Design of Piston Air Compressor Unit Control System based Converter

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***Abstract*—Based on the running characteristics and high energy consumption of air compressors in coal mines, an air pressure PID closed loop control system has been designed in this paper. The system is composed of PLC, converter and sensors etc and adopts the control method of converter triple-evaporator which makes air supply "need-based". The designed system has been applied in multiple coal mines and the results show its energy saving is remarkable and potential application is widely.**

Keywords* — *air compressor, converter, triple-evaporator, air pressure closed loop, energy saving

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1.Introduction

According to statistics, annual electricity consumption of the air compressors is about 10 percent of the total electricity consumption in coal mines [5]. Especially, with increasing of the coal production and consumption in recent years, electricity consumption of compressor which is one of the four most important equipments is more and more prominent. How to reduce the air compressor's energy consumption and saving energy have been the main targets in many coal mines [6].

At present, the control systems of the mine-used piston air compressors (PAC) are mostly based on Y-Δ auto-induction voltage-reduced starter and relays simply. There were many disadvantages in these control systems such as large starting current, frequently loading and unloading, large fluctuation of air pressure, high rate of the mechanical fault and low automation, etc. This work mode will waste more electrical energy and shorten equipment's life.

Energy saving of air compressor is considered mainly from run and control mode, transmission mode and waste heat utilization, etc [7]. In this paper, an air pressure PID closed loop control system which includes PLC, converter and sensors etc was designed to change the original run and control mode. The control method of converter triple-evaporator has been adopted and it can realize the dynamic regulation and "need-based " air supply. Then the load rates of the compressors can be balanced because of the using of "first starting then first stopping". Compared with intake throttling control, the application of the converter control in compressors unit will save energy about 30%~50% [8].

The designed converter control in the compressors unit has been applied in multiple coal mines such as XinYi mine. The energy saving is significant and application is wide. With the development of frequency conversion technology and the upsurge of energy saving requests, the technology that the speed control and energy saving are realized by the converter in the compressors unit will be extended widely in coal mines and other industries.

2.Conversion Control System of Piston Air Compressors Unit

2.1Converter Triple-evaporator Air Compressors Control System

In order to realize the "need-based" air supply, that is the air supply amount is adjusted automatically by the system according to the needs of air under coal mine and the stable air pressure in pipe network will be kept, the converter control technology has been adopted.

As for three piston air compressors unit (PACU), the basic frame of the converter control system is shown in Fig.1. The main compositions of the system are a touch screen, a set of converter, a set of S7200 PLC (including the EM231 module), EM277 communication module, industry PROFIBUS field bus, CB communication boards, motor electronic protector and sensors of current, voltage, pressure and temperature.

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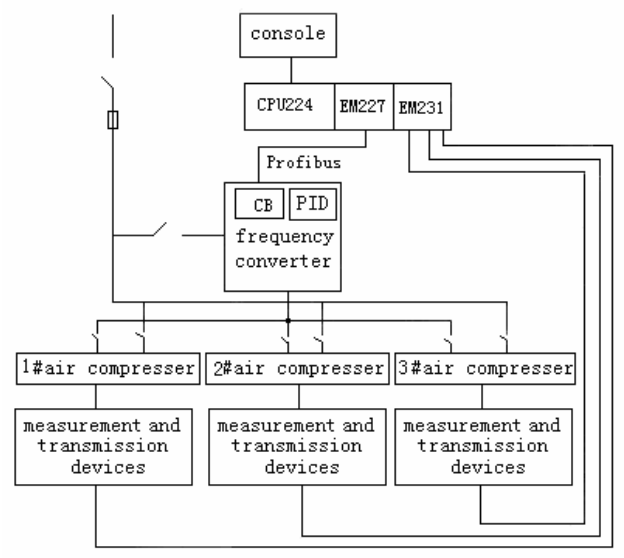

Fig.1 The basic frame of the converter control PACU system

In coal mines, the supply air pressure can not vary greatly within a short time and the PAC must be driven one by one. So it is reasonable and feasible to adopt the control method of converter triple-evaporator in PACU. Here the converter, which capacity is the same as that a PAC, sequentially drives the three piston air compressors. Thus not only the system energy consumption can be much saved but also the cost of system can be decreased.

2.2 Selecting and Parameter Setting of Converter

Considering the load characteristic, speed range, starting torque, application environment of the PAC, we have adopted the siemens 380V132KW converter of MM440 series to realize speed control with constant torque in the system. The converter is of faster self-starting, starting torque bigger and stronger overload capacity.

In order to realize the good control performance of the system, we must set concrete numerical value to the converter inherent parameters and BICO. Table I has listed main parameter setting of converter

Tab.1 Set Value to the Parameters of Converter

parameter	Set value	parameter	Set value
P0304	380	P1080	30
P0305	255	R2050[1]	P2253
P0307	132	R2050[2]	P2264
P0308	0.78	P2200	1
P0640	120	P2280	0.4
P0700	6	P2285	10
P1000	6	P2051	21

3. The work process of the system

3.1 The Control Process of the System

When the system working, the pressure transmitter converts the air pressure signal of main pipe into electrical signal and sends it to PLC, the air pressure setting value and pressure detection value are send to converter by PLC through PROFIBUS industrial bus and CB communication board, the motor speed is controlled by the internal PID of converter, then the air supply amount is regulated, and the actual air pressure value is adjusted to the setting pressure value. Furthermore the close loop control of air pressure has been realized. When the operating frequency of converter has reached 50HZ, if the actual air pressure value can not reach the setting value, then the compressor which is driven by converter will work with industry frequency automatically, at the same time another compressor was drove by converter to supplement air. PLC regulates the number of compressors unit and realizes IF-FF switching by measuring the air pressure of main pipe and monitoring the converter status. In addition, the system can also monitor the important online parameters, such as temperature, pressure, electric quantity etc, if these parameters are abnormal, it can alarm after a while. Fig. 2 is the control process of the compressor system.

3.2 "First Starting then Fist Stopping" Sequence

Fig.3 shows the start-stop sequence of the compressors which is called "first starting then fist stopping". When the 1# compressor has been started by converter, it is loaded and made the PID regulation after the frequency reaches 30HZ. If the outlet air pressure of main pipe has not reached the presupposition-pressure after the frequency value of converter reaches 50HZ, the PLC will stop the converter and do the make-break of relays, in the meantime the 1# compressor which has been driven by converter will work with industry frequency automatically, and 2# compressor is driven by converter to supplement air. 3# follows 2# compressor with the analogous switch steps, and the last operating compressor will be driven by converter. If the frequency value decreases to 30HZ after the using air pressure reduces, then the PLC will stop the compressor which has the longest running time and works with industry frequency. During the system working, the malfunction machine will be stopped and cut out of automatic control cycle by PLC when the fault or stopping signals occurs. The malfunction machine can just enter the automatic cycle only after debugging and fault reset.

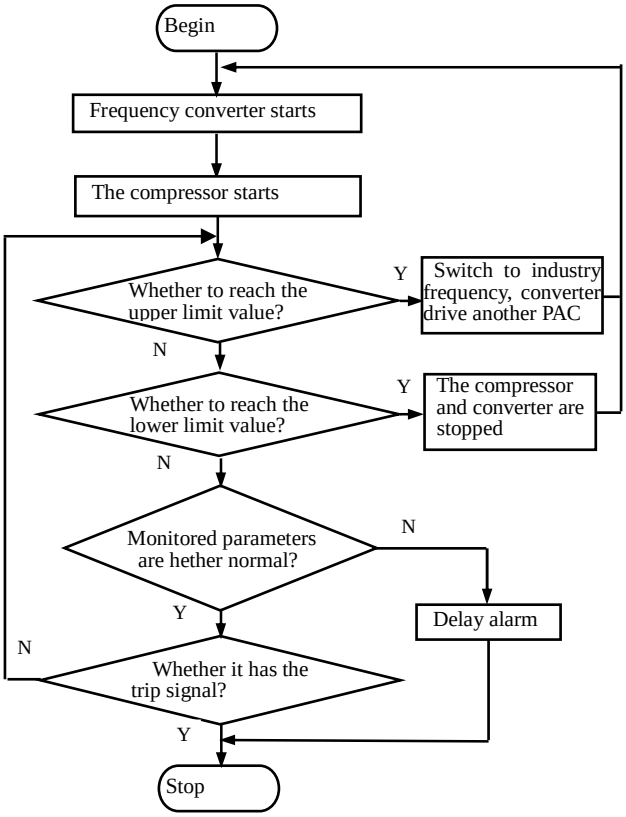

Fig.2 The control process of the compressor system

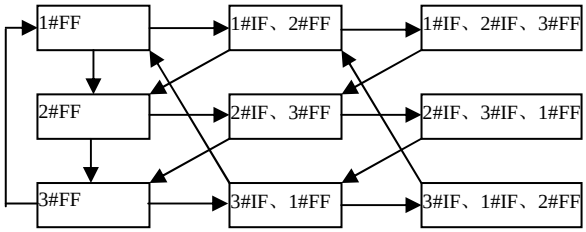

Fig.3 The control sequence of "first starting then fist stopping"

4. The Change of Operation Parameters in System

There are four key operation parameters of compressor which are voltage, current, power and air supply amount. Their ranges were six discrete points (Expressed as A1, A2, A3, A4, A5 and A6) because the system is controlled by relays simply. It is shown in the Fig. 4.

When the converter is adopted to control the compressors, the ranges of operation parameters changes into continuous lines from some discrete points, which are shown in Fig. 5. Because the parameters ranges are dynamically continuously adjustable, the air supply of the whole system becomes flexible, the starting current is decreased, the cost and energy are saved, the reliability and automation level of the system are improved.

The comparison of the parameters in the primary control system and new designed system is shown in table II.

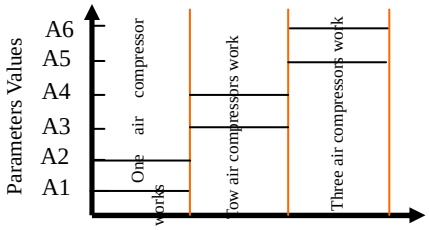

Fig.4 The adjustable ranges of the parameters in relays system

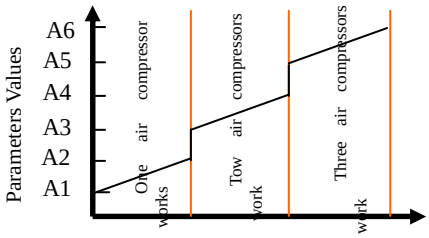

Fig.5 The adjustable ranges of the parameters in new system

Tab.2 The Comparison of the Parameter in the Primary Control System and New Designed System.

parameters		The parameters ranges of the primary system	The parameters ranges of the new system
A air compressor	Current	100A,210A	100A~210A
	Voltage	0V,380V	230V~380V
	Power	105KW,132KW	78KW~132KW
	Supply air	0 m^3,22m^3	12 m^3~22 m^3
The air compressors	Current	100A,210A,310A, 420A,520A,630A	100A~210A 310A~420A 520A~630A
	Power	105KW,132KW, 237KW,264KW, 369KW,396KW	78KW~132KW 210KW~264KW 342KW~396KW
	Supply air	22 m^3,44 m^3,66 m^3 (A1=0,A2=A3,A4=A5)	12 m^3~22 m^3 34 m^3~44 m^3 56 m^3~66 m^3

5. Energy Saving Analysis of the Converter Control System

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(From P.52)

The running cost of the PACU is mainly of electricity, oil and mechanical wear etc. After using the conversion control system, the system is realized electricity saving, oil saving, low fault rate and small mechanical wear. The saving of the electricity and oil has been analyzed as follows:

i. Annual electric quantity saving

Here a mine with three 132KW PAC takes as a example. If the PACs work on rated speed for 12 hours and work on 60%~70% rated speed for another 12 hours every day, and electricity saving rate is 50%, then the annual electric quantity saving is

$$3\times12\times132\times0.5\times365=867240\ (\text{KW}) \quad . \quad (1)$$

ii. Annual oil saving

According to the using oil rule of "low speed then low lubrication", the converter control system can save oil 60%.

6.Conclusions

As for the problem of high energy consumption in compressors, we have designed the converter triple-evaporator air compressors control system. Compared with the original relays control system, the starting current and equipment wear of the new system are much reduced, besides the system is low operation cost and high automation. This system has been used in some mines such as XinYi and the energy saving is remarkable, the control technology and system can be used or referenced in other mines and corporations.

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