Research Journal of Engineering Sciences E- ISSN 2278 – 9472
Vol. **5(3),** 49-52, March **(2016)** *Res. J. Engineering Sci.*

Anti-Surge Control Software Using General Purpose Programmable Single Loop Controller

Tamrakar Lokesh Kumar*and Agrawal Swati
ET and T Department, BIT, Durg, CG, India
lokeshtamrakar19@gmail.com

Available online at: www.isca.in, www.isca.me
Received 24th February 2016, revised 20th March 2016, accepted 26th March 2016

Abstract

The work is aimed at developing an anti-surge control software for the Turbo-blower number 11 and 12 at Power And Blowing Station of Bhilai Steel Plant. Surge is the phenomenon in which there is a sudden increase in the discharge pressure of the blowers and hence the decrease in the flow rate which leads to the flow reversals. This flow reversal can cause severe damages to the blower turbine and can also be fatal for the human lives working over there. The work starts with studying the anti-surge control systems already installed at the blower Number 11 and 12. The present surge control system is hardware programmed, i.e., it is designed with the use of potentiometers, rectifiers, analog controller, etc. on a printed circuit board. Due to the aging and the involvement of the various circuit components there is always a possibility of control system failure due to the component failure. This project is intended to replace that hardware programmed circuit with a controlling software which will be designed and fed to a general purpose programmable single loop controller. It will decrease the probability of the system failure and hence will increase the reliability of the surge control system.

Keywords: Surge control system, Compressor, Turbo-blowers.

Introduction

Turbo-blowers are the machines which are used for blowing large volumes of gases with a moderate increase of pressure in the pipelines of the process. These are used in a number of production processes. In a steel production process, they are used for the supply of air to the hot blast stoves of the blast furnace with the required flow and pressure. Any interruptions in the supply of air may create loss of production.

Whenever the pressure of the air blown out of the turbo blower is higher than the pressure inside the turbo blower a reverse flow of air is created towards the impeller and inlet of the blower, which reduces the speed of the turbine shaft and creates noise and vibrations. This phenomenon is known as surge.

The established method of controlling a surge is to avoid its occurrence by limiting the operating range of the turbo-blowers which affects the efficiency of the machine[1-3].Work has also been done for an active control strategy for developing anti-surge control system using fuzzy logic controllers and other methods[4]. Efforts were also made to establish the anti-surge mathematical model and anti-surge control algorithm for gas compression pumps which fits to the proposed safety curve[5]. Anti-surge control system are also designed through the two valve systems operated by the PID and PI controllers for the surge line specified by the pressure ratio versus volumetric flow graph[6]. Adaptive neuro fuzzy inference system (ANFIS) by using some data and operation conditions from compressor site is used with fuzzy controllers which effectively addresses the surging[7].

Surge Fundamentals

Surge is a dynamic instability. It causes vibrations, noise, throttle and temperature which can together harm the machinery severely and in the worst case also cause damage to the human life working around the machine. The stable operating region of the compressor lies to the right of point B in Figure-1, where pressure rise decreases for increasing flow. Also assume that the compressor speed is constant, implying that the operating point lie on the speed line shown in the Figure-1. The surge cycle can then be described by the following steps:

i. Assume that the compressor operates at point A, when the downstream pressure starts to increase. This causes compressor flow to decrease to the point where no further pressure rise through the compressor is possible, marked by B. ii. If the downstream pressure still exceeds the maximum pressure increase, flow will decrease and even become negative at point C. The negative flow causes the upstream pressure to increase, and as a result the pressure rise over the compressor goes down. iii. At point D, the upstream pressure of the compressor is almost equal to the downstream pressure. The compressor will then restore positive flow. iv. Flow will continue to increase until reaching point A. If no means are employed to move out of the surge region, the surge cycle will repeat[8].

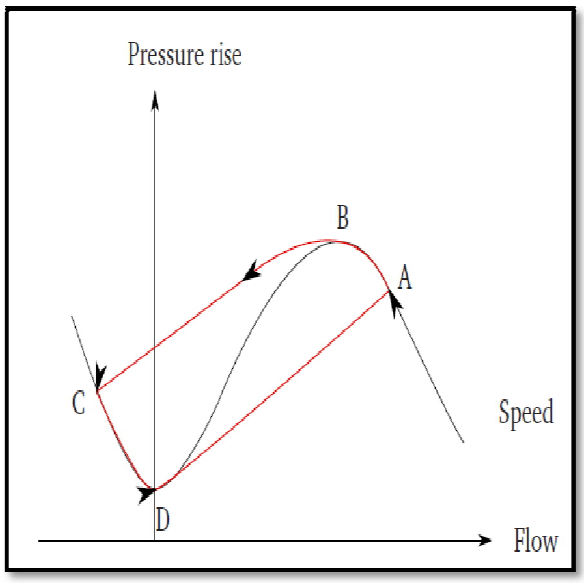

Figure-1
Surge Cycle

It is a very quick phenomenon so it is extremely essential to design a control system that would react to the surge conditions in almost no time and prevent the system from entering in the surge cycle.

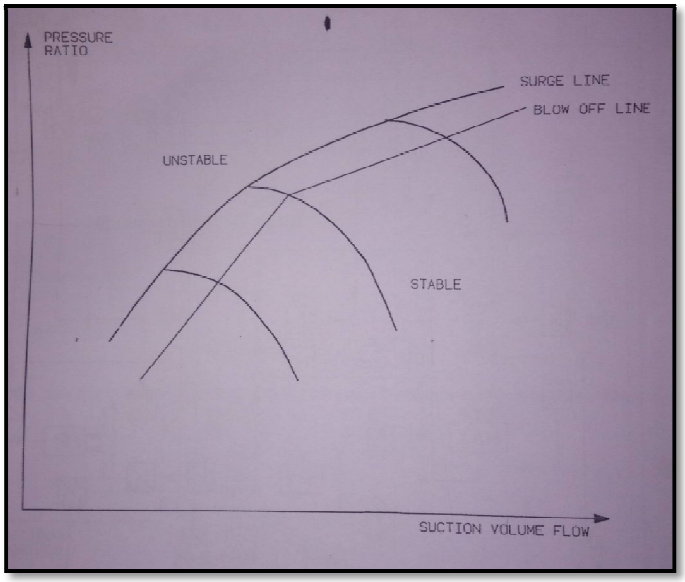

Figure-2
Pressure Ratio Vs Suction Volume Flow Rate

Anti-surge control system

The present hardware programmed control system's design is based on the surge and blow-off lines which are carved in the pressure ratio (discharge pressure to inlet pressure) versus suction volume flow rate graph as shown in Figure-2. The area at the right of the surge line is considered as stable where as to the left of the surge line is taken as unstable region where surging phenomenon takes place. The blow-off line is defined to the right of the surge line as per the safety requirements of the system. The system is connected to the blow-off valves which are initially closed and are made open whenever the system starts operating to the left of the blow-off line so that to restrict the turbo blower from reaching or crossing the surge line. It is a preventive approach to control the blower from entering the unstable region. Because surging is a very dynamic phenomenon so the control system is also made to respond very quickly to the adverse conditions.

The control system satisfies the following three requirements: i. when the blower is operating to the right of the blow-off line there must be no intervention by the control system. ii. With the machine operating on the blow-off line a stable control behavior is required. This can be achieved by the low controller gain. iii. On the other hand, in the event of operation to the left of the blow-off line, the control system must react at the high-speed which requires high gain.

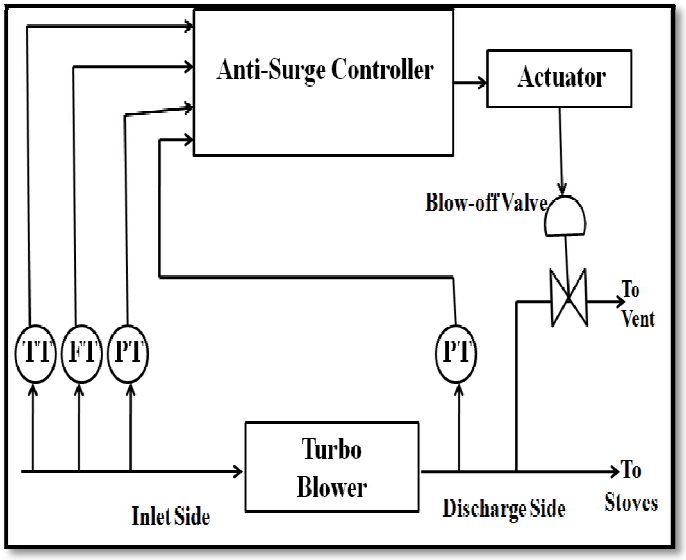

Figure-3
Anti-Surge Control

Control scheme

Since the turbo-blowers with which we are dealing in this paper is a constant suction pressure type so the minimum allowable compressor suction flow rate (set-point for the control system) is merely a function of the blower discharge pressure.

Since the surge limit moves towards larger flow rates with rising suction temperature, correction is required by the addition of a corresponding variable. Contrary to common practice the control deviation is established at a point upstream of the controller rather than in the controller so that the control deviation can be influenced according to the actual position of the operating point.

When the blow-off line is exceeded by more than two percent, the controller's gain is increased by 5 times so as to take the corrective action in a very quick manner.

The distance of surge limit and the blow-off line is varied as a function of the rate of change and the distance of the point of operation of the machine from the blow-off line. In this way, protection of machinery is improved without the need of a wider safety margin when operating under stationary conditions.

Maximum discharge pressure limitation is also set. The minimum flow rate check with respect to a specific discharge pressure and the maximum discharge pressure limitation gives their respective control deviation to the maximum selector circuit which selects the highest control deviation to be passed to the controller so that it produces the highest amount of blow-off valve opening. This ultimately ensures that neither the blow-off line is passed nor the discharge pressure limitation line is passed.

Development of the control software

Since the turbo-blower which is used in the Power and Blowing Station of Bhilai Steel Plant are constant suction pressure type hence we are designing the surge control software based on the surge line defined using discharge pressure versus suction volume flow rate graph. The surge line is first defined by the data that we have got from the test results during operation of the turbo blower. Based on this defined surge line, we are working for a 10% safety margin between surge line and the blow off line. Hence we have got the equation of line for the blow-off line. Apart from the blow off line we are also taking in account the maximum discharge pressure limitation for the line. So, we have defined a safe operating area or stable operating region with the combination of the blow off line and the maximum discharge pressure limitation line on the discharge pressure versus suction volume flow rate graph.

We are using Toshiba Tosdic 211 D single loop controller for the controlling action. It has dedicated software developing tool which we are using for developing software which is used for operating the turbo blower in the stable region defined by the derived blow off and discharge pressure limitation line. The approach to develop the software may be termed as the functional block diagram programming approach.

The entire data processing flow in the controller has ten different stages out of which five stages are routine processing cycles which have in-built functions to be performed necessarily by the controller such as high and low alarm checks, etc. Apart from these routine processing cycles there are five intelligent spaces which are to be used by the users as a part of their programs to perform a specific task. According to the need of the programmer, he can choose the required spaces and leave blank the rest of the spaces.

Expected result

The designed system which will be the outcome of this project work will follow the above graph. AB is the surge line. DC is the blow-off line defined at 10% safety margin from the surge line. Line CE is the discharge pressure limitation line. The area on the right of the blow-off line and under the discharge pressure limitation line is the safe operating region in which the system is to operate without the danger of crossing the surge line.

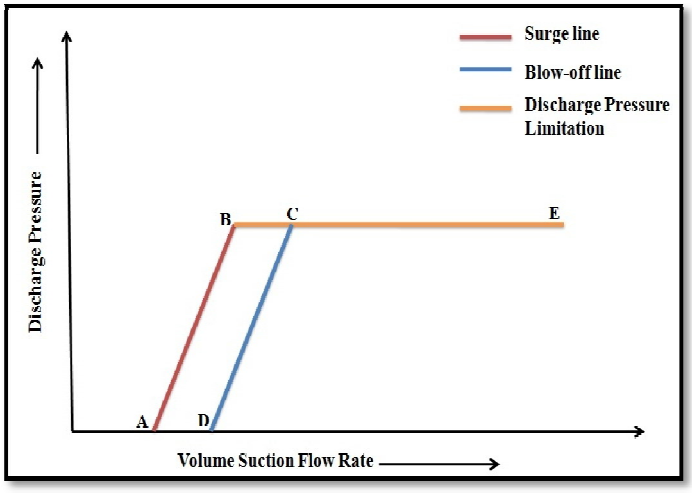

Figure 4
Expected Characteristic Curve

Conclusion

The designed system will definitely increase the reliability of the anti-surge control system as the analog components and its associated aging will be completely eradicated by the system. It is also a very simple and cost effective solution to the problem of surging.

Acknowledgement

We are very thankful to the Bhilai Steel Plant administration for providing all the facilities and support, at every stage which is very essential for this work. We would also like to thank Dr. Manisha Sharma, HOD, Electronics and Telecommunication Department, Bhilai Institute of Technology for her inspiration, guidance and valuable suggestions. We are also very much thankful to Mr. G. K. Kundu, AGM, Instrumentation Department, Bhilai Steel Plant for sharing his elaborate knowledge about the system.

References

1. N. Staroselsky and L. Ladin (1979). Improved surge control for centrifugal compressors. Chemical Engineering, McGraw-Hill, Newyork, 86, 175-184.

2. Willems F. and de Jager B. (1999). Modeling and control of compressor flow instabilities. *Control Systems Magazine, IEEE,* 19(5), 8-18.

3. Gravdahl J. T. (1998). Modelling and control of surge and rotating stall in compressors, Ph. D. Thesis, Department of Engineering Cybernetics. *Norwegian University of Science and Technology*, Norway.

4. Salim Al-Mawali and Jie Zhang (2007). A Novel Fuzzy Logic Control Strategy for Compressor Surge Control Using a Variable Area Throttle. 22nd IEEE International Symposium on Intelligent Control, *Part of IEEE Multi-conference on Systems and Control, Singapore,* 1-3 October, 682-687.

5. Liu Xiaoyang and Wang Ping (2013). Anti-surge Control Technologies of Large–sized Chinese Gas Compression Pump, *IJCSI International Journal of Computer Science Issues,* 10(2).

6. Ghanbariannaeenni Ali and Ghazalehsadat Ghazanfarihashemi (2012). Protecting a Centrifugal Compressor from Surge. *Pipeline and Gas Journal,* 239(3).

7. Mohamed A. Waly, Ibrahim F Tarrad and Mohamed M. Fouad (2014). Surge Detection System for Centrifugal Compressor. *International Journal of Engineering and Science Technology, Waly*, 3(2), 692-698.

8. Terje Kvangardsnes (2009). Anti-surge control: Control theoretic analysis of existing anti-surge control strategies, Department of Engineering Cybernetics. Master thesis, Norwegian University of Science and Technology, Norway.

9. Wang Shenghui and Jin Xing (2010). A research on anti-surge and predictive control method of centrifugal air compressor. International Conference on Computer Application and System Modeling, 22-24, October, 2010, 3, 590-593.

10. Mohamed A. Waly, Ibrahim F. Tarrad and Mohamed M. Fouad (2014). Surge Detection System Using Gaussian Curve Membership Function. *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,* 3(11).

11. Zhang Hua, Wang Taofen and wang Yigang (2012). Antisurge Control of Compressors in Catalytic and Cracking Devices for Heavy Oil. 2nd International Conference on Materials. Mechatronics and Automation Lecture Notes in Information Technology, 15.