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Applications of Frequency Conversion Technology in Air-compressor Units Control System

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Abstract

Reconstruction of control system has been conducted through adoption of frequency conversion technology-three driven by one shared converter targeting control system shortcomings of piston air-compressor in a mine of Shandong. The necessity of frequency conversion and principle of frequency control is elaborated in this paper, so are problems in frequency conversion. And also advantages and disadvantages are analyzed in frequency conversion. Through actual operation, the reliability and stability of this system are well proved; pressure control precision and automatic level have been improved; goal of energy-saving and cost-reducing have been achieved. The frequency conversion can provide references for enterprise air-compressor frequency conversion reformation and is of great value in its popularization.

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Keywords: Air compressor unit; Inverter; Variable Velocity Frequency; Energy-Saving Retrofit

1. Introduction

The air-compressors are the important equipments in mine production and its electric-power

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consumption possesses a large proportion of the whole consumption. It bears the power-supply of pneumatic machinery and main well unloading machinery of the mine. Its normal and stable operation can directly affect the production safety and economical benefits.

Relay-contactor control and reduced-voltage starting by autotransformer are adopted in the current three piston air-compressors of a mine in Shandong .The system is adopted low-pressure loading and high-pressure unloading of air-compressor to adjust the air exhaust quantity . The load and unload are realized by on and off of the intake valve; when exhaust release pressure reaches the up-limit, the intake valve will be off to unload; the intake valve will be on to load when the pressure reaches the down-limit. Shortcomings of this system are the following:

- Motors are still run in working frequency after unloading of air-compressors, then energy-consumption is about 30%-60% of the total, which is not only electricity-wasting but also increasing mechanical abrasion of equipment. The high speed of air-compressors and frequent on-off of intake valve resulted in higher noises, vibration, severe motor heating and energy-waste.
- Adoption of autotransformer reduced-voltage starting caused big starting current, long-time starting, low power-factor and large reactive loss, which has a large impact on power-grid and equipment.
- When air-consumption varies, air-compressor will load and unload frequently, which has a large impact on power-grid and equipment, resulting a high rate of equipment failure. At the same time, safety and reliability of the system will be decreased because of the large pressure-vibration and low adjusting-precision.
- Manual control of air-compressors on-off will cause delay of system pressure adjustment.

In connection with the shortcomings of air-compressor control system discussed above, it is of great value to conduct frequency conversion reconstruction, improve motor starting performance, reduce equipment mechanical abrasion, improve running reliability and safety of air-compressor units, reduce running-cost, improve workers' working conditions and improve system automation.

2. Principle of Air-compressor Frequency Conversion Speed Regulation

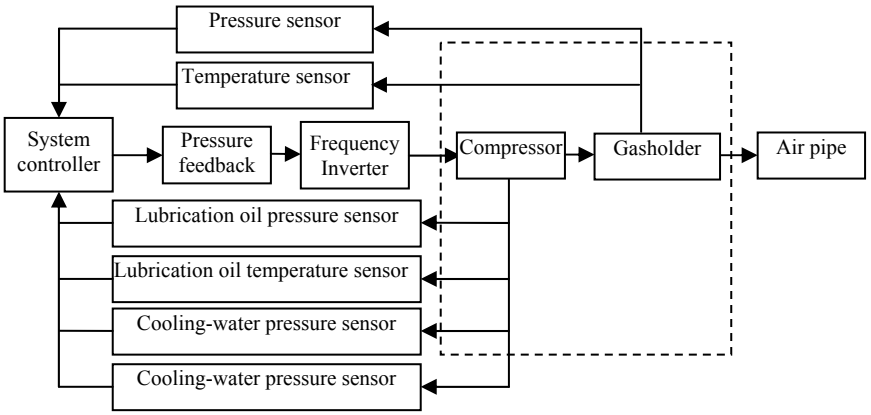

Fig.1. principle diagram of air-compressor frequency conversion speed regulation

Air-displacement of air-compressor and crank rotating speed are in an approximate direct proportional relation; air-displacement can be changed through adjustment of motor rotating speed drove air-compressor. Unit interval air-output of air-compressor can be controlled through adjustment of motor rotating speed by inverter thus to control pipeline pressure. Comparing gasholder pressure value

collection by pressure sensor and set pressure threshold, corresponding inverter frequency can be acquired through PID accounting; corresponding motor rotating speed can be realized to drive air-compressor and adjustment of compressed-air output flow can be realized to adapt changes of air-consumption load. At the same, purpose of air-supply according to requirement is realized. Principle diagram of air-compressor frequency conversion speed regulation is shown in Fig.1.

3. Notice of Air-compressor Units in Frequency Conversion Reconstruction

Lower limit of inverter frequency should be above 30Hz. Generally coaxial self-air-cooler is used in air-compressor motor. When output frequency is too low, input air will not be enough generated by blower, which causes overheat of motor. In addition to, if rotating speed is too low, it can affect lubricity of air-compressor cylinder body, which can cause heating of cylinder body and accelerate abrasion [1-3].

Control process should be focused when powerfrequency and variable frequency of inverter with "three driven by one" switches due to non-extinguishment of voltaic arc after inverter cut-off; if powerfrequency switches too early, short circuit will be caused easily; Firstly, Air-compressor should be stopped freely in state of frequency conversion; Then motor will be separated from inverter; Finally working frequency switch can be realized thus switching tripping caused by unsuitable-switching can be avoided.

High-harmonics electric current can be generated in feed backside and output side when inverters are in operation. Input and output of AC reactors are used to filter high-harmonics effectively in the current and reduce electromagnetic interference caused by high-harmonics; thus interference in grid can be reduced; noises and temperature rise in operation can be reduced; stability of motor can be improved.

Power cable between inverter and air-compressor should not be too long so as not to affect its performance; cable splice between motor and inverter should be handled properly to avoid failure of motor caused by large current heating of long-running; inverter should be earthed separately.

4. Control Scheme for System Frequency Conversion

4.1. Transducer selection

Inverter shall be selected according to load torque characteristics of equipment, speed range, starting torque and the demand of use environment. Air compressor is a machine with constant torque load of a large moment of inertia whose characteristic can easily lead to over-current protection when inverter is started. Therefore, such a constant torque converter with a high starting torque shall be adopted, which can ensure to realize a continuous and dynamic adjustment for air-supply, but also to make equipment in reliable and stable operate. Siemens MM440 Inverter with constant torque control mode was chosen in the system. The series of inverters adopted such a constant torque control technology with fast self-starting, high starting torque (the maximum starting torque up to 200% of rated torque) and starting impact current less than 1.2 times of rated current.

4.2. Control strategy and process for piston air compressor

According to the characteristics that there is no great changes for air-consumption flow of mine in a short time, one inverter was chosen to drive three piston air-compressors alternately, which can not only save energy, but also lower equipment costs. Main controller S7-300PLC communicates pressure monitoring value and threshold value in gasholder to inverter through industrial bus and CB communication board, and control motor speed by the internal PID regulator function of inverter which

can make actual pressure value constantly close to threshold value of pressure [4]. When one piston compressor runs according to the demand of air-consumption, a single air compressor runs with frequency operation so as to maintain constant pressure. However, the original air compressor converted automatically to powerfrequency operation, the inverter drives the next piston air compressor to run under PID frequency operation when wind-supply for the system is not enough under the condition of increasing air load. PLC can adjust automatically operating numbers of air compressors to realize automatic switches of powerfrequency through detecting air pressure of gasholder and operating state of inverter, which then can finish the closed-loop control of air-supply. Three piston air compressors adopt the control sequence with first-start and first-stop. The standby soft start is adopted control the circuit for the system and still can softly start air compressors so as to maintain system pressure when the inverter is out of work. Air-supply can realize adjust dynamic continuous and dynamic adjustment and make supply air with constant pressure through frequency transformation.

The control process is as follows for piston air compressors to run automatically: Firstly, No.1 compressor is started in frequency state. No.1 compressor begins to run in load state and then is in a process of frequency PID adjustment after the inverter frequency is up to 30Hz. When the frequency is up to 50Hz, No.1 compressor switches to be in a powerfrequency operating state while No.2 compressor in a frequency conversion operating state if the gasholder pressure is still lower than the default boot pressure threshold. And so on, if he frequency is up to 50Hz running and the pressure is still lower than the boot-pressure threshold, No.2 compressor switches to powerfrequency running, and No.3 compressor will be started under frequency conversion and PID adjustment state. At this time, the three air compressor run automatically so as to increase wind-supply. If the air supply of the system decreases and the frequency of inverter decreases to 30Hz, the system will stop automatically No.1 compressor in powerfrequency operating state when the wind pressure is still larger than stop pressure threshold. When No.1 compressor is stopped and the pressure is still larger than stop pressure threshold, No.2 compressor in powerfrequency running state will stop automatically. At the same time, No.3 compressor runs in frequency conversion state so as to ensure that the system supplies air. Thus, the numbers of air compressors can be adjusted dynamically according to the demand of air-consumption. Theory diagram of control system for piston compressor is shown in Fig.2.

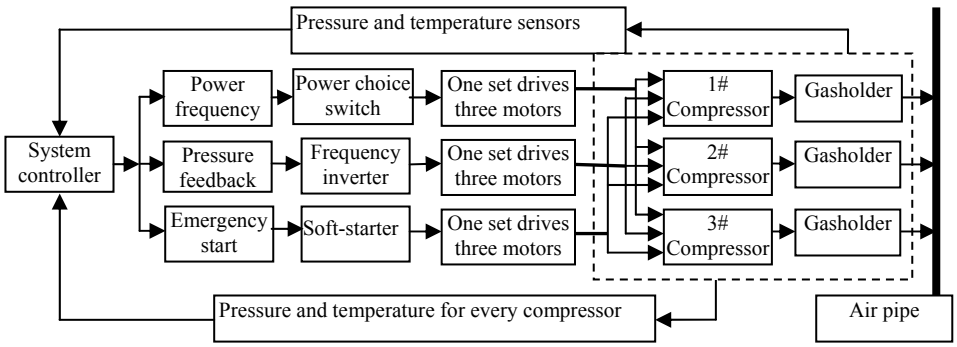

Fig.2. theory diagram of control system for piston compressor

5. Advantages of Air-compressor Frequency Conversion Reconstruction

- Electricity-saving
  After frequency conversion reconstruction, air-compressor unload loss can be reduced; on the other

hand, motor input power has declined due to air-compressor operation under the lower pressure under guarantee of production; combining with pressure closed-loop control, dynamic matching of air-supply and rotating speed of air-compressor has been realized and actual input power has been reduced, thus energy-saving has been realized.

- Extension of equipment life

Frequency conversion can make current rise smoothly in starting and loading of motor thus to reduce impact on electrical components and mechanical components in starting, which is helpful in extending equipment life and reducing maintenance and repair costs. In addition, frequency control can reduce current fluctuations in air-compressor units starting and this fluctuating current can affect electricity-use of grid and other equipment, inverter can effectively reduce peak starting current to a minimum.

- Realization of constant air-supply

According to change of air-consumption in pipe network, inverter adjusts rotating speed and running numbers of air-compressors automatically and makes pipe-network pressure constant all the time, which improves air-pressure adjusting ability in loading change and reliability of air-supply, ensuring mine safe production.

- Decease of air-compressor noise

After frequency conversion reconstruction, mechanical motion noises become smaller because of the slower speed of motor rotating; there is no frequent loading and unloading noise because of adjusting way of motor rotating; noises caused by unstable pressure disappear too.

6. Conclusion

The Control system of frequency conversion reconstruction in piston air-compressor units is in better running for more than one year in a mine of Shandong. Electricity-saving rate can be reached 30% or so; all the performances are safe and reliable and full approval has been accepted by customers; Good social and economic benefits have been achieved. This can provide references for enterprise air-compressor frequency conversion reformation and is of great value in its popularization.

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