HIGH PERFORMANCE PID CONTROLLER FOR PRESSURE PROCESS STATION

[1]Dr.S. Yuvaraj, M.E. PhD, [2]R. Seshasayanan, M.E, Ph.D, [3]A. Mani Annamalai, DMIT (Instrumentation), B.Sc. (Phys)
[1]Associate Professor, [2]Professor, [3]Associate Professor,
[1, 3] Electronics and Instrumentation Engineering, [2] Electronics and Communication Engineering,
[1, 2, 3] Meenakshi College of Engineering, Chennai, Tamil Nadu, India.

Abstract: In this paper to study the various performances of Manual Mode, ON-OFF/P/PI/PD/PID controllers on Pressure process station. In various pressure process control applications, such as servo-valves or variable displacement pumps, Train traction and Stem boiler are used to meter the flow into a supply line or a chamber with relatively constant capacity parameter, thereby controlling its pressure gauge under this influence of disturbances such as flows in and out of the controlled volume. For most applications proportional integral derivative (PID) controllers are suited and widely used in research and practice applications. However, tuning of various pressure controller parameters for pressure control is usually done by trial and error method due to the lack of applicable tuning rules for in this case. In this paper examines the various pressure controllers' performance controlled by pressure applications and proposes a set of effective but simple PID feedback gain formulas. They can be implemented by practitioners on the basis of data that in most cases is available from station drawings and the process control software data graph. The tuning rule's parameters are based on a straight forward frequency response design. They yield swift and robust performance various pressure process in simulation and experiment.

Index Terms **–Process control, ON-OFF, PID controller, PSI, Pressure Process Station.**

I. INTRODUCTION

Process control is an engineering mechanism that uses continuous monitoring of an industrial process' operational variables (e.g., temperature, pressure, chemical content) and algorithms and then uses that information to adjust variables to reach product output specifications and objectives. Process engineers are often responsible for the operation of chemical processes. As these processes become larger scale and/or more complex, the role of process automation becomes more and more important [1].

Proudly announces the introduction and applications of pressure process control systems for all engineering transport, train traction, chemical and industrial plant and medical equipments. The systems are the outcome of the efforts of our R&D team. Typically, the process control system is comprised by five independent process work stations (viz. flow, temperature, pressure and level). Each work station is individually supported by a computer which acts as the PID controller [2]. This helps the researches to visualize the Process graphically on the screen. Further, these process work stations can equip the Instrumentation measure and Control to the various processes. Each process station is provided with one PC with relevant software for independent operation. All the parameters of the process stations are controlled by the software. ON-OFF, Proportional, Integral and Derivative Control (PID Control) are done by software. Since each Process Station is based on computer, some experiments can be conducted by the industrialists. Temperature, pressure, flow, and level are the four most common process variables. Similar to temperature, pressure is another key process variable because pressure provides a critical condition for boiling, chemical reaction, distillation, extrusion, vacuuming, and air conditioning. Poor pressure control can cause major safety, quality, and productivity problems. Overly high pressure inside a sealed vessel can cause an explosion. Therefore, it is highly desirable to keep pressure in good control and maintained within its safety limits [3].

Why Pressure Control Can Be Difficult

The many reasons why a pressure loop is difficult to control are listed and described in the following table:

Reason	Example	Control Headache
Nonlinear	Natural gas pipeline. Pressure of a fluidize-bed boiler. Gas mixing plant.	A PID or model-based controller may work well in its linear range and fail in its nonlinear range.
Multivariable control	Multiple gas lines may draw gas from a master line. When the load changes, they will interact with each other.	A multivariable process cannot be effectively controlled by using SISO controllers due to interactions among the variables.
Large load changes	Steam generators in co-generation plants have to deal with large steam load changes due to demand changes.	Load changes can cause major disturbances to pressure.
Large and varying time-delays	Pressure in municipal gas grids or a product powder transport system has large and varying time delays.	PID cannot effectively control a process with large and varying time delays.
High-speed and open-loop oscillating	The pressure field and Mach speed value of an ultra-sonic wind-tunnel used in the aerospace industry is open-loop oscillating.	Due to the poor frequency domain behavior of this process, tying to control an open-loop oscillating loop can be a nightmare.
Nonlinear and high-speed	Vacuum vessels used in thin film or material deposition.	It is desirable to reach the vacuum state but the process is nonlinear.

II. SYSTEM OVERVIEW

The pressure process station can be invariably classified under three heads i.e.,

i) Pressure Process Station Mainframe

ii) Data Acquisition Card

iii) Process Control Software
iv) Compressor

2.1 Pressure Process Station Mainframe

The mainframe is a metallic structure mounted on open platform. It consists of a bottom plate houses the process tanks. A frame contains pressure transmitter, I/P convertor, control valve, process tank and a cabinet. The cabinet accommodates the multi-output DC power supply and inlet socket for AC mains as shown in Fig. 1. Front Panel Pressure Process Station.

2.2 Data Acquisition Card

VAD-104 is a high performance ADD-ON Data Acquisition Card. It easy to interface with our PC through parallel port. The board incorporates with 8 single ended analog inputs through 12-bit ADC, two channels I to V converter and single of V to I converter.

2.3 Process Control Software

Process control software is indigenous software designed by our in-house R&D for pressure process station. The software package for pressure control application is very powerful, general purpose package which measures the process variable, displays it on the screen and issues control action to the controller (pneumatic control valve).

2.4 Industrial Standards:

Prior to the widespread adoption of electrical and electronic controls, buildings often used pneumatic control systems. Large and powerful compressors drove 3psi to 15psi pneumatic signals throughout a plant and these pneumatic lines connected to pneumatically controlled valves and pneumatically controlling valves in order to drive proportional controls and actuators throughout the building, all powered from compressed air. Air pressure at 3psi served as the “live-zero” and 15psi represented 100%.

In this way, the more modern 4-20mA signal standard emulated the earlier 3-15psi pneumatic controls. Any pressure below 3psi was considered “dead zero” and an alarm condition. Some installations still use pneumatic control today. Modern I/P converters (current-to-pressure transducers) are available to convert the 4-20mA control loops to common pneumatic ranges, such as 3-15psi. In two-wire 4-20mA control loops, we use 2-wire transmitters to convert various process signals representing flow, speed, position, level, temperature, pressure, strain, pH, etc., to 4-20mA DC for the purpose of transmitting the signal over some distance with little or no loss of signal. its advantages, in particular as it relates to two-wire transmitters and the associated 4-20mA current loop.

III. Front Panel Diagram

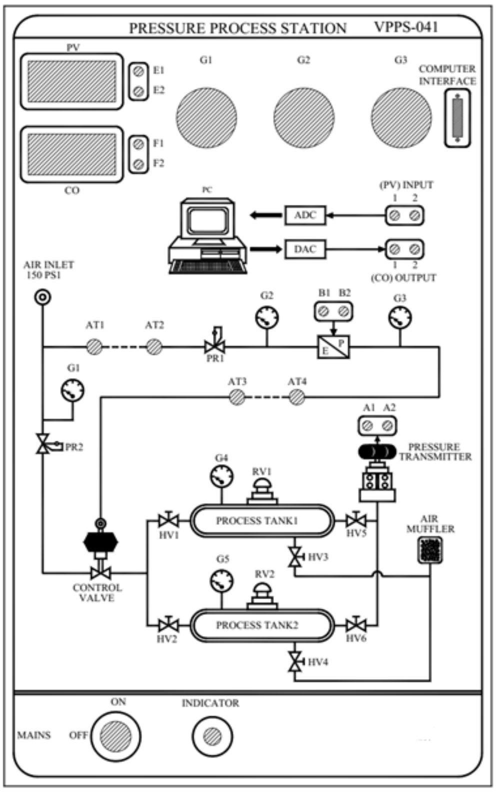

Figure.1. Front Panel of Pressure Process Control Station

3.1 Current to Pressure Converter

Principle of Operation

The input current pressures through the coil (1), thereby magnetizing the soft-iron yoke (2). The flux lines of this system being exposed at the gap (3) apply a force proportional to the input signal on the permanent magnet (4) which is made from a highly coercive metal. The small magnet (4) together with the flapper (5) forms the moving parts, controlling the air pressure at the nozzle (6), which is proportional to the magnetic force. The air pressuring from the nozzle forms a restoring force balanced by the force applied to the magnet. The nozzle (6) is supplied with air through a throttle and back pressure through power amplifier gives proportional output. The described units are properly matched. Hence, a linear correspondence of electric input and pneumatic output signals is achieved. The direction of action of the converter is determined by the coil polarization. Zero adjustment is performed using the potentiometer connected with a resistor in parallel to the coil (1) as shown in Fig.2. Current to Pressure Converter.

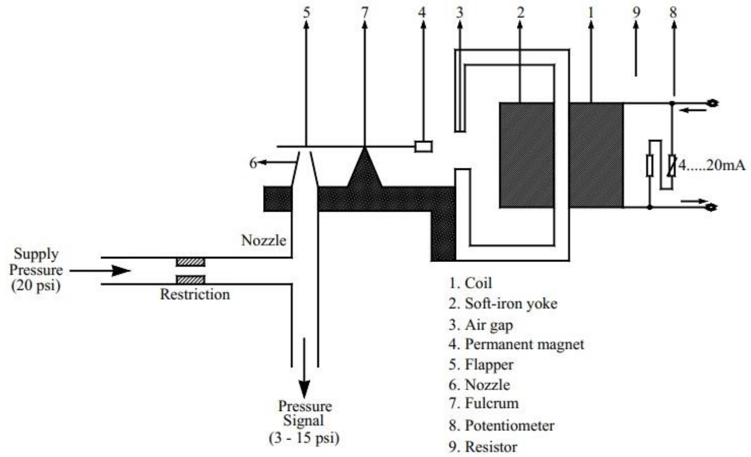

Figure.2. Current to Pressure Converter

3.1 Application

The electro pneumatic (I/P) signal converter is used as a linking component between electric or electronic and pneumatic systems. It converts standard electric signals (4-20) mA, respectively into the standard pneumatic signal (3 - 15) psi. Due to its innovative construction principle based on a fixed coil and a low-mass (100 mg) moving permanent magnet, the I/P signal converter is highly resistant to shocks and vibration.

3.2 Pressure Transmitter (Pt)

Pressure transmitter is works on the principle of force balance. PT is used to measure the pressure (gauge pressure or absolute pressure). The output in terms of (4 - 20) mA DC and it can be transmitted by a lead to other devices of controller. Pressure transmitter have primary sensor of diaphragm and secondary transducers of piezo electric sensor. Capsule type of diaphragm is kept inside of the transmitter. Diaphragm movement depends upon the pressure difference between the surfaces. The variation is allowed to strike one face of the crystal material, the crystal produce electrical energy by the principle of piezo electric effect. These outputs can be conditioned by using micro controller based calibration technique

3.3 PID Control

Here, a positional PID algorithm is implemented into the software.

$$c(t) = K_P[e(t) + \int e(t)dt + \frac{d\,e(t)}{dt}] + c(0) \quad --- \quad (1)$$

$$C(s) = K_P\left[E(s) + T\frac{E(s)}{sT_1} + \frac{sT_d\,E(s)}{T}\right] + C(0) \quad --- \quad (2)$$

Kp	=	Proportional	gain
Ti	=	Reset	time
Td	=	Rate	time
Co	=	Controller	bias
T	=	Sampling time	

Controller Bias

It is necessary to indicate the controller being in active condition and protect (immune) the controller from noise when the error is zero.

Advantages of PID control

* Extremely simple
* Inherently stable when properly tuned
* Easy to tune
* Better dynamic (i.e Reduces Lags)

IV. Types of Control

4.1 ON/OFF Control

One of the most widely used type of control is the ON/OFF control. ON/OFF control is also referred as “TWO POSITION” control or “OPEN AND CLOSE” control. Two position controls is a position type of controller action in which the manipulated variable is quickly changed to either a maximum or minimum value depending upon the controlled variable is heater or less than the set point.

If the process variable is below the set point, the controller output is 100% (i.e. control valve is fully open). If the controlled variable is above the set point, the controller output is 0 % (i.e. control valve is fully closed), when the differential gap is zero. The tuning parameters for ON/OFF control are differential gap and time delay.

i. Differential Gap

Differential gap is the region in which the control causes the manipulated variable to maintain it's previous until the controlled variable has moved slightly beyond the set point. Small differential gap is not preferred. Because, it introduces oscillations and reduces the life of the final control element.

4.2 Proportional Control

Two position controls applied to a process results in a continuous oscillation in the quantity to be controlled. This draw back was overcome by a continuous control action which could maintain a continuous balance of the input and output. A mode of control which will accomplish this is known as "PROPORTIONAL CONTROL". Proportional control is defined as follows "It is a controller action is which there is a continuous linear relationship between value of the controlled variable and position of the final control element within the proportional band'. **The tuning parameters for proportional control are,**

i. Proportional Gain [Kp]
ii. Time Delay [Td]

i. Proportional Band [Pb]

Proportional band is defined as the percent deviation in measurement of its full scale required to give 100% valve deviation. Narrow band proportional control gives a comparatively large corrective action to the valve for a small change in the measurement. For wide band proportional the corrective action to the valve is small land therefore the offset will be large. Usually, narrow proportional band is preferred. If proportional band is zero, the controller behaves as two position control.

ii. Time Delay (Td)

Time required to take the successive samples of process variable.

4.3 Proportional + Integral (P+I)

The proportional control mode provides a stabilizing influence while the integral mode will help to overcome OFFSET. Integral controller will provide corrective action as long as there is a deviation in the controlled variable from the set point value. Integral control has a phase lag of 90° over proportional control. This lagging feature of reset will result in a slow response and oscillation will come into picture. This is suitable for pressure control and pressure control where the process has little lag. But required a wide proportional band for stability. The small process lag permits the use of a large amount of integral action.

4.4 Proportional + Derivative (P+D)

Derivative control action combined with proportional gives a controller which is good on process containing appreciable lag. Because the process lag can be compensated by the anticipatory nature of derivative action (i.e.) derivative action provides the boost necessary to counter act the time delay associated with such control by 90<. Since this controller combination is most effective where the system lags are high, it could be used on most multi capacity process applications. Where the process lag is short, this combination could not be used. This controller combination does not eliminate OFFSET after a sustained load disturbance. It does reduce the magnitude of OFFSET. Because of narrow proportional band. A proportional plus derivative controller properly fitted and adjusted to a process acts to prevent the controlled variable from deviating excessively and reduces the time required to stabilize.

4.5 Proportional + Integral + Derivative (P+I+D)

This controller offers the benefit of each control action and moreover the effect duplicates the action of a good human operator on the process. A three mode controller contains the "stability" of proportional control and the ability to eliminate offset. Because of reset control and the ability to provide an immediate correction for the magnitude of a disturbance because of rate control.

4.6 Manual Mode

In the manual mode, the controller power or output is set manually by the use.

V. WORKING PRINCIPLE

The Pressure Process Station is used to control the pressure of process tank. The pressure transmitter is used. In pressure control action, a compressor discharging the air from atmosphere and give it to control valve. The accumulation of the air in the tank is known as a pressure of the tank, which is sensed by pressure transmitter. The corresponding current output (4-20mA) is given to the VAD-104. Every internal transaction is in voltage. Here, PC acts as an error detector and controller.

According to the error signal and controller parameters, the corresponding control signal is given to the I/P converter. It controls the pressure of the tank by varying stem position of the control valve. For maintaining the pressure of the process tank, valve opening is manipulated. From this station also study the characteristics of pressure transmitter, I/P convertor, control valve and justify the various control action on the process as shown in Figure. 3. The all the patch cords are connected as shown in Figure.4.

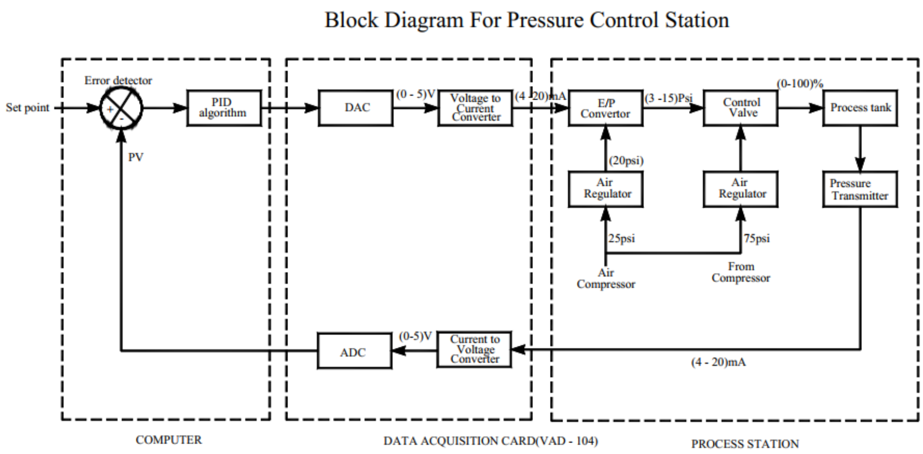

Figure.3. Pressure Process Station

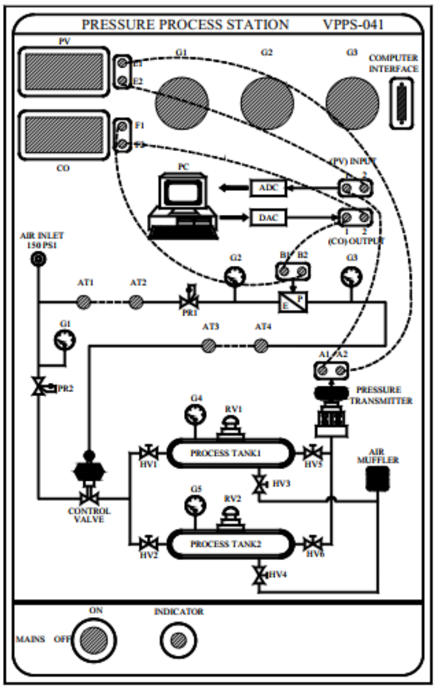

Figure.4. Patch connection

VI. RESULTS AND DISCUSSION

TABLE1: Manual Mode and Various Controllers

Controller	Set point	Kp	Ki	Kd	Diff. Gap	Reaching set point at PV (PSI)	Error at PV in (PSI)	Reaching set point at PV (Volts)	Reaching Set point at CO (%)	Reaching Set point at CO (mA)	Reaching set point in (sec)
Manual Mode	50	2.00	0.01	1.00		49.5	0.5	2.48	40	8	378.38
On/Off	50				20	49.87	0.13	2.49	100	20	30.41
PD	50	2.00		1.00		49.84	0.16	2.49	50	10	30.95
PI	50		0.01			49.84	0.16	2.49	50	10	30.95
PID	50	2.00	0.01	1.00		49.96	0.04	2.5	80.78	16.16	39.42
Proportional (P)	50	2.00				49.87	0.13	2.49	83.61	16.72	22.67

The comparisons of various controllers for Pressure process control system in open loop and closed system with K_p = 2.00, K_i = 0.001 and K_d = 1.00, for all controllers except on/off controller have the differential gap is 20 in TABLE 1. Also the reaching set point at Actual and Practical process variable (PV) in PSI and it's the corresponding voltage are shown in TABLE 1. The various controllers to reach the set point at control output (CO) in percentile, with respect CO in mA and various time taken in sec as shown in TABLE 1.

Figure.5. Manual Mode output

The pressure process control response using manual mode as shown in Figure.5. Similarly, On/Off, PD, PI, PID and Proportional controller output as shown in Figure.6, Figure.7, Figure.8, Figure.9, and Figure.10. Are respectively. The manual mode i.e., open loop system to give the input control output CO = 10 %, 20 %, 30 % and 40 % in 3.6mA, 5.2mA, 6.8mA and 8.4mA then only reach the set point PV = 50 PSI in actual but in practical reach the set point = 49.5 PSI

Figure.6. On/Off controller output

Figure.7. PD controller output

Figure.8. PI controller output

Figure.9. PID Controller output

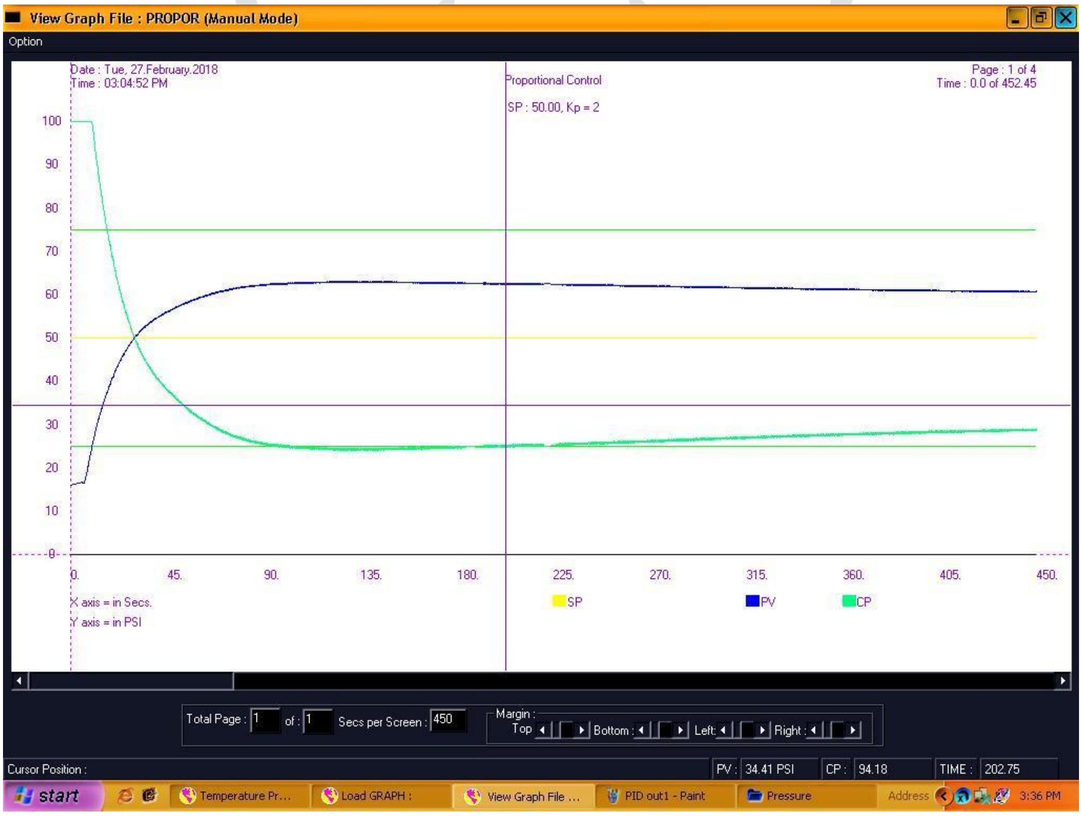

Figure.10.Proportional controller output

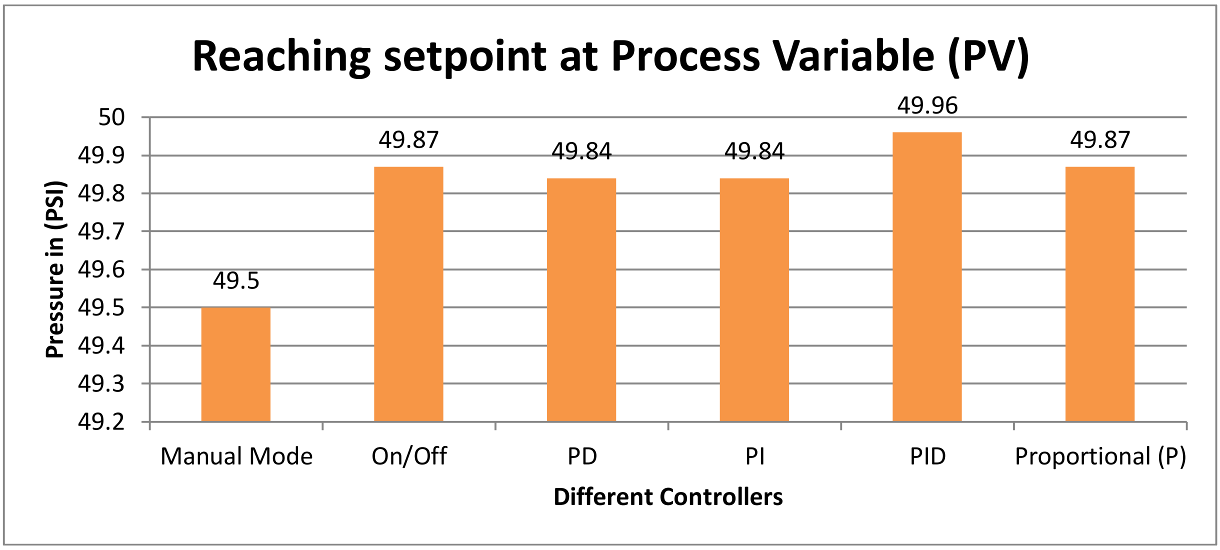

Figure.11. Actual Process variable (PV) using different controllers

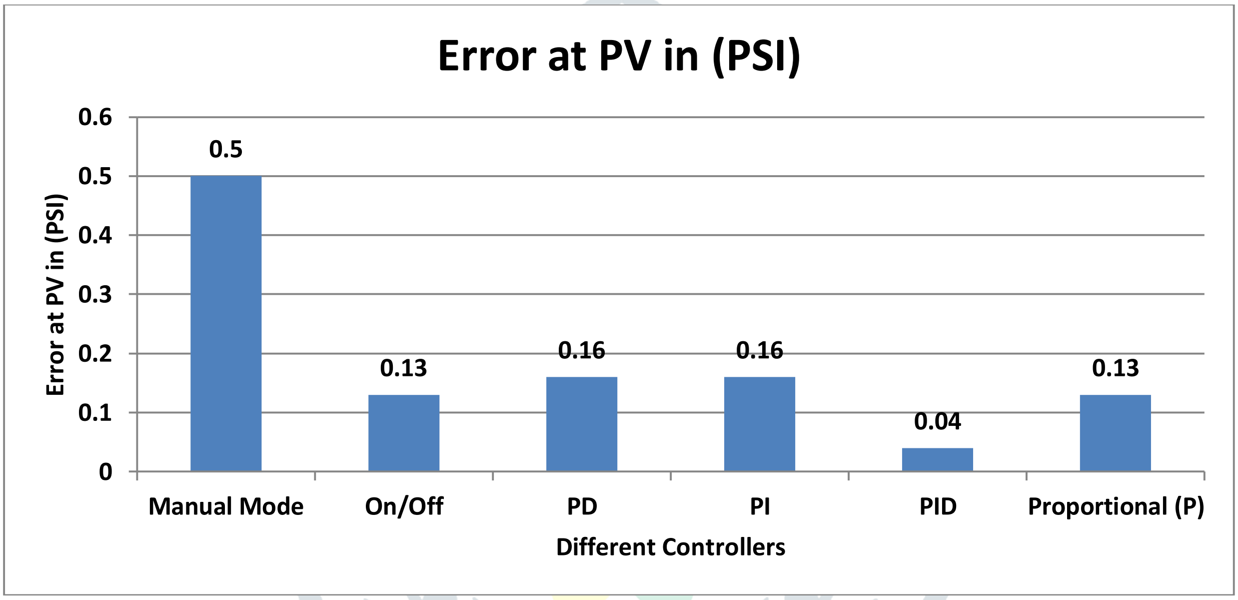

Figure.12. Actual and Practical Error in Process variable (PV) using different controllers

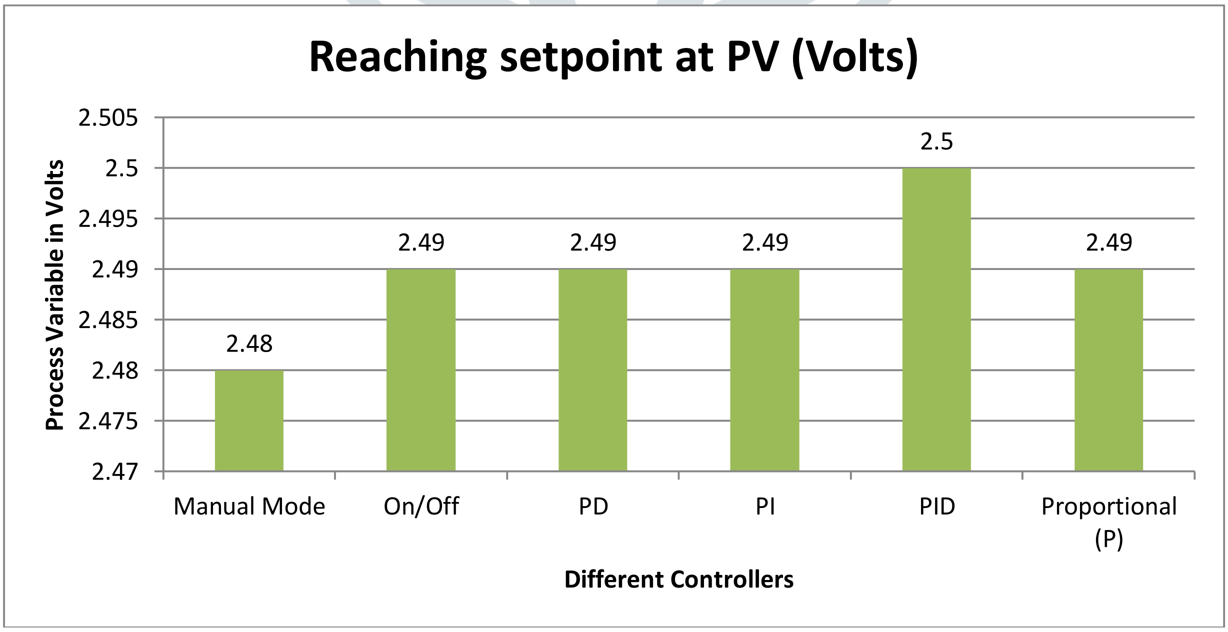

Figure.13. Actual Corresponding Process Variable (PV) in Volts

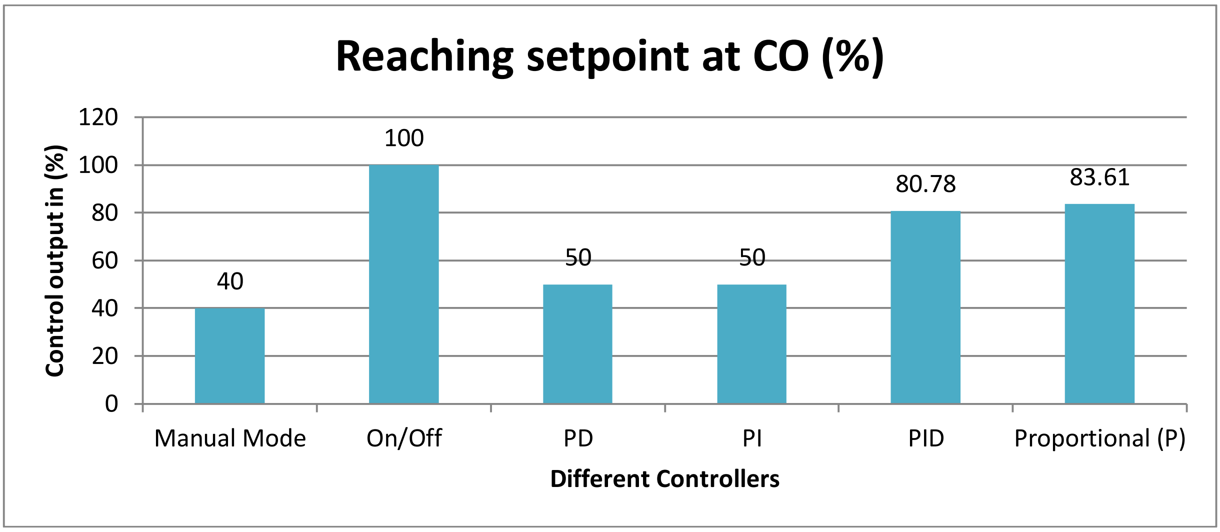

Figure.14. Actual control output (CO) in (%) using different controllers

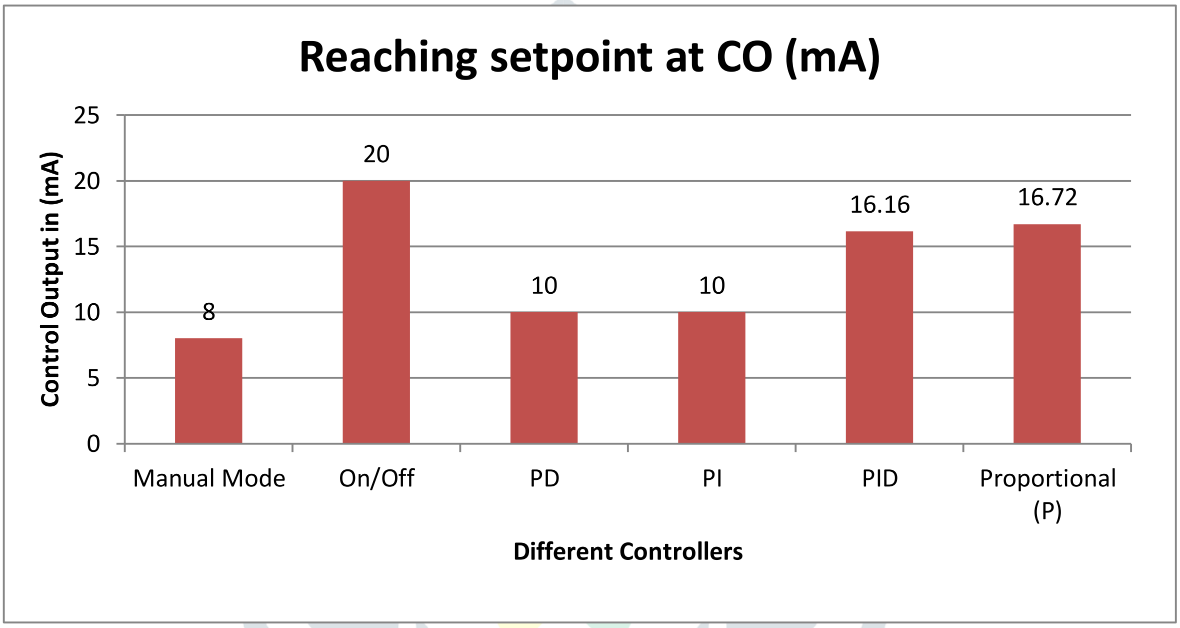

Figure.15. Actual control output (CO) in mA using different controllers

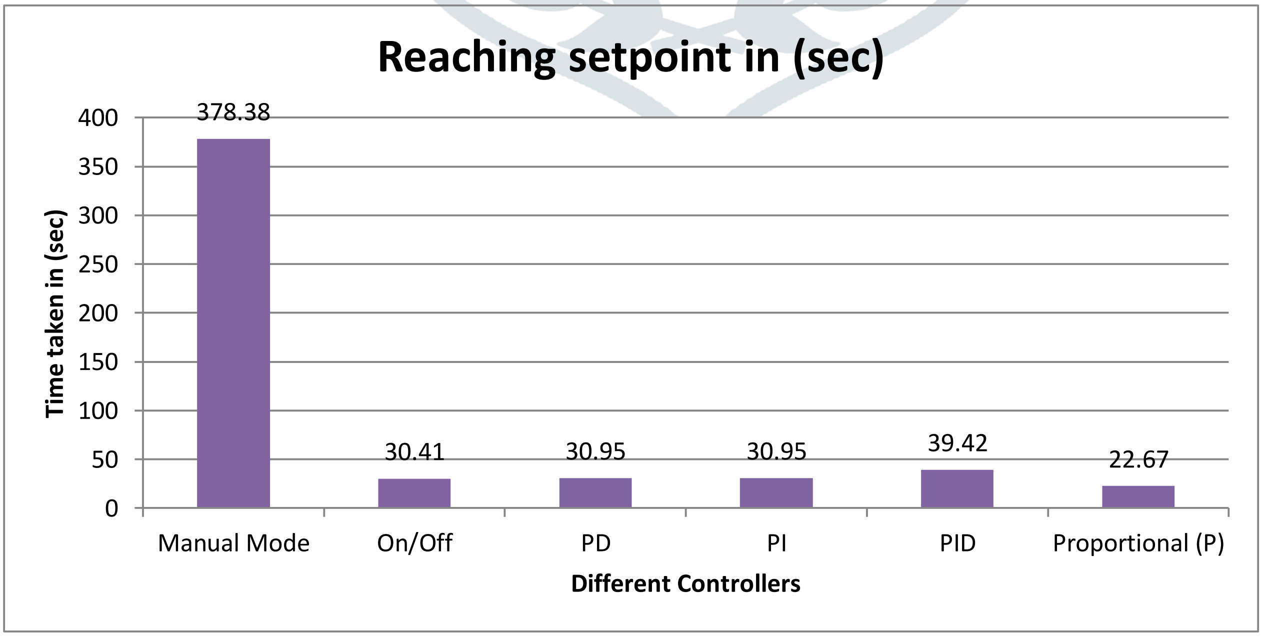

Figure.16. Actual Time Taken in (sec) using different controllers

VII. CONCLUSIONS

Thus the performance of the entire Manual mode, ON-OFF/P/PI/PD/PID controllers on pressure process was studied. In specific PID controllers have long been used for pressure control various applications but parameterization still poses a problem for the commissioning instrumentation engineer. Conventional tuning rules are more difficult with take time in the commissioning process and do not always lead to sufficient results. In results Actual setpoint 50 PSI and The above results PID controller only is best controller compare with other Manual mode, ON/OFF, PD, PI and Proportional controller because the PID controller only reach the setpoint at process variable (PV) is 49.96 psi and in terms of voltage 2.5 V with minimum error 0.04 psi only. The PID controller control output (CO) is 80.78% with CO in 16.16mA. And also the PID controller reaching the setpoint to take in 39.42sec.

So compare all the other above controllers experimental results in worst case is Manual mode controller because the Manual mode controller to reach the set point at process variable (PV) is 49.5 psi and in terms of voltage 2.48 V with maximum error 0.5 psi. The PID controller control output (CO) is 40% with CO in 8 mA. And also the PID controller reaching the setpoint to take in 378.38 sec. In Future studies should focus on relevant practical issues such as noise, non-ideal differentiation, and added phase lag due to sampling time and sensor dynamics. Also a relationship between capacity, expected pressure steps, valve size and reaching time could be found on basis of this experimental study, which may help the designer to choose the right valve size and controller for a pressure control application.

VIII. ACKNOWLEDGMENT

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