and frequency, but it cannot directly control the torque of the motor. The vector control is through the vector decomposition of the motor current, the current is decomposed into magnetic axis current and axial current, and the magnetic field generation and torque generation are respectively controlled, so as to achieve accurate control of the motor. Secondly, vector control can be divided into inductive vector control and magnetic field oriented control. Induction vector control is based on the induction relationship between the voltage and the current of the motor, and the induction vector algorithm is used to control the motor. The magnetic field orientation control is to accurately control the magnetic field direction of the motor, so that the motor can maintain stable torque output under different speeds and loads. In addition, in terms of control strategy, vector control has two kinds of closed-loop control and open-loop control. Closed-loop control is to obtain the current speed and torque information of the motor through the feedback system, and adjusts the current and magnetic field direction of the motor according to the set value to achieve accurate control; Open loop control is to directly control the motor current and magnetic field direction according to the preset speed and torque parameters. Finally, vector control has significant advantages in speed regulation accuracy, dynamic response and overload capability. It can realize efficient control of the motor at low speed and

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static state, and avoid the problem that the traditional speed regulation method is easy to fail at low speed. At the same time, the vector control can also realize the rapid start of the motor, accurate positioning and high-precision speed regulation, which is suitable for occasions with strict torque requirements [5].

Vector control is widely used in industrial production, transportation, wind power generation, elevator and other fields. For example, the use of vector control in the drive system of electric vehicles can improve the efficiency and performance of the motor and extend the battery range; in industrial production, vector control can achieve efficient speed regulation and precise control of the production line, improve production efficiency and product quality.

2.4 PID Control

PID control is a classical closed-loop control method, widely used in AC motor speed control. The PID controller generates the control output by summing the error, integral and differential of the system, and realizes the accurate adjustment of the motor speed. The three parts of the PID controller represent proportional (P), integral (I), and differential (D) control. The proportional control is used to adjust the output according to the current error, the integral control is used to eliminate the static error of the system, and the differential control is used to predict the future change trend of the system, thereby improving the stability and dynamic response of the control.

PID control can adopt different control modes, including positional PID control and incremental PID control. Position-type PID control is based on the current error PID calculation, the output control directly acts on the actuator (such as the motor), suitable for the need to directly control the position or speed of the scene; Incremental PID control calculates PID based on the rate of error change, and the output control is applied to the control increment. It is suitable for scenarios where the control increment is required, for example, the incremental control in the speed control system. At the same time, in terms of parameter adjustment, PID control needs to adjust the proportional coefficient, integral time constant and differential time constant to achieve good control effect. The proportional coefficient affects the sensitivity and stability of the control system, the integral time constant affects the integral action and anti-interference ability of the system, and the differential time constant affects the dynamic response and anti-interference performance of the system. It is usually necessary to determine the best parameter configuration through testing and adjustment. In addition, PID control has a wide range of application scenarios in industrial automation, including temperature control, pressure control, flow control and motor speed control. In AC motor speed control, PID control can realize accurate control and stable operation of motor speed, which is suitable for speed regulation requirements under various loads and working conditions. At the same time, PID control also has the advantages of fast response speed, good adjustment performance and strong adaptability, and is a common adjustment method in the field of industrial control.

In the AC motor speed control, PID control can adjust the control output in real time according to the system feedback signal, so that the running state of the motor is closer to the set value. This control method is simple and intuitive, easy to implement, and has good stability and robustness in practical applications, so it is widely used in various automation systems, including industrial production lines, mechanical equipment and other fields.

3. The Application Strategy of AC Motor Speed Regulation Control Method in Automation System

3.1 Optimization of Process Flow

In automation system, AC motor speed control method plays an important role in process optimization. Process optimization aims to improve production efficiency, optimize resource utilization and improve product quality, and AC motor speed control is the key technology to achieve this goal. In the production process, different processes require different motor operating parameters, such as higher speed and torque in the mixing stage, while lower operating parameters are required in the conveying or assembly stage, through the AC motor speed control, the running state of the motor can be accurately adjusted according to actual needs to ensure the continuity and efficiency of the production process.

In addition, in many process processes, the start and stop process of the motor will produce shock

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and vibration, affecting the stability and quality of the equipment and products. By using soft start control or gradual speed control method, the smooth start and stop of the motor can be achieved, the impact and vibration can be reduced, and the reliability and service life of the equipment can be improved. At the same time, AC motor speed control can also be combined with other intelligent technologies, such as the Internet of things, big data analysis, etc., to achieve intelligent optimization and management of the process, based on real-time monitoring of the motor's operating status and process parameters, combined with data analysis algorithms, can optimize the control strategy of the process, improve production efficiency and product quality.

3.2 Energy Saving and Consumption Reduction

Energy saving and consumption reduction is a very important part of modern industrial production and automation system design, which can effectively reduce energy consumption, reduce production costs, and have a positive impact on environmental protection. In many industrial applications, the motor is usually run at rated speed, but the actual workload is sometimes low, when the motor running at rated speed will lead to energy waste. By using variable frequency speed control or vector control technology, the motor can reduce the speed when the light load or low speed operation, so as to reduce the energy consumption of the motor and realize the purpose of energy saving.

The traditional motor start-stop mode often produces a large starting impulse current, which leads to energy waste and power grid pressure increase. The soft start control method can reduce the starting impulse and energy consumption. In the operation process, by dynamically adjusting the motor speed or operation mode, optimize energy utilization, reduce energy consumption, and achieve the goal of energy saving and consumption reduction. In addition, through the collection of motor operation data, load, energy consumption and other information, the use of big data analysis, artificial intelligence and other technologies for energy forecasting and optimal scheduling. For example, according to the production plan and the load of the power grid, the motor operation mode is rationally scheduled, and the best energy-saving speed regulation control strategy is selected to improve the energy utilization efficiency and reduce the system energy consumption.

3.3 Precise Control Requirements

In many industrial applications, for precise speed requirements, such as the need to control the rotation speed of the workpiece in machining, accurate motor speed control can ensure product quality and processing accuracy. By using advanced control methods such as vector control or PID control, accurate control of motor speed can be achieved to meet the required accuracy requirements. Especially in some application scenarios that require stable output torque, such as conveying machinery, lifting equipment, etc., accurate torque control can ensure stable system operation and load balancing. By adopting vector control technology or torque control algorithm, the output torque of the motor can be accurately controlled to meet the requirements of the system for torque stability. In addition, AC motor speed control can also be applied to the needs of precise position control. In some automation systems that require precise positioning, such as robots, CNC machine tools, etc., the position control requirements for the motor are very strict. By adopting closed-loop control method, encoder feedback and other technologies, the position of the motor can be controlled with high precision to ensure that the system can meet the precise position requirements in the working process.

3.4 Application of Intelligent Speed Control System

Intelligent speed control system based on artificial intelligence technology, combined with fuzzy control, neural network control, genetic algorithm and other methods, through the real-time monitoring and analysis of system operating state and environmental parameters, to achieve intelligent optimization and predictive control of motor speed control [6]. The basic principle is to establish an intelligent speed regulation model, use fuzzy rules or neural network to learn and optimize, and achieve accurate control of motor speed.

On the one hand, intelligent speed control system can adopt fuzzy PID control, fuzzy logic control, neural network control and other control strategies. Among them, fuzzy PID control combines the accuracy of PID control and the robustness of fuzzy control, which is suitable for the occasions with high speed requirements. Fuzzy logic control can make fuzzy rules according to different working conditions and needs to realize the self-adaptive adjustment of motor speed. The neural network control realizes the intelligent prediction and optimal control of the motor speed by learning and training the

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system data. On the other hand, with the support of intelligent technology, the speed control system has the advantages of fast response speed, good adjustment performance and strong adaptability. It can be adjusted intelligently according to real-time operating status and environmental changes to improve the stability and performance of the system. At the same time, the intelligent speed regulation system can also realize energy management and energy-saving optimization, intelligent control according to the energy consumption data of the system, reduce the system energy consumption, and improve the energy utilization rate. In the automation system, the intelligent speed regulating system can realize the high precision control and stable operation of the motor speed, improve the operating efficiency and production quality of the system; At the same time, combined with the energy management function of the intelligent speed control system, it can also realize the effective use of energy and energy-saving optimization of the system.

4. Conclusion

In summary, the application strategy of AC motor speed regulation control method in automation system is multi-dimensional, including process optimization, energy saving and consumption reduction, and precise control needs. By means of variable frequency speed control, soft start control, vector control and PID control, the motor running state can be accurately adjusted, thereby improving production efficiency, reducing energy consumption, optimizing process flow, and meeting the requirements of the system for accuracy, stability and responsiveness. The above strategy not only helps to improve the overall efficiency and quality of industrial production, but also helps to improve the overall efficiency and quality of industrial production. It can also promote the rational use of energy resources and promote the automation system towards a more intelligent, refined and sustainable development.

References

[1] Ji Yongchun, Sun Weizhe. Ac Motor Speed Regulation and Its Application. Science and Technology Information, 2005, (27): 1.

[2] Wu Yuxiang, Wu Xinsheng, Hu Yueming. Application of ac frequency conversion motor in the automatic door control system. Journal of small and medium-sized motor, 2003, 30(4): 4. DOI: CNKI: SUN: ZXXD. 0.2003-04-009.

[3] Xue Wei, Qi Guoyuan, Shi Xiumin, et al. High order differential controller and its Application in AC Speed Regulation. Electrical Automation, 2006, 28(3): 3-4.

[4] Luo Chunfang. Variable frequency speed regulation technology and its application in Pharmaceutical Industry electrical automation control. Enterprise technology development: the ten-day, 2015, 34 (4): 2. DOI: CNKI: SUN: QYJK. 0.2015-11-027.

[5] Xu Maosheng, Gu Aiyu. Ac motor speed control system of vector control technology in the FPGA implementation. Mechanical and electrical information, 2014, (9): 3. DOI: 10.3969 / j.i SSN. 1671-0797.2014.09.051.

[6] Xi Yang. Application of Electric Automation Control Technology in Power System. China Science and Technology Investment, 2013, (35):10.