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Optimization of Air compressor Motor speed for Reducing Power Consumption

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Abstract -- In this paper we are saved high amount of electrical energy by controlling electric motor speed with respective air pressure demands. According to required air pressure we have maintained optimum motor speed with the help of variable speed drive which is controlled by programmed microcontroller AT 8952. In addition to speed reduction we have also maintained motor ON/OFF control. In on/off control, the compressor turns on and begins to add compressed air to the system when the system pressure falls to the lower activation pressure. The compressor continues to run the electric motor and put in compressed air to the system until the system pressure reaches the higher activation pressure when the compressor shuts off. Typical lower and upper activation pressures would be 85 psig and 100 psig. On/off control may also utilize a timer to decrease short-cycling. Reciprocating air compressors typically employ on/off control. On/off control is the most efficient type of part-load control, since the compressor draws no power when it is not producing compressed air. In modulation control, the situation of the receiver inlet air valve is modulated from full open to full block in response to compressor output pressure. Modulation control normally employs PID control with a narrow control range about ± 3 psig. Inlet modulation is a relatively incompetent method of controlling compressed air output.

Keyword: Energy saving comressor, PID controlled compressor

1. INTRODUCTION

The three fundamental types of air compressors are reciprocating, rotary screw and centrifugal compressors. Reciprocating compressors use pistons to compress air in cylinders. Single-acting compressors compress air on one-side of piston, and double acting compressors compress on both sides of piston. Large reciprocating compressors in industries may use multiple stages with intercoolers and double acting pistons to attain high compression efficiencies. Single-stage compressors control compressed air output by stopping the pistons when required amount of compressed air is not needed. Multi-stage compressors control compressed air output by sequentially dropping the number of stages in use.
Rotary-screw compressors compress air by forcing air between two rotating screws with decreasing volume between the screws. Most rotary-screw compressors manage compressed air output by modulating the air entering at intake valve, and or alternating between full open and fully clogged operation.
Centrifugal compressors compress air by forcinging air from the tips of impellors rotating at very high speeds into a volute. Centrifugal compressors are typically 240-hp or larger, and frequently employ multiple stages to attain the desired compressed air output pressure. Centrifugal compressors control output compressed air by modulating an inlet valve or variable inlet vanes on the air intake, loading and unloading, or blowing off compressed air to atmosphere somewhat than into the compressed air system.

2. COMPRESSOR CONTROLS:-

Compressor controls typically equivalent compressed air output to compressed air demand by maintaining discharge output air pressure within a specified pressure range. There are five primary control strategies are there for maintaining the pressure within the desired range.

ON/OFF CONTROL

In on/off control, the compressor turns on and starting to add compressed air to the system when the air pressure falls to the lower activation pressure. The compressor continues to run and filled compressed air to the system until the system pressure reaches the upper activation pressure when the compressor turns off. Typical lower and upper activation pressures range appx would be 90 psig and 100 psig. On/off control may also employ a timer to reduce short-cycling. Reciprocating air compressors typically utilize on/off control. On/off control is the most efficient type of part-load control, since the compressor draws no power when it is not producing compressed air.

LOAD/UNLOAD CONTROL

In load/unload control, the air compressor "loads" and begins to fill compressed air to the system when the system pressure falls to the lower activation pressure. The compressor continues to run and fill compressed air to the system until the system pressure reaches the upper activation pressure. It then "unloads" and does not add compressed air to the system unless the system pressure drops to the lower activation pressure. Typical lower and upper activation air pressures would be 90 psig and 100 psig. When unloaded, rotary screw compressors naturally partially close the air inlet valve and bleed the remaining compressed air in the sump to atmosphere.

Power draw when fully unloaded changes from about 60% of full load power to about 30% of full-load power, depending on air compressor design and on the length of time the compressor runs unloaded. To fully unload, the load/unload cycle time ought to be long enough to permit the compressed air in the sump to bleed to atmosphere when the compressor unloads. Thus, load/unload control works best when coupled with sufficient compressed air storage, which lengthens load/unload cycles whereas modulating pressure variation to end uses.

Most of the compressors with load/unload control also have an "automatic shutoff" choice, in which the compressor get itself off if it runs unloaded for about 5 to 10 minutes. The compressor will remain off for a specified period of time before restarting to avoid short-cycling. Running the compressor in "automatic shutoff" mode can result in considerable energy savings during periods of low compressed air demand. In addition, ample amount of compressed air storage increases load/unload cycle time, and the likelihood that the compressor shuts off after running unloaded for a few minutes.

MODULATION CONTROL

In modulation control, the position of the inlet air valve of compressor is modulated from full open to full close in retort to compressor output pressure. Modulation control typically employs PID control with a fine control range about $\pm$ 2 psig. Inlet modulation is a relatively wasteful method of controlling compressed air output.

VARIABLE-SPEED CONTROL

Rotary-screw air compressors can be operational with variable frequency drives (VSD) to fluctuate the speed of the screws and the corresponding compressed air output. As in other fluid flow applications, the variation of speed to vary output is extremely energy efficient.

BLOW-OFF CONTROL

In centrifugal compressors units, the amount of air flow through the compressor can only be controlled by modulating the inlet air valve over a comparatively small pressure range. When flow is reduced below this pressure range, the flow becomes unstable in a "surge" condition. To keep away from surge, centrifugal compressors may discharge compressed air to the atmosphere to control compressed air output to the system. Blow-off control is the least well-organized method of controlling compressed air output, as input power remains constant as the supply compressed air to the system decreases.

POWER / OUTPUT RELATIONSHIPS BY CONTROL TYPE

The following figure shows emblematic relationships between fraction input power to the compressor (FP) and fraction compressed air output (FC) for different types of control. At full output capacity (FC = 1.0), compressors draw full power (FP = 1.0). The power draw at less than full output capacity is a function of the part-load control. The figure FC vs FP shows that at part load, most energy efficient control mode is on/off, followed by variable speed, load/unload, modulation and blow-off control.

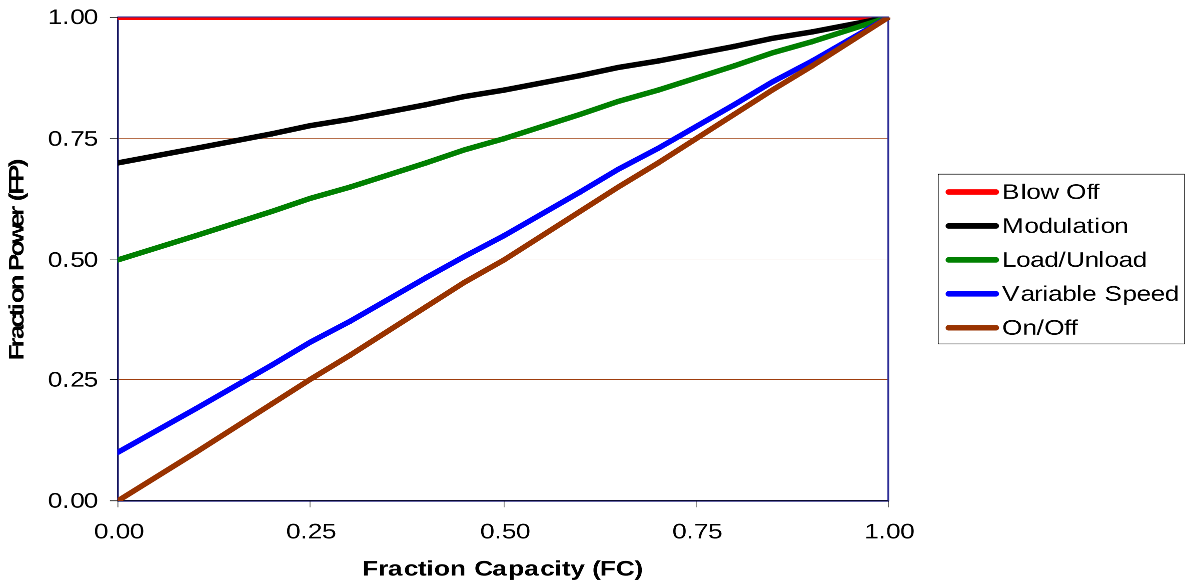

Fig 1 Graph of FC vs FP

Assuming linearity, fraction power, FP, can be calculated from fraction capacity, FC, and fraction power at no load, FP_0, according to the following relationship:

$$FP = FP_0 + (1 - FP_0)\,FC$$

Some air compressors use a mixture of basic control modes described above. For example, the figure shows the relationship between fraction of full-load power and fraction of full-load output capacity for a compressor by means of a combination of modulation and load/unload control. The top line shows full modulation control, in which the compressor continues to draw 70% of full load power even when producing no compressed air.

The bottom line shows a combination modulation and load/unload control, in which compressed air output is modulated by the inlet valve down to 40% of total capacity. Below 40% of full output capacity, the compressor loads and unloads to vary compressed air output. In this example, the compressor draws 25% of full-load power when fully unloaded.

3. Experimental Procedure :-

- Connect Air compressor motor with variable speed drive unit which is controlled by microcontroller unit.
- Here solenoid pressure sensor valve (E/p I/p 900X Transducer) is used which senses output pressure and regulate it.
- 150 pound compressor is used for this setup with 0.5 HP 3 phase induction motor @ 2880rpm

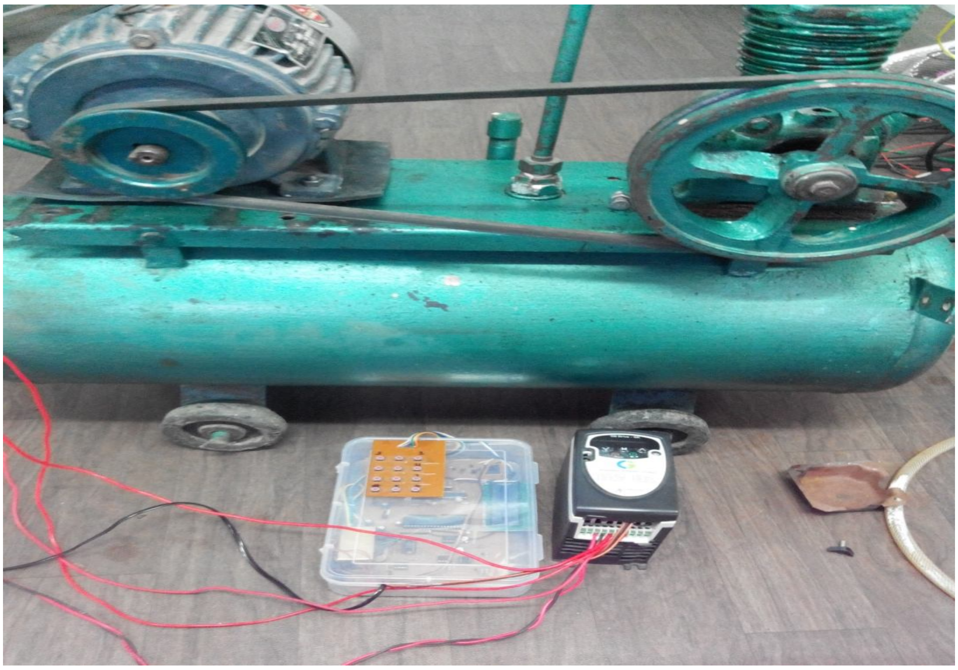

Fig 2 Experimental Set up of Air compressor

- Power ON all the equipment and then according the demand pressure, insert desire value through 4X3 matrix keypad.
- Pressure sensor (900X Transducer) sense the air pressure in the tank and compare with input pressure. According to that its linear signal converted through digital and given to microcontroller.
- If initial tank pressure is below desired input pressure then motor start running at full speed (2880 rpm) till to achieve input pressure. After achieving input pressure motor slow down its speed and come to optimum speed. Optimum speed detail is given in table number 1.
- Suppose initial tank pressure is 2 bar and we are required 5 bar pressure for any desire application say cleaning. In such case Pressure sensor (900X Transducer) senses that initial 2 bar pressure and compare with 5 bar pressure. Of course initial pressure is lower than input pressure then Pressure sensor (900X Transducer) give signal to microcontroller and then to variable speed drive. Motor start filling air at full speed i.e. @2880rpm till tank pressure reaches to 5 bar. As soon as tank achieve 5 bar pressure motor reduces its speed to optimum speed which is given in table 1. Then that optimum speed is maintained with a constant pressure of 5 bar.
- In this case we are also saving power by maintain low speed of motor.

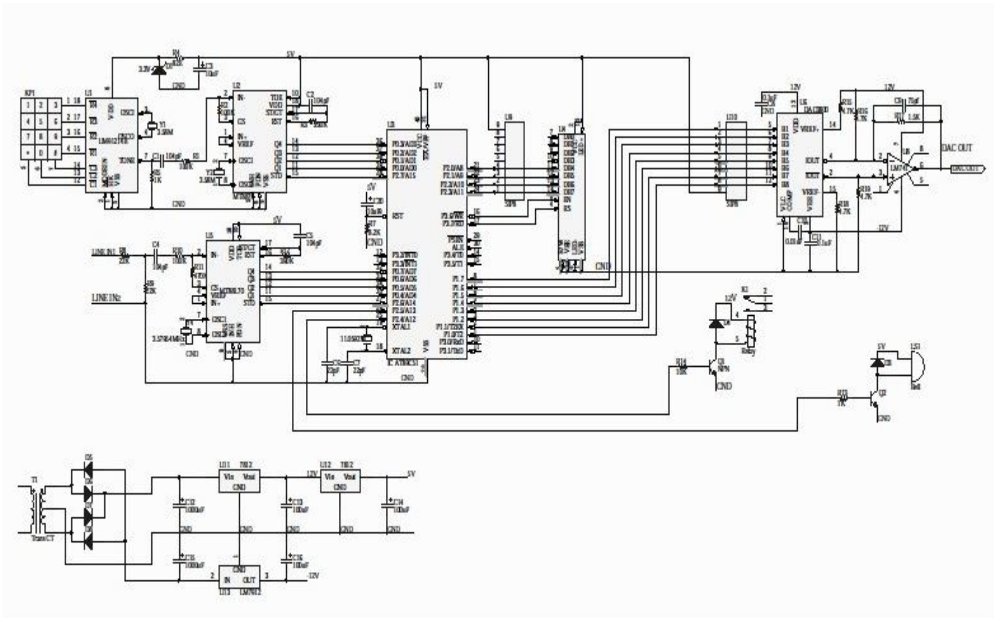

Fig 3. Schematic circuit diagram of Micro controller unit.

The major benefit of maintaining low pressure is low wear and tear of mechanical components, low power consumption and higher volumetric efficiency.

SNo	Pressure (Bar)	VSD Load Value Reading	Optimum Motor Speed (rpm)
1	1	180	1776
2	2	175	1896
3	3	170	2010
4	4	165	2130
5	5	160	2250
6	6	155	2368
7	7	150	2484
8	8	145	2604
9	9	140	2724
10	10	135	2840

Table 1. Optimum motor speed required for desired pressure

IV. Result and Discussion:-

We have conducted various experimental tests and finally maintained here constant desired pressure at optimum speed. Mainly its aim is to reduce electricity cost as well as constant output pressure. It has been observed that by reducing motor speed automatically life of compressor components is enhanced.

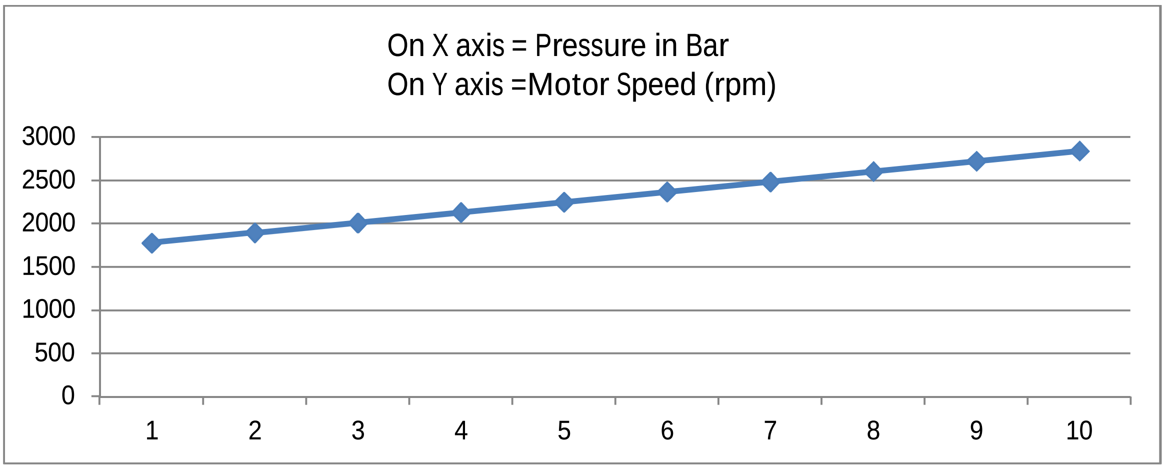

Fig 4. Graph of Pressure Vs Motor Speed.

V. CONCLUSION:-

This paper aiming at to minimize motor speed of air compressor with the help microcontroller and variable speed drive unit. The monitoring system was 900X transducer which control output pressure as well as given signal to microcontroller for speed reduction. Definitely this concept will reduces electricity cost of your plant at higher level.

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