Research on Design Method of Computer Control System for Frequency Conversion Speed Regulation Based on Cloud Technology

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Abstract. With the development of power electronics technology, frequency converter as the controller of AC motor has been more and more widely used. With the continuous development and application of frequency converters, more and more occasions need to be remote controlled through the network. With the input system of computer, the process parameters can be easily changed. Intelligent control has become the feature and symbol of the new generation of control products, so intelligent control is bound to become a research hotspot in the field of control. Whether it is civilian or military, the variable frequency speed control synchronous control system has occupied a dominant position. Therefore, it is the current development trend to use a computer to control the inverter through communication. In order to meet the requirements of the production process, it is necessary to carry out technical transformation of the original system with new technology. This paper mainly describes the application of frequency conversion and automation technology in this system. The characteristic of the power supply voltage regulation synchronization system is that each unit is powered by its own power source. This method has better adaptability and a wider range of speed regulation.

1. Introduction
Since the birth of the first motor in the world in the 19th century, a historic revolution has taken place in modern industry. With the development of power electronics technology, frequency converter as the controller of AC motor has been more and more widely used [1]. Motion control plays an important role in industrial production, and speed control is an important branch of motion control. Although the theory and practical application of DC speed regulation system are relatively mature, the main technical indicators of single motor capacity, maximum voltage, maximum speed and overload capacity are constrained by mechanical commutation [2]. Most of the equipments are driven by two or more units working together. The problem of synchronous control is often encountered, that is, the control devices of these equipments are required to drive two or more motors to run synchronously [3]. Because DC motor torque is easy to control, it has been widely used in industrial production as a representative of variable speed motors for most of the century [4]. With the continuous development and application of frequency converters, more and more occasions need to remotely control them through the network [5]. Therefore, it is the current development trend to use a computer to control the inverter through communication. AC speed regulation has developed rapidly and has gradually replaced DC speed regulation.

The essence of synchronization is speed regulation, or synchronous operation is completely achieved by speed regulation. The most commonly used speed control methods are pressure regulation and magnetic speed regulation [6]. The main advantage of the AC motor is that it has no brush and commutator, simple structure, reliable operation, long service life, convenient maintenance, and the
price is lower than that of the same capacity DC motor [7]. In order to ensure the quality of the processing, it is usually required to keep the linear velocity of the product constant or the tension constant during the processing [8]. When the parameters of the stator and rotor circuits of the asynchronous motor are constant, the electromagnetic torque of the motor is proportional to the square of the voltage applied to the stator windings at a certain slip [9]. This requires that there is an adjusting device between the motor units, so that when the speed of each unit is different, it can adjust its own speed in time and automatically keep the same as the adjacent units [10]. According to the way of synchronous regulation, the control equipment can be divided into two types: the synchronous system of common power supply and the synchronous system of voltage regulation of sub-power supply [11]. Synchronization between units is achieved by adjusting the excitation of each driven motor. In order to meet the requirements of production process, the original system was revamped with new technology. This paper mainly describes the application of frequency conversion and automation technology in the system.

The automatic control system can be roughly divided into four kinds of motion control, process control, sequence control and stochastic control according to the control characteristics. It is very necessary to study the system of multi-unit synchronous control system. At the same time, it is also an important research direction in the field of motion control [12]. Changing the stator voltage of the motor can change the functional relationship of its mechanical sustainability, thus changing the speed of the motor under a certain output torque [13]. Its main disadvantage is that the equipment is bulky and huge. Speed regulation of series resistance in rotor loop of wound rotor asynchronous motor is realized by series resistance in rotor loop [14]. The common power supply synchronous synchronization system is characterized in that the armature voltage of each unit drive motor is supplied by the same common DC power supply [15]. The characteristic of the power supply voltage regulation synchronization system is that each unit is powered by its own power source. This method has better adaptability and a wider range of speed regulation [16]. As the prime mover, the cage motor drives the armature rotation of the electromagnetic clutch at a constant speed, and the speed adjustment of the magnetic pole is realized by controlling the excitation current of the electromagnetic clutch [17]. Because the original control system consumes a large amount of energy, low efficiency, frequent fluctuations in gas supply pressure, and high labor intensity. The DC speed control system has the advantages of good starting and braking performance, wide speed regulation range, small static difference and good stability.

2. Structure of Computer Control System

The frequency conversion technology was born in response to the need for stepless speed regulation of AC motors. In the transmission control system, if it is differentiated according to the type of control object, it can be divided into DC drive and AC drive. The main magnetic flux and the armature current of the DC motor are independent of each other, and they can be controlled separately, and it is easy to obtain satisfactory dynamic and static performance. On the contrary, the AC motor has a simple mechanical structure, but it is a nonlinear, strong, multivariable control object [18]. Since the motor is in an electric or power generating braking state, its power factor cannot be one. In the electric drive system, the simulation technology can be used to establish the simulation model of the motor and its transmission [19]. When the unit composed of AC motor, fan, compressor and so on needs to adjust the flow rate, it can only adopt the measures of baffle, gate valve, reflux and vent, which cause a lot of energy loss. Nowadays, the widely used high-performance frequency converter has been fully digital controlled by micro-computer, which can accomplish various functions mainly by software on the basis of the simplest hardware circuit.

There is always a reactive power exchange between the intermediate DC link and the motor. This kind of non-functional energy is buffered by the energy storage elements of the intermediate DC link. The simulation model can simulate the real motor field operation experiment in the simulated environment or condition. The vector decoupling method achieves complete decoupling of the speed and flux linkage control of the AC motor. Variable frequency speed regulation and spurious losses that are often overlooked in classical vector control but have a significant impact on control performance also vary with the slip frequency. Both of these factors can cause rapid and rapid changes in the rotor
time constant, affecting the dynamic performance of the control system. Fig. 1 shows the flow of the control system fault diagnosis algorithm.

![Fig. 1 Control system fault diagnosis algorithm flow](image)

The AC motor non-speed control system widely used in the past adopts the direct start mode. It only produces a large amount of power loss and seriously affects the stability of the power grid. The analog detection circuit is used to detect most of the parameters of the system. Analog detection uses two identical sets of interface circuits, and the chips of the two sets are independent of each other. Properly increasing the stator voltage can enhance the load carrying capacity. As the frequency increases and the voltage does not change, the air gap flux will weaken, resulting in a reduction in torque. However, the speed is increased at this time, so that the output power can be considered to be substantially unchanged. The AC speed control system has been extended to the field of speed control of high-precision, high-response high-performance indicators by general applications such as soft start and open-loop variable frequency speed control of fans and pumps [20]. The reliability of zero current detection circuit directly affects the reliability of thyristor bridge switching. For the closed-loop control system of frequency conversion speed regulation, the running speed is an important parameter. Under the condition of automatic operation, all the return valves are closed, and the gas pressure at the outlet of the fan is completely controlled by the closed-loop speed regulating system. In the transmission system, a new pattern has been formed. The AC speed regulation system has risen to the leading position and will gradually replace the DC speed regulation system.

Considering the torque error, the torque remains unchanged when the stator flux space vector stops rotating. When the torque rotates clockwise or counter-clockwise, the voltage vector changes clockwise or counter-clockwise. Considering the non-linearity of the inverters, the parameters of the inverters are shown in Table 1.

| Tab.1 Driver Power Inverter Parameters |
|----------------------------------------|
| Parameter                              | Numerical value |
| Modulation Carrier Period (Us)         | 120             |
| Modulated carrier frequency (kHz)      | 20              |
| Delay time (mus)                       | 10              |
| Continuous Diode Voltage Drop (V)      | 6               |

The existence of variable frequency speed regulation only affects the response of electromagnetic torque, but the flux of the molecule is not affected, so the estimated value is larger than the actual value. The actual torque is:

$$P_{f \rightarrow n_w} = \sum_{i=1}^{M} \sum_{I=1}^{n} P_I \left\| h_{I, n_w}^{t} W_{I, h} \right\|_2$$

Frequency conversion speed regulation power is also a function of frequency:

$$cell_{ps \rightarrow t} = \arg \max_n \left( \sum_{n=1}^{M} P_{f \rightarrow n_w} \right)$$
In order to study the control performance of dual-three-phase variable frequency speed control system in low voltage and high current environment in detail. This chapter designs and builds a complete low-voltage and high-current motor experiment system. The whole motor system includes a dual-frequency variable frequency speed control system, a set of low-voltage and high-current six-color electrochemical variable frequency drive, a tester for measuring load torque, and a corresponding display instrument, and a PC as a host computer. The motor parameters are shown in Table 2.

| Tab.2 Frequency control system parameters |
|------------------------------------------|
| Stator resistance                        | 1.5Ω |
| Relative number                          | 4    |
| Rated speed                              | 900r |
| Moment of inertia                        | 0.103kg·m² |

The modern automatic control system has a wide range of applications, with mechanical motion as the main production mode and electric motor as the execution component of the electric drive automatic control system. The modular design of the program not only facilitates parallel processing, system reconfiguration, but more importantly, it can well support the redundant design of the software, and constitute a fault-tolerant system with the module as the basic unit. The DC motor excitation circuit and the armature circuit are separated and can be separately controlled. The excitation current and torque current of the AC asynchronous motor are combined with the stator current vector. Simply controlling the stator current directly can not achieve effective control of the torque. The difficulty of the AC speed control system mainly comes from the mathematical model of the AC motor, which causes difficulty in torque control [21]. The speed with which the associated electronic devices and microprocessors are updated has constrained the development speed of the AC speed control system. In the output calculation module of the current regulator and speed regulator of the system, each redundant operation unit can adopt different algorithms, and make the algorithms as different as possible and as independent as possible. In the field-oriented coordinates, the stator current vector is decomposed into the excitation current component which generates the flux and the torque current component which generates the torque. With the development of large-scale integrated circuits and computer control, as well as the application of modern control theory, it has created favorable conditions for the development of AC electronic drive.

The appropriate space voltage vector is selected from the switching table to determine the switching state of the inverter at the next time. To minimize the switching frequency of the inverters, the average switching frequency of the inverters is taken as the value function. If the current loop feedback filter can be removed, the current loop bandwidth can be greatly improved. The current loop data of the low pass filter with or without feedback link are shown in Fig. 2.

![Fig. 2 Performance data of variable frequency speed control induction motor](image)

Due to centralized control, the situation is timely, accurate and rapid, and the connection between the station attendant and the switcher is no longer needed. The stator current vector can be regarded as
a combination of the orthogonal excitation current and the torque current vector. Then, the proportional relationship between the excitation current and the torque current not only affects the magnitude of the stator current but also the phase angle of the stator current [22]. According to the analysis of the basic principle and control scheme of direct torque control of induction motor, the control effect is analyzed by simulation. Build the system simulation model. In the simulation, the parameters of induction motor are shown in Table 3.

| Magnetic pole pair | Cross-axis inductance | Stator resistance | Rotor flux linkage |
|-------------------|-----------------------|------------------|-------------------|
| 5                 | 8.5mH                 | 2.5Ω             | 0.355Wb           |

For such a complicated control object, the new control method and the new speed control system composed of new devices are difficult to achieve the precision of the mature DC speed control system. The biggest difference from the DC motor speed control system is that the AC motor has no mechanical commutator-converter with motor current flowing. Future artifacts should be intelligently controlled at the lowest level of the architecture [23]. Based on this idea, the fieldbus control system emphasizes the completion of the underlying basic control functions by intelligent field devices. As a voltage model, because of the integration operation, because of the low voltage at low frequencies, the integration calculation will have errors, resulting in cumulative drift, and the accuracy will be greatly reduced. While realizing the closed-loop control function of automatic frequency conversion and constant voltage, the original manual function is retained. Manual or automatic operation mode can be converted in the control loop, and electrical interlocking, in order to prevent Inverters from power supply.

3. Reliability Design of Control Computer System
In important occasions directly related to production and personal safety, in order to reduce the fault of DC motor and save maintenance time, AC speed regulation is used instead. After the transmission of the computer control system, the first task is to power on and self-diagnose. Since direct torque control is based on the control of stator flux by voltage space vector, it is necessary to establish a mathematical model of electromagnetic torque relative to stator flux. The industrial computer is used as the upper computer, and the control software is integrated in the industrial computer. The control system software provides a friendly man-machine interface and all the operations that users need to perform. The controller uses the corresponding control algorithm to control the turn-off timing of the power devices in the inverter according to the given value of the speed and the feedback amount. After adopting the frequency conversion speed regulation method, the synchronous machine can be directly started and operated at any variable speed. At the same time, it overcomes the startup problem, the loss of synchronization and the oscillation problem during heavy load. Therefore, the frequency conversion speed regulation of the synchronous machine will also become a development direction of the speed control system in the future.

Because the working process of the computer is more complicated, it is difficult to accurately calculate the power consumption of each part. Therefore, the design is only theoretically calculated, and the motor power of the same type of computer is referenced. The flux linkage and the torque data are obtained by the flux linkage simulation model and the electromagnetic torque model. The hysteresis comparison state signal is generated compared with the given value, and the voltage state vector table is logically controlled to switch the state of the switch. The corresponding rated torque can be analyzed when the rotating speed is 30r, 70r and 100r respectively, and the three-phase rms current ripple value is shown in Table 4. At a given rotational speed, the torque of vector control establishes a stable rated torque and the response time to the rated torque are shown in Table 5 respectively. The system dynamic performance simulation waveform for a given speed is shown in Fig. 3.
Tab. 4. Current ripple values of vector control under different torques and rotational speeds

| Torque  | 30r | 70r | 100r |
|---------|-----|-----|------|
| 75.5Nm  | 2.53| 1.52| 1.42 |
| 55.5Nm  | 2.55| 1.47| 1.49 |
| 30.5Nm  | 2.59| 1.59| 1.37 |

Tab. 5. Different vector control Establish stable time under torque and speed

| Torque | Torque response time |
|--------|----------------------|
| 30r    | 50ms                 |
| 70r    | 35ms                 |
| 100r   | 27ms                 |

According to the equivalent principle of the rotating magnetic field, the two-phase stationary coordinate system takes the same number of turns, the same structure and is orthogonal under the power conservation algorithm. The mathematical model of the surface type in the two-phase stationary coordinate system is as follows.

(1) Voltage equation:

$$\frac{dx_i^{(1)}}{dt} + a x_i^{(1)} = \sum_{j=1}^{N} b_j x_j^{(1)}$$

Another form is:

$$x_i^{(0)}(k) + a x_i^{(1)}(k) = \sum_{j=1}^{N} b_j x_j^{(1)}(k) \text{ for } k \in K, K = 1, 2, \ldots, n, \ldots$$

(4)

(2) Magnetic flux equation:

$$E_{r_1}(l) = E_{r_1 - elec}(l) = l I_{elec}$$

(5)
Another form is:

\[ ES_i = \sum_j (1 - \sum_q p_{i,q,m_{i,q}}), q \neq i, j \]  

(6)

With the development of control technology, the use of AC motors is particularly extensive, especially the application of AC motor frequency conversion control technology makes the application range of AC motors greatly expanded. The full digitalization of the control means makes use of the powerful information processing capability of the microcomputer, so that the software functions are continuously strengthened, and the flexibility and adaptability of the frequency converter are continuously enhanced. If the detection circuit of the deceleration section axis pulse encoder fails, the system will be based on the speed detected by the tachogenerator [24]. Although the converter has one more intermediate DC link, the frequency of AC output can be higher than that of power grid. The fuzzy controller is in the outermost loop, while the inner loop still retains the traditional control methods such as vector control and sliding mode control. After system debugging and normal operation for a period of time, it is found that there is a non-periodic phenomenon of protective shutdown due to overvoltage and overcurrent. The function code tells the slave to read the value of the register, then the data area must contain the starting address and reading length of the register to be read. For different slaves, the address and data information are different. When the phase-controlled rectifier is used for voltage regulation, the power factor of the grid side becomes lower as the adjustment depth increases.

If a reactor is used as the reactive power buffer, and the DC side power supply is equivalent to a high-impedance current source, it is called a current source type inverter. In the traditional vector control mode, the total harmonic content of the stator phase current is 6.48%. When the improved vector control method based on the quasi-PR controller is adopted, the total harmonic content of the stator current of the motor decreases. The harmonic content of each control mode is shown in Table 6. Due to the use of a quasi-PR controller, the harmonic current is effectively suppressed compared to the conventional vector control control method.

| Harmonic number | PR control | Space vector decoupling |
|-----------------|------------|-------------------------|
| 6               | 3.69%      | 0.78%                   |
| 9               | 2.46%      | 0.66%                   |

Considering the characteristics of high-speed motor, the design of lubrication system has also been fully considered. The fixed-point, quantitative and timing lubrication of important transmission parts and gears prolongs the maintenance cycle of the machine. It is necessary to estimate the rotor flux and torque to form a closed loop control, and the stator current and voltage are used for the estimation of flux and torque. The relationship is as follows:

\[ cell_{p_m-n_p} = \arg\max_{n,m} \left( \sum_{n=1}^{b} \frac{P_{f-n_p}}{a} \right) \]  

(7)

The electromagnetic torque of the motor is:

\[ \hat{R}_c^w = \log_2\left(1 + \frac{p_{max,n}}{\sigma_{max}} \right) \]  

(8)

Generally, the carrier frequency is kept constant when the reference wave frequency is changed, thereby increasing the carrier ratio at low frequencies, so that the number of pulses of the inverter output voltage in one cycle can be increased as the output frequency decreases. The equation of motion of the motor is:

\[ S^* = \arg\{ f(S) \} = \sum_{j=1}^{\max} \left( T_{c_m,n} - D_{c_j} \right), 0 \rightarrow \min \]  

(9)
The induction motor is the sum of the electromagnetic power of each phase and can be expressed by the following formula:

$$\mu_{s,d} = \frac{1}{MN} \sum_{m=1}^{M} \sum_{n=1}^{N} \left| W_{s,d}(m,n) \right|$$

Manually adjust the output frequency of the frequency converter with an intelligent manual operator. The manual operator automatically tracks the output frequency of the inverter through the feedback signal of the inverter, and keeps the output consistent with the output frequency of the inverter for tracking detection. The output loop current signal can also be decomposed into a fundamental wave containing only a sine wave and other harmonics, while the higher harmonic current directly interferes with the load [25]. Synchronous modulation and asynchronous modulation are combined to complement each other and form piecewise synchronous modulation. The way of harmonic propagation is transmission and radiation, and the main way to solve the conduction interference is to filter out or isolate the conduction high frequency current in the circuit. Considering that the linear velocity difference of the product will cause the tension fluctuation in the product first, and then the displacement of the elastic frame. So tension can also be used as a measure to design the system. But this is not applicable to loosely processed machines. If the DC voltage rectified by the rectifier is directly supplied to the inverter without being processed, the AC voltage or current ripple after the inverter will be large, which will cause great harm to the motor.

The rotational speed response during motor dynamics is an oblique line, which is evidenced by the fact that the motor is basically started with maximum torque. The speed stabilizes after reaching the target speed of 200 rad/s, and the motor torque is also stabilized. The motor torque waveform is shown in Fig. 4.

![Motor torque waveform](image)

**Fig. 4 Motor torque waveform**

The electromagnetic torque equation of the variable frequency speed control system has the ratio of the electromagnetic power of the motor to the mechanical angular velocity of the rotor, and the ratio of the electrical angular velocity of the rotor to the angular velocity of the mechanical is the pole pair of the motor. Based on this, the motor electromagnetic torque expression is obtained as follows:

$$S_w = \frac{1}{2} \int_{0}^{t} \frac{4P_v^2}{\pi d^2 E_a L_a} dx = \frac{4PL_a}{3\pi d^2 E_a}$$

In addition, from the perspective of energy conservation, the electromagnetic torque of the variable frequency speed control system drives the load on one hand and the damping and inertia on the other hand. From this, the mechanical equation of motion for torque balance is obtained:

$$S_w = \frac{4P}{\pi d E_a \alpha} \left( \frac{\alpha \cdot L_a - x}{d} \right)^{\frac{1}{2}} \cdot \frac{1}{\pi \alpha E_a} + \frac{AR}{\pi \alpha E_a} \cdot x$$

With the development of power electronics technology and microelectronics technology, as well as the application of computer control, AC motor variable frequency speed regulation technology is becoming more and more mature, and AC speed regulation is gradually replacing the original DC speed
regulation. The essence of synchronization is speed regulation, or synchronous operation is completely achieved by speed regulation. The two components are perpendicular to each other, independent of each other, and then controlled separately. Then the control signal is synthesized and converted into the control signal of the parameters of the frequency converter, which imitates the control characteristics of the DC speed regulating system to realize the effective control of the electromagnetic torque. In the vector control system, the stator current is controlled, so the relationship between the two components of the stator current and other physical quantities must be found in the mathematical model. After investigation and analysis, it is known that when the inverter trip protection, there are heavy-duty devices in the vicinity of the grid that cause peak voltage and current to cause a shutdown. In the vector control inverter, the microcomputer software has a vector operation module, which functions to simulate the running state of the asynchronous motor at all times.

4. Conclusion
With the rapid development of control theory and production technology, the application of speed control systems is more and more extensive. Because the motor uses soft start and soft stop, it often works at lower than the power frequency. This extends the mechanical life of the system and the life of the appliance, reducing maintenance. From the perspective of the development of control theory, intelligent control theory is the development trend of traditional control theory. With the application of variable frequency vector control technology, it is easy to realize the process of low-speed production and automatic head generation, and smoothly transition to normal working state. The research of synchronous control system of variable frequency speed regulation has become a hot topic in the field of control today. In various fields, whether civilian or military, frequency conversion speed regulation synchronous control system has occupied a dominant position. The design of control system should be taken as the main line, and some influencing factors in practice should be considered at the same time. In the established mathematical model, appropriate compensation is given for some cases. The optimal process parameters of different varieties and different counts can be stored in the computer database. Process parameters can be easily changed using the computer's input system. Intelligentization has become the feature and symbol of a new generation of control products, so intelligent control will inevitably become a research hotspot in the field of control.

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