The PLC Based Design for the Air Compressor Control Process

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***Abstract*— Oil and Gas industries use the air compressor to control a process and generate the compressed air utilized to make combustion. Technically speaking, generally in industry two types of compressors are used to generate the compressed air that are known as: The dynamic compressor and the positive displacement. The present study aims at controlling the compressor inlet guide vane angel or IVG, the blow off valve and the compressor engine by the controller; such that aims of controlling the pressure are achieved at the suitable point. In a laboratory design, centrifugal compressors with the IGV angel and the blow off valve are assessed by the step 7-300 Siemens PLC controllers.**

***Index Terms*—inlet guide vane, centrifugal, axial, positive displacement, dynamic, reciprocating, rotary, reservoir, flow, stall, rotary stall, surge, choke, stonewall, head, blow off valve, critically damped, dead zone.**

I. INTRODUCTION

Concerning the how-ness of the energy transmission from a compressor to a fluid, compressors are divided into two types:

Dynamic Compressors:In this kind, the energy transmission to the fluid is permanent.

Dynamic compressors are known as:

Centrifugal compressors: In this kind, air is guided outside from the center by some channels installed on the vane.

Axial compressors: Here, the air paralleled with the axis is directed and enhanced by some vanes installed on the axis.

Positive displacement compressors: In this type, the energy transmission into the fluid is alternative.

Different kinds of positive displacement compressors are known as:

Reciprocating compressors: Compressing air by a piston attached to the crank.

Rotary compressors: Compressing air by a rotary movement of the rotter toward the cylinder.

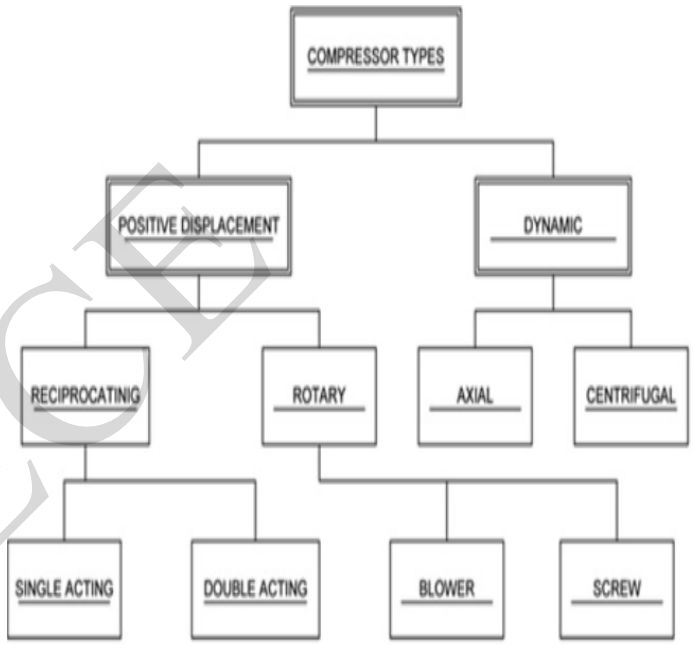


Fig.1
Compressor types

In the positive displacement compressors, there is no limit on the output pressure. The mere disadvantage of these compressors is that they have a pulse form output pressure. To remove this shortcoming, a reservoir rectifier (stroke-absorber reservoir) is installed in the output to eliminate the air pulse. However, in dynamic compressors, the output pressure is limited that is the output pressure is changed based on the input air flow.

If the air angel of attack is changed by any given reason, air jets are dispatched from the vane and ‘’ separation phenomenon’ is happened. Because of this phenomenon, the air pass surface is decreased. This is called ‘stall’. Since the total flow is constant, the total air excess is blocked from the next vane. This makes the air attack angel changed in the next vane that is called stall. Repeating this process makes the rotary stall happened [1]. When a complete stall happens on a row of

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vanes, the pressure drop takes place and air goes to the low pressure point from the next rows which have high pressure or from the combustion chamber. This means that air goes to the input from the output that makes so much noise and can get vanes broken or corroded. This phenomenon is called 'surge'. Indeed, because of a friction between the air flow and vanes, some distortions are happened and show themselves by some effects like shakes.

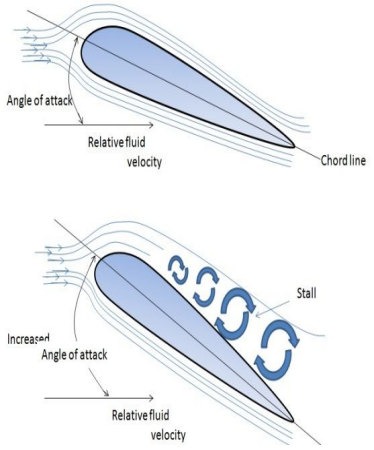


Fig.2
Stall phenomenon

Since the ideal aim is to prevent entering the compressor to the surge area, the centrifugal compressor is investigated.

PLC controllers are used to hold compressors in a suitable working point, due to existing an appropriate relation between industries in Iran regarding the utilization of Siemens PLCs.

The aim of the present study is to enable an operational user to control a compressor by means of the control room and to watch the working point online; therefore, the network accessible PLC is used.

II. Stability in Compressor

The compressor ability in overcoming some distortions possibly made around its operational point is called the compressor stability.

The compressor stability can be analyzed from two different views: the first view assesses the compressor pairing stability with its subordinate components like electromotor or turbine and the second view is devoted to the dynamic analysis of fluid passing through the compressor like an analysis of the separation phenomenon along with the flow. Therefore, totally the stable operation of a compressor depends on two factors: the characteristic curve of the compressor and the characteristic curve of the subordinate vehicles and systems paired with the mentioned compressor.

The stable operation of a centrifugal compressor is limited in high and low velocities because in the mentioned velocities, the compressor components entangle strangle and the 'choke phenomenon' is taken place [2]. In high mass flows, there are some restriction factors like reaching the fluid velocity to the sound velocity and the choke phenomenon. Notwithstanding, in low mass flows two instabilities cause the compressor operation area limited. One of these instabilities is called surge which can be prevented by controlling the input air.

At the time of initiation or at the time of generating power, the required air is regulated by Gideon or the input inlet guide vane angel.

III. The Operational Curve of the Centrifugal Compressor

The compressor map of any compressor is prepared by its manufacturing company. This map consists of the vertical and horizontal axes along with some curves. The horizontal axis shows flow or the capacity and the vertical axis represents head or the pressure ratio. Besides, the group of curves manifest the compressor operation at different speeds. In this map, for any given speed, there is at least a maximum and a minimum point. The maximum capacity point is called stonewall and the minimum capacity one is named surge. Among these points, the compressor operation is considered stable and predictable. [5]

Figure 2 represents the compressor surge curve. In this diagram, closed curves have the same efficiency. The operation compressor in the right border is stable and in the left border is unstable. In some zones where the operational lines become close to the vertical mode, the flow encounters choke through the vanes . [4]

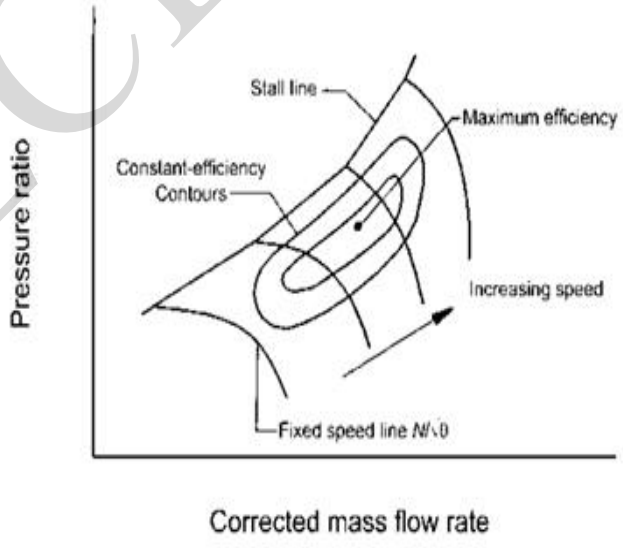


Fig. 3 Compressor map

To ensure the stable operation of the compressor, the input air flow must be controlled such that its falls between its minimum value (to prevent establishing surge) and its maximum value (to prevent performing choke). Dynamic compressors have a row of inlet guide vanes that their angels alter from 0 to 90 degree (Actually, they change from 37 to 84 degree). By controlling the value of these angels, the input flow is possible to be adjusted in a desired zone. Since the air attack angel is possible to bechanged by any reason that leads to making the stall phenomenon resulting in irreparable harms of the compressor, one of these two following methods can be used to protect the compressor.

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Applying load-unload valve: since the output pressure is increased by any reason, the density ratio is increased, too and the input flow in decreased; therefore, the compressor closes to the surge mode more than before. In this case, before reaching at the surge control line, the unload valve is opened automatically and the gas flow discharged into the air. As soon as the gas is discharged, the output pressure and consequently the density ratio are decreased that makes the gas flow increased. It is proper to mention that, when the gas flow increases, the possibility of making the surge mode is decreased. In this method, the output is directly goes to the air; therefore, this method is used in those cases when the gas is not dangerous or costly.

Applying the flow reciprocal valves: This method is used provided that the gas is hazardous or expensive. In this method gas is not discharged into the fresh air, but, it returns into the compressor. When the gas temperature is increased at the density time, the direct connection of the output gas to the input makes the input temperature increased and consequently gets the efficiency decreased. Thus, the flow reciprocal valve must be installed after the cooler to reciprocate the cool gas to the compressor input. The flow reciprocal valve like the unload valve is able to work automatically.

IV. Simulation of Control Process with PLC

The purpose is to keep away a centrifugal compressor having a constant speed electromotor from the surge zone by adjusting the angel of the inlet guide vane and by applying the blow off valve such that the compressor have a stable operation while utilization.

Some situations must be established before the initiation stage of the compressor. At first, the Gideon vane angel must be closed. Practically speaking, this angel is 37 at which no air can actually enter the compressor, system is unload that is its blow off valve is open and the out valve is closed. Therefore, if there is any air in the compressor, it is discharged by means of this blow off valve.

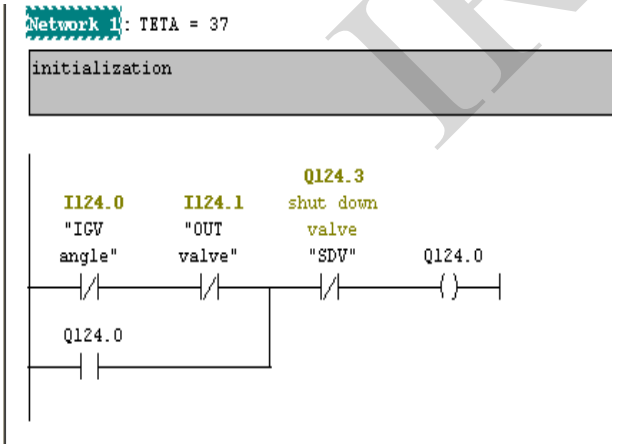


Fig.4

Then the lubricating stage is performed. To do so, lube oil or an Ac /dc pump which has a hydraulic oil is used. This pump spread the oil all over the compressor by utilizing the city electricity. The oil surface of this reservoir must not be lower than the set point; therefore, LSL > SP (LSL: low level oil shut down). In PLC, this condition is assessed by means of a comparator. If the mentioned condition is not true, the compressor faces trip phenomenon. To establish this condition, a normally close valve known as the shutdown valve or SDV is installed at the startup of the program [2] which can stop the program in case it is activated. Otherwise, the pump is activated and the lubricating operation is done.

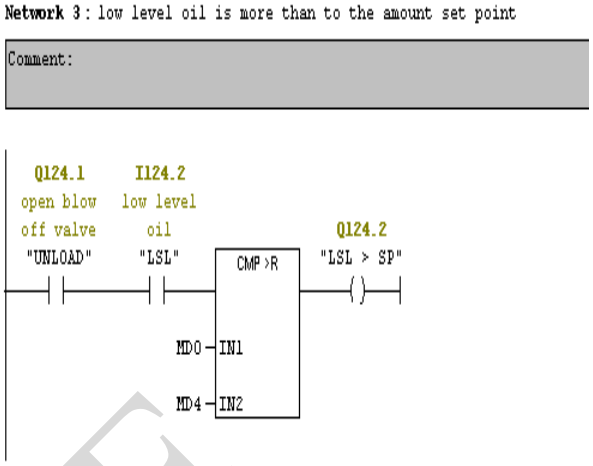


Fig.5

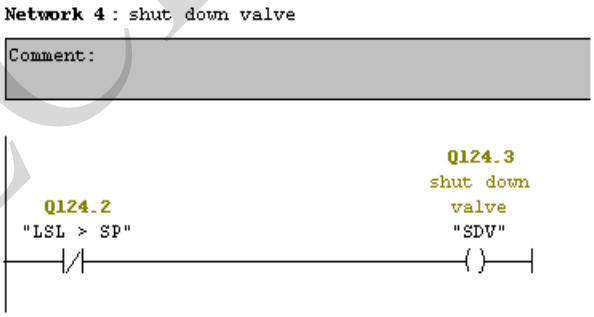


Fig.6

The pressure of the existing oil in the compressor is evaluated some while after turning on the lube oil pump. This pressure must be exactly the same as its set point. Thus, a time period is defined for the system to supply the desired pressure. During this time period, if the comparable is activated, the timer is reset, the ac/dc pump is placed out of the circuit and the mechanical pump replaces it. Otherwise, the shut -down valve becomes activated and the compressor faces trip.

After finishing the lubricant stage, since this pump is fed by the city electricity, it is replaced by the mechanical pump which supplies the oil pressure by turning the motor shaft around.

Shakes of the motor and compressor are considered an inherent phenomenon that its excessive enhancement makes the connectors loose and wobbly and gets the system collapsed. To measure the value of these shakes and to compare this value with its set point, a vibration sensor is used. When the motor speed is trying to reach at its nominal value and is increasing

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from zero, the system frequency gets equal with electricity network frequency in a special speed.

In this frequency, the system shake is increased and natural frequencies or the closed loop poles of the system are placed on the horizontal axis and create a dead zone in which the compressor motor is critically damped. [6] The most important factor in controlling the engine speed is to minimize this zone.

Moreover, stall can create shakes and too much noise. Therefore, while initiation stage, the highest value of the vibration is determined 1.5 times more than the set point to get rid of forming the trip while passing this zone.

Consequently, at the start up stage, by means of a comparator the vibration value is compared with a value which is 1.5 times more than its set point. If VSH < SP (high vibration shut down), values of the input and output pressures as well as the input flow are measured by a transmitter though in PLC, they are measured by function FC 105. Otherwise, the unit faces trip.

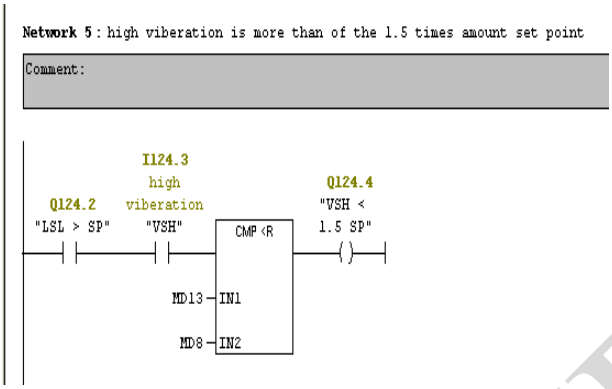


Fig.7

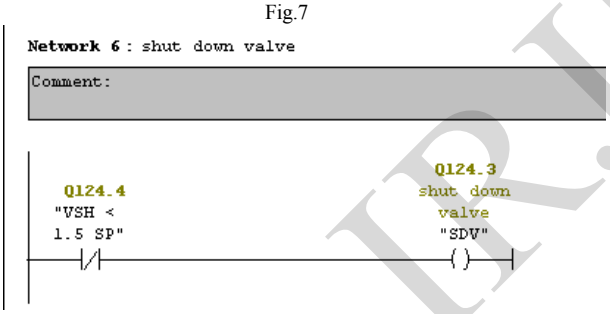


Fig.8

The minimum and the maximum values are defined by considering the mechanical structure of the compressor such that the function is entered the surge zone and is not faced with choke. If the measured value is in the mentioned zone, the output coil is activated and its quantity is shown as MW (16 bit) and MD (32 bit).

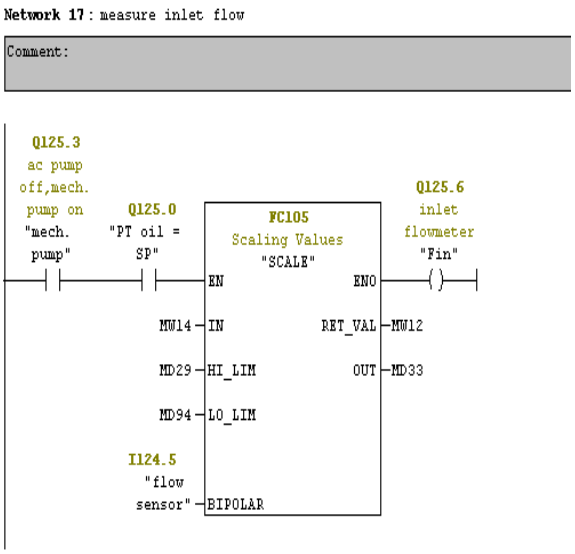


Fig.9

In this stage, by applying a divider function, the ratio of the compressor output pressure to the input which is called head is computed. Then, head < Fin condition in evaluated [2]. If the mentioned condition is not true, the blow off valve opens; otherwise, the motor speed is measured by means of a transmitter.

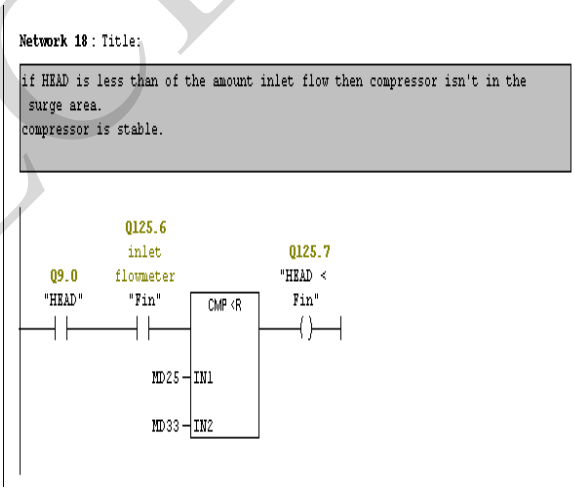


Fig.10

When the nominal speed of the motor and the compressor are equal and placed within the set zone [2], the pressure difference of the compressor input is computed before and after the air filter. This difference manifests the amount of the dirtiness of the filter. Since dirty air harms the compressor vanes, $\Delta p < sp$. In spite of the mentioned fact, the unit faces trip. [3]

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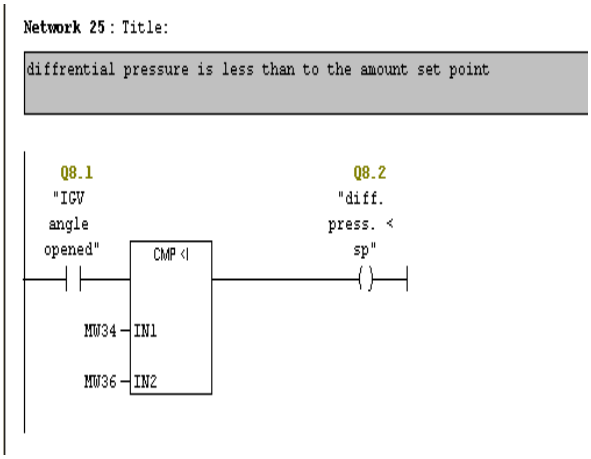


Fig.11

Now, the Gideon angel starts increasing that leads to increasing the input air velocity. To enhance the Gideon angel, a PID controller is used. This controller has three parameters Ti, the integrating coefficient Td, the derivative coefficient and the gain coefficient.

These coefficients can be determined by the Ziegler-Nichols regulating rule based on the critical gain and the critical alternative time that are all measured empirically [6]. Here, it is supposed that gain=1, Td=0 and Ti=10s. In other words, one PI controller or a programmable integrate controller is designed for the system since it is the simplest form of the controller. Adding the derivative coefficient enhances the velocity feedback to the system efficiency and boost the system velocity.

Thus, if the system behaves slow an operator can increase this coefficient. In this case, system is in load mode that is the blow off valve is closed and the out valve is open.

By regulating the Gideon at 90 degree which actually means 84 degree, the system unit behavior is considered natural, bearing shakes are no longer increased, generating power is not decreased anymore and no unusual sound will be heared .

V. Conclusion

In the present paper, different kinds of compressors, their differences and the problems of each kind has been studied. Besides, the centrifugal compressor is manifestly analyzed.

Since the operational curve of any compressor is special, a general curve is assumed. As a result, by applying PLC a zone is designed in which a compressor has a stable operation and does not enter the surge or choke.

This area is determined by considering the minimal and maximal values of the input flow (which is a necessary condition of stability), the output pressure ratio to the input (which is a sufficient condition of stability) and the highest efficiency around the surge line.

References

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