Application of Variable Frequency Speed Regulation Technology in Fan System

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Abstract. With regard to the problem in fan air volume control, the research on air volume method was carried out, and the air volume control method for frequency conversion speed regulation was adopted. In this regard, a motor variable frequency speed regulation system was designed, and a variable frequency control software was developed. In order to verify the control effect of the system on the fan air volume, a measurement experiment on the fan speed was carried out, and it was concluded that the variable frequency speed regulation method was highly precised, and had a sound linearity. While finally, this variable frequency speed regulation system was applied in the fan system, and the equal thickness collection experiment on the material was carried out in order to ensure the strict control over the air volume, which has obtained a relatively sound application effect.

1. Introduction
Electric motors, as an effective power source, are widely applied in the real production, which are generally applied in driving various machine tools, elevator, fans and water pumps [1]. As in the fan system, the ordinary electric motor will only provide the fan with rated speed, but the air volume of the system is normally nonadjustable. In a certain pneumatic experimental equipment, the fan system is required to provide different air volume for different experiments, that is, the air volume of the system is required to be adjustable and range for the air volume adjustment shall be large. After studying the method of air volume regulation [2,3], an idea for controlling the air volume of the fan system through regulating the motor speed based on variable frequency speed regulation method is determined. With regard to this, a set of variable frequency speed regulation system is designed and developed. And in order to control the air volume more precisely, a trial experiment on the effect of the variable frequency speed regulation method is carried out. As shown in the results from the experiment, this method is high precision and has a good continuous effect. While finally, the actual application is conducted on the system, which has realized the strict control over the air volume. It has seen a relatively sound application effect of the system.
2. Research on Air Volume Control Technology of Fan

2.1. Air Volume Controlling Method
In the application of fan system, there are many control methods for fan air volume, which can be further divided into blade control, baffle control, mechanical speed change control and electrical speed change control [4]. At present in the system with the electricity as the power source, the most commonly speed control method is the variable frequency speed regulation method, in other words, the frequency converter is used to adjust the power frequency of the motor, so as to make the speed of the motor varied, thus further to change the speed of the motor, then the adjustment towards the air volume is realized. The realization of speed regulation through variable frequency, as one of the most effective methods in controlling the air volume, has various advantages [5].

2.2. Relationship between Motor Frequency and Speed
As it could learn from electrical mechanics, the basic expression for speed control of asynchronous motor is shown in Formula (1):

\[ n = \frac{60f (1-s)}{p} \]  

(1)

Where: \( n \) represents the actual rotation speed of the motor; \( f \) represents the power supply frequency for motor stator windings; \( p \) represents the polar logarithm of the rotating magnetic field; \( S \) is the slip ratio, which indicates the synchronous speed of the stator rotating magnetic field.

From Formula (1), it is known that the motor speed is related to the three factors, namely \( P, f \) and \( s \). The motor speed can only be controlled through three ways, namely, the variable polar logarithm, the variable slip ratio and the frequency conversion.

Polar logarithmic speed regulation is a kind of speed regulation without slip loss and it has relatively hard mechanical characteristics, but it is a kind of polar speed regulation and a stable and continuous adjustment of speed cannot be realized. It is quite simple for the variable slip speed control method simple, since its essence is to convert part of the input power into slip power so as to weaken the output power, and the motor speed is forced to drop and further the power factor is reduced. Frequency conversion speed regulation is a method of speed regulation by changing the power supply frequency of the motor. The stepless speed regulation could be realized through frequency conversion speed regulation in a wider range. It can obtain a better starting and running characteristics, and it is a speed regulation method with higher efficiency [6]. Conditionally when \( p \) and \( s \) are unchanged, \( f \) and \( N \) have a linear change rule, that is, the rotating speed of the motor is proportional to the frequency of the power supply.

3. System Design and Experiment

3.1. Hardware System Design
Based on the aforesaid theories, a motor frequency conversion speed regulation system is designed. The system is composed of motor, frequency converter, host computer and control software. See Figure 1 for hardware connection of the system. The hardware system structure design is based on the frequency converter 485 bus. The frequency converter of this system supports Modbus communication protocol and has RS-485 communication interface. The RS-485 interface of the frequency converter is connected with the RS 485/232 converter for the conversion of RS-485 signals and RS-232 signals, and then it is connected with the host computer, so that a serial communication between the host computer and the frequency converter is established. (Refer to Fig. 1)
3.2. Software System Development

In order to facilitate the frequency conversion control operation, to further improve the frequency conversion control accuracy and frequency conversion resolution, and to make the display of the frequency conversion system more illustrational, the frequency converter monitoring system software is designed.

The communication between the software system and the frequency conversion follows ModBus protocol. ModBus protocol is a reliable and effective communication protocol for industrial control system. Its data communication is realized by means of inquiry or response between host and slave, which mainly includes inquiry and response towards messages [7]. The serial port communication program design on the host computer end is realized by MSComm control, as a special communication control, which can be used to conveniently realize the communication management of computer serial port without considering the underlying communication protocol. With the usage of ModBus protocol and MSComm control, the development of serial communication program for the host computer could be realized. While MSComm is applied for the serial communication, the “Switch on, Switch off, Sending and Receiving” instructions of the serial are mainly used. As for the design of software function, functions, such as startup, frequency conversion, real-time monitoring, frequency setting, state detection and fault diagnosis, are designed respectively. The progress bars, buttons and meter dial controls are adopted for the input and output control of the software, which a three-dimensional man-machine interface has been realized. Refer to Figure 2.2 for more details.

3.3. Speed Precision Experiment

In order to further study the adjustment precision of this motor speed controlling system, a motor speed precision measurement experiment has been conducted. The experiment is to measure the actual output speed at certain frequencies through a speed measuring instrument. While in the experiment, the minimum resolution of the frequency converter is taken as the variable, and 1.5Hz, 3Hz, 6Hz, 10Hz, 15Hz, 20Hz, 30Hz, 40Hz and 49.5Hz are taken as the base frequencies respectively. Suppose under each base frequency, the actual rotation speed of the motor is measured for each time the frequency increment increase by 0.01Hz. However, in order to simplify the amount of experimental data, the frequency variation at each base frequencies is varied from 0.00 to 0.02Hz. Then, measure
the motor speed for three times under each frequencies, and taken the average of three measurement results as the final result. The experimental data is listed as shown Table 2.1.

As it could be analyzed from the experimental results in Table 2.1, when the base frequency is within 30Hz, for each 0.01Hz increase in the frequency, the basic increment of rotational speed is 0.3r/min, which is with strong regularity. While when the base frequency is above 40Hz, it can only be accurate to over 1r/min due to the resolution of the speed measuring instrument. For every 0.01Hz increase in the average available frequency measured by increasing the frequency increment point (the frequency increment is varied from 0.00 to 0.09Hz), the basic increment or the speed measuring instrument is also 0.3r/min, which is with a high precision. Moreover, the data analysis tool is used for data analysis, while the linear correlation reaches 0.9999. The frequency and the rotational speed strictly follows a linear change rule.

Table 1. Experimental Data of Motor Speed at Different Frequencies

| Frequency increment (Hz) | 0.00 | 0.01 | 0.02 | Frequency increment (Hz) | 0.00 | 0.01 | 0.02 |
|--------------------------|------|------|------|--------------------------|------|------|------|
| Base frequency (Hz)      |      |      |      | Base frequency (Hz)      |      |      |      |
| 1.5                      | 44.5 | 44.8 | 45.1 | 20                        | 598.2| 598.5| 598.8|
| 3                        | 89.5 | 89.8 | 90.1 | 30                        | 896.8| 897.2| 897.4|
| 6                        | 179.3| 179.6| 180  | 40                        | 1194 | 1195 | 1195 |
| 10                       | 299  | 299.4| 299.7| 49.5                      | 1477 | 1477 | 1477 |
| 15                       | 448.6| 448.9| 449.2|                          |      |      |      |

4. Application
As in the pneumatic collection experiment, the fan pneumatic system was used to carry out the equal thickness collection experiment. This experiment is to adjust the air volume as required by the material suspension speed. Under the condition that the distance between the suction port and the material remains unchanged, the rotation speed of the fan is strictly controlled to obtain the appropriate air volume so as to achieve the equal thickness collection of the material. During the experiment, sandy soil material with a certain thickness was laid on the soil tank. The material was collected by moving the soil tank at a constant speed and using the relative movement of the soil tank. Refer to Fig 3.1 for the process of experiment.

![Fig. 3 Equal Thickness Collection Experiment](image)

In the experiment, the air volume from the system is remain fixed and unchanged, and the collection areas are taken the coordinate plains, and measurement points within the collection areas are selected after the collection, the collection thickness are measured so as to obtain the experimental data. The distribution map in three-dimensional for the collection thickness obtained from the experimental data is shown in Fig 3.2. As it could be seen from Fig 3.2 that most of the collection thickness of measurement points within the collection areas are within the range of between 24mm and 25mm, while the different between the maximum value and the minimum value is 1.8mm. The variation of the data is relatively smooth, the distribution of thickness variation is relatively average, and the three-dimensional curved surface in the figure is relatively close to that of the plan surface.
Therefore, from the results collected, this system can collect sandy soil with an equal thickness has a sound collection effect. The main reason for this is that the frequency conversion speed regulation system is designed in the fan control, which ensures the strict control over the air volume.

5. Conclusion
On the basis of comparative analysis, the air volume control method based on frequency conversion speed regulation is adopted, the motor frequency conversion speed regulation control system is designed, the hardware system construction and software system development are completed, and the speed accuracy measurement experiment is carried out. While finally, the actual application is conducted on the system, and the equal thickness collection experiment on the material was carried out, which has seen a relatively sound application effect of the system.

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