Air Compressor Control System for Energy Saving in Manufacturing Plant

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Abstract

Most industrial facilities need some form of compressed air, whether for running a simple air tool or for More complicated tasks such as operation of pneumatic controls. Air compressor is key equipment to provide air power. One of the major problems associated with the compressor system is pressure fluctuation. This paper discusses actuality and disadvantages of traditional high power asynchronous motor drive air compressor system in manufacturing plant. In order to reduce energy consumption and safe running an efficient, monitoring and control system for compressor system is supplied. The discussed monitoring and control system is comprises of VFD-PLC and SCADA. The PLC and VFD correlates the operational parameters to the pressure required by user and monitors the system during normal and under trip condition with the help of SCADA.

Keywords: Induction Motor (I.M.), Programmable Logic Controller (PLC), Variable Frequency Drive (VFD), supervisory control and Data Acquisition System (SCADA), PID controller

I. INTRODUCTION

Compressed air is typically onefa of the most expensive utilities in an industrial facility. Based on energy assessments of mid-sized industries, we found that on an average, compressed air typically comprises from about 5% to 20% of plant's annual electric cost. Energy consumption represents approximately 80% of the total life cycle cost for compressor air.

Air compressor is the key equipment to provide air power, which is driven by asynchronous motor. To provide efficient output of air compressor, continuous fluctuation of current and pressure has to be reduced which ultimately reduce electrical and mechanical wear And tear of the system. Therefore air compressor is tried to operate at constant pressure and motor at constant speed by using integral PID function of VFD along with PLC and SCADA, and system has proven energy efficient, reducing power consumption of the system up to 40% of current energy consumption.

In general, the output air pressure in pipeline of the air tank is acted as controlling object in the system.
The air pressure in the pipeline is controlled to be fluctuating in a certain range. Usually there are two ways to control the air pressure in the pipeline to content this demand. The first method is starting up and stopping the motor continually for adjusting air pressure in pipeline. When the air pressure is under the upper limit, the air compressor operates until the air pressure goes up to the upper limit, then the motor stops running. But the air pressure will be lowered with air leak or air consuming equipment operating. When air pressure goes down to the lower limit, the motor begins to work and air compressor operates again. The variable pressure in the pipeline is shown in fig.1. This method is simple and low cost, but it is suitable for small power motor because the motor will be started up continually.

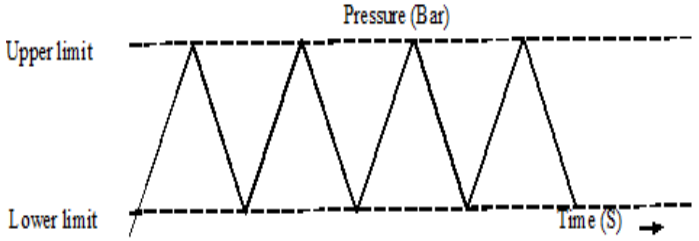

Fig.1. Variable Pressure in Pipeline

The second method is using pressure valve to limit air pressure in the pipeline. When the pressure goes up to the upper limit pressure, the valve will close entrance of air compressor, then the compressor is in idle state. In this case compressor is still driven in operation by the motor, but does not export compressive air, so air pressure will not go up further. When pressure goes down to the lower limit, the valve will be open again and then compressor export compressive air and the air pressure will be up again.

The variable air pressure is same as that of the first method; in this case motor is running continuously, which is used for high power motor. In manufacturing Company, second method is widely used for control of air pressure from air compressor

because of high power motor being used, which power rating is about 22 KW. Although motor is in running operation, it's starting should be controlled. Traditionally there are two ways to fulfill the starting up, which are which are linking series resistor in rotor loop and converting Y-Δ connection of starter loop. However there are still some disadvantages in these two ways as follows.

(1) The air pressure in pipeline fluctuates greatly between the upper and lower limits.
(2) During loading unloading current also get fluctuate between two limits continuously.
(3) The continual upload and download of air compressor causes voltage fluctuation in electrical power supply.
(4) The air compressor is in full speed rotation all the time, which may lead to mechanical failure and temperature rise.
(5) Air compressor and the air pressure valve in their operation causes a great noise pollution.
(6) The driving motor of air compressor is inefficient and energy consumptive and cause lower power factor.
(7) So it is necessary to change the traditional control method of air compressor operation for energy saving, less pollution and low failure possibility.

II. VARIABLE FREQUENCY CONTROL OF AIR COMPRESSOR MOTOR

A. SYSTEM PRINCIPLE:

With the rapid development of power electronics technology PLC-DRIVE-SCADA based system is widely used for adjusting speed AC synchronous motor. So PLC-DRIVE based system is designed as an executer in the air compressor control system to adjust output air pressure

In order to control the air pressure in the pipeline, the motor's rotation speed should be in control. However, the motor's disables to change its rotation speed itself the only method is to adjust its frequency to change the rotation speed. So, PLC and VFD is used to control the motor's rotation speed, and then the flux from air compressor can be adjusted. The system schematic diagram is shown in fig.2.

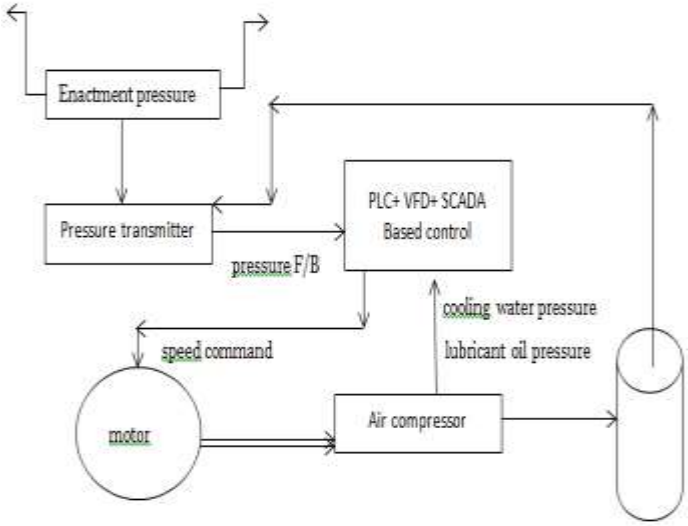

Fig. 2: System schematic VFD-PLC and SCADA

After comparing enactment pressure signal with feedback pressure signal, a pressure signal error is obtained which is used for calculation of PID arithmetic and the converted error signal will be send to VFD to a control value to adjust frequency of Ac power supply. Then the asynchronous motor will drive air compressor to an appropriate rotation speed with variable frequency power supply to eliminate pressure error and ensure constant air pressure. The air pressure adjusted by PID arithmetic in the pipeline is shown in the fig.3

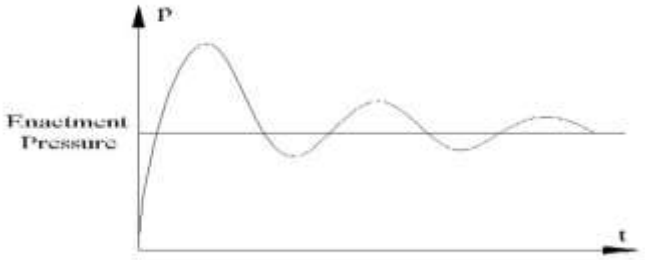

Fig. 3: Air Pressure adjusted by PID arithmetic.

When the pressure detected by pressure transducer is higher than enactment pressure, PID regulator output signal declines and drive output frequency falls down, then the air compressor rotation Speed reduces and output air pressure declines. When the detected pressure is lower than enactment pressure, PID regulator output signal raises and the transducer output frequency increases then the air compressor rotation speed increases and output air pressure increases. The system will maintain air pressure automatically through the above method.

B. VFD DETAILS

In the fig. 4, connection diagram for VFD has been shown which is acting as actual control element for compressor system. In VFD, R-Y-B provides three phase power supply (415 V, 50 Hz). I_6 provide feedback through remote pressure transducer, this feedback pressure is continuously compared with pressure set-point from PLC(AI1) and error is calculated, by which PID arithmetic is used for calculating control variable. The VFD has self-educated ability i.e. PID parameters can be adjusted automatically in terms of actual pressure change characteristics in the VFD. D1, D2 and D3 are ports for certain commands like Enable (R1), Run (R2) and Reset (R3) from PLC. Drive healthy (R1A) and Drive trip (R1B) feedback are taken out to the PLC for safety interlocking purpose. VFD provides 24V supply to PLC through terminal P. and variable frequency AC power supply is exported to Induction motor through terminal U-V-W.

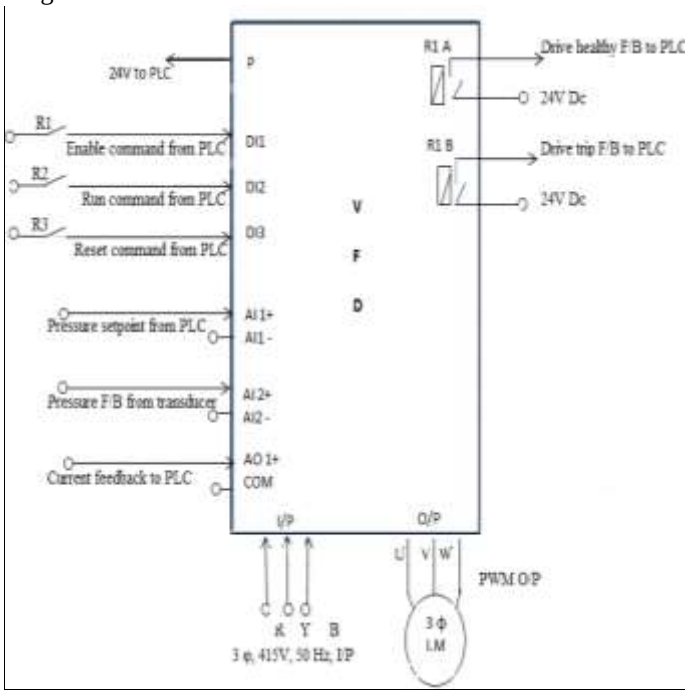

Fig. 4: connection diagram for VFD

In this besides, the starting torque required when the air compressor start up is large, however, using the conventional method to control will bring damage to other relevant equipment's. This system adopts vector control technique to raise the starting torque of motor. Besides, more accurate rotation speed can be gained to control the air compressor. So, almost constant pressure of air can be acquired from this system

III. PLC MONITOR AND CONTROL

A. STATUS PARAMETER MONITOR

Cooling water and lubricating oil are the necessary substances for the air compressor running normally. When the air compressor operates, temperature rise of the compressor body can be used to monitor if compressor runs normally, or not. So, there are three parameters to be monitored in the system, which are pressure of cooling water, pressure of lubricating oil and temperature of compressor body.

The pressure of cooling water can be used to show cooling system normal operation easily, which includes pump, pipeline and valve. Any problem can cause the pressure abnormal. So, a pressure transmitter is mounted at output of cooling water pump for monitoring whole cooling water system. In the same way, another pressure sensor is used for the lubricating oil monitoring.

As the temperature of compressor body is one of the synthetic image to show all malfunctions. In order to show temperature of compressor body, a temperature transmitter is mounted at the output pipeline of cooling water from the compressor. The temperature of cooling water from the output pipeline is almost equal to compressor body temperature.
All these transmitters will be mounted on pipeline outside the compressor, so it is convenient to maintain and repair.

B. DESIGN OF PLC-SCADA MONITOR AND CONTROL

In order to monitor and control whole air compressor system, a PLC with SCADA is used. The PLC is composed of power module, digital input module, digital output module, analog input module, analog output module. A SCADA is connected to computer, which can display status of VFD, pressure in air tank, pressure of cooling water and lubricating oil and so on. It can also accept many soft instructions instead of mechanical buttons. The CPU module can receive all kind of data from analog and digital module from internal bus.it also has memory for program and data and serial bus RS232 for connecting with computer. The power module provides power supply for every module, which includes +5V and +12V voltages.

Analog input module(0-+5v input) accepts voltage signal from sensor to measure compressed air pressure, cooling water pressure, lubricating oil pressure and temperature of cooling water.

The digital input module accepts status of signal of Transducer and some operation signals from output buttons. Digital output module (relay output) send several control signals like air cooler The digital input module accepts status of signal of transducer and some operation signals from output buttons. Digital output module (relay output) send several control signals like air cooler on command, oil pump on command, Drive enable command, Drive run command, speed reference to drive and certain failure status.

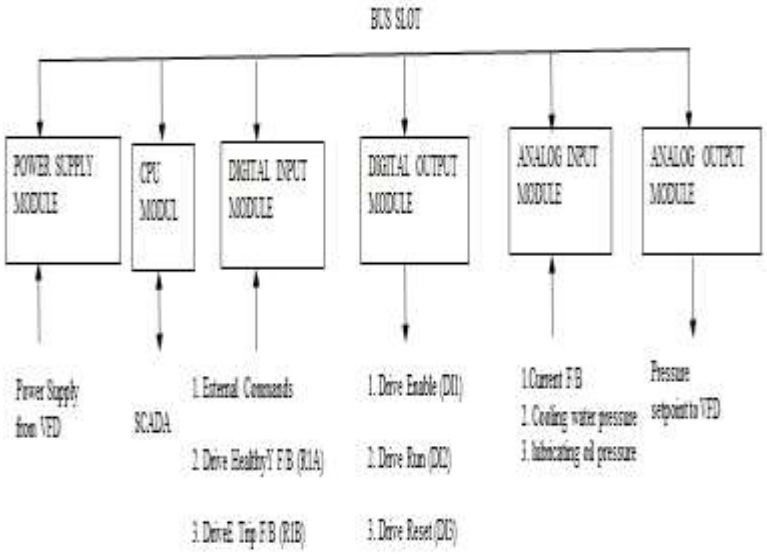

Fig. 5.Configuration of PLC

IV. EXPERIMENTAL RESULTS

We use a PLC and a VFD to rebuilt one air compressor control system in manufacturing plant, which use a high power motor of 22KW rating power. Its other parameter ratings are frequency of 50Hz, voltage of 400V Ac, and current of 38.5A. we have measured a set of actual parameters of the motor and its power supply at the same regular load condition before and after the rebuilding, which are listed in table1. On the majority of time, the motor run normally at 38Hz frequency of power supply to content air supply requirement of whole plant.

From the table 1, it can be shown that

Current decrease rate (δ_i) is:

$$\delta_i = (I_1 - I_2) / I_1 \quad (1)$$
$$= (32- 28) / 32$$
$$= 12.5\ \%$$

Cost per 1000 cf decrease rate (δ_c) is

$$\delta_c = (c_1 - c_2) / c_1 \quad (2)$$
$$= (23.39 - 11.14) / 23.39$$
$$= 52.37\ \%$$

Electricity energy saving rate (Π) is

$$\Pi = (p_1 - p_2) / p_1 \quad (3)$$
$$= (37.56 - 21.31) / 37.56$$
$$= 43.26\ \%$$

Table 1: Testing parameters 22Kw motor

Item	***Voltage (V)***	***Current (I)***	***Frequency (Hz)***	***Rotate Speed (rpm)***	***Input Power (Kw)***

Ac Power supply	*400 V*	*32 A*	*50 Hz*	*2955 rpm*	*37.56 Kw*
Transducer Power supply	*300 V*	*28 A*	*37.49 Hz*	*2216 rpm*	*21.31 Kw*

Obviously, the new system can save lots of energy. Beside it have other advantages:

(1) It reduces greatly noise, realizes soft start and soft stop of the equipment and avoids the shock current of power grid when the air compressor starts up.

(2) It has high degree of automation and overcomes the disadvantages of manual adjustment.

V. CONCLUSION

High power air compressor is a kind of equipment widely used in manufacturing plant. In order to save electrical energy and improve operation condition, it is necessary to rebuilt traditional control system of high power motor with the PLC-VFD-SCADA system. In fact the system also has low cost, high reliability and efficiency. It also reduces greatly noise of air compressor operation and possibility of failure. Finally, these systems has solved the interference by high order harmonic and adopted VFD control technique to acquire high starting torque and stabilize motor rotation speed. As the effect of this system is obviously energy saving, It should be widely used in such a manufacturing plant.

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