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Design of Smart Positioner for a Control Valve to Optimise Backlash Problem

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Abstract

Control valves are an increasingly vital component of modern manufacturing around the world, since control valves are mechanical devices, their performance is less than ideal, and degrades over time. For a plant to perform optimally control valve performance must be tracked and maintained. Backlash is one of much invertible nonlinearity present in control valve, if a valve has some backlash, the loop will have a tendency to oscillate, which will get bigger and bigger as time goes by and will also make the loop slower to respond. At present, pneumatic valve Positioner is used which uses mechanical cam to correct the non-linear nature of control valves. Pneumatic valves Positioner typically are very simple and do not implement integral control. In this project a novel low cost Smart Positioner is designed and developed to improve the performance of control loops. A rotary potentiometer with a linear actuator is used to give feedback signals to the controller of the current position of the control valve. A specially designed control system which is cascade in nature increases the performance of the control system. The Position sensor control being a slave controller acts faster to position the valve and thereby avoiding backlash problem. The developed design is implemented in the Second Order Two Tank Level control system and the performance metrics such as Rise time, Settling time and Steady state errors evaluated found improved after implementing smart Positioner. The oscillation of control valve was found minimum compared to pneumatic Positioner which clearly an indication of reduced backlash in the system. The low cost smart Positioner is RVDT which fixed on a pinion rack and interfacing the proposed second order system using MATLAB for error analysis and LabVIEW software and NI DAQ6008 to run the proposed second order system.

Keywords: Control Valve, FCE, RVDT, Second Order, Smart Positioner

1. Introduction

The common industries in our country mainly oil, chemical and gas have problems that cause a poor control valve application are discussed. The final control element is being the control valve faces inherent risk due to the failures of them resulting in leaking of dangerous chemicals or gases. By designing a Smart Positioner for this control valve will improve the safety measures of the control valve. The Smart Positioner will improve the safety systems in detecting the potential risks and judging them before itself and prevent the process control system from danger. The opening and closing of control valves is done automatically by pneumatic, hydraulic and electrical actuators. The control valve is also called as the Final control Element. Positioner are used to control the opening and closing of actuator based on electric or pneumatic signals. For a plant to perform optimally control valve performance must be tracked and maintained. The performance of the control valve degrades day by day due to some of the factors like backlash, improper bench set, due to aging, due to leak in the I to P converter, holes in the actuator doom, improper tightening of the actuator diaphragm and seal leak between the actuator and the stem. Backlash is one of much invertible nonlinearity present in control valve, if a valve has some backlash, the loop

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will have a tendency to oscillate, which will get bigger and bigger as time goes by and will also make the loop slower to respond.

At present, pneumatic valve Positioner are used which uses mechanical cam to correct the non-linear nature of control valves. Pneumatic valves Positioner typically are very simple and do not implement integral control. In this project a novel low cost Smart Positioner is designed and developed to improve the performance of control loops. A one turn rotary type potentiometer with a linear actuator is used to give feedback signals to the controller of the current position of the control valve.

The backlash effect is defined as the problem in which the path followed from open position to close position is not the same as that from close to open position. In our project we are designing a smart positioned such that it eliminates all the problems stated above and yields to make the control valve work properly and efficiently. A smart positioned consists of an electrical circuit board, a potentiometer, power supply of 9 volts and a terminal block with input and output terminals. The output terminal from the POT is given to the DAQ. Before connecting to the DAQ the POT is checked and calibrated properly. The DAQ is then interfaced with the computer loaded with the Lab VIEW software. Firstly the system is run in 2nd order level process station. The system is first run in auto mode and the errors are noted without using the sensor. Then the system is run in the same mode and the sensor is utilized if any fault or leakage has occurred. The performance metrics such as Rise time, settling time and Steady state errors evaluated found improved after implementing smart Positioner. Through our project we would like to conclude the oscillation of the control valve was found minimum compared to pneumatic Positioner which clearly indicates that the backlash problem has reduced in the system.

The objectives of the project are – BACKLASH.

The path followed from opened position to the closed position will not be the same from the closed position to the opened position is known as backlash problem. This arises due to Ageing. Due to ageing the tensile strength of the actuator, spring weakens and the elasticity of the spring weakens.

Benchset - It occurs due to inlet line pressure the stem pressure may get open hence a force is given to the stem is known as benchset. Due to the improper benchset adjustment variation in the inlet pressure the stem will tends to open.

This can be avoided by giving more force to the stem by using the spring, Due to leak in the tube from i-p converter to the actuator, due to the holes in the actuator doom, due to improper tightening of the actuator diaphragm, due to the seal leak between the actuator and the stem[1–4].

Occasionally it is necessary to provide added support for a valve actuator. This may be a need if the actuator is quite heavy, such as for many electrical and electro-hydraulic designs or when the valve is installed in a position in which the actuator is off the vertical centerline. In these cases it is very critical that the support be flexible enough to allow for thermal growth of the piping system and that the installation does not impose large lateral forces. Such forces will cause higher friction on the valve moving parts. The ideal support system is simply a pulley with a dead weight counterbalancing the weight of the actuator.

Other support systems require enough design effort to be assured that the actuator is not constrained or deflections imposed that add undesirable side loads on the actuator. One criterion that should never be used in the design of a support system is to attempt to limit vibrations and in particular to limit a pipeline vibration problem. The former almost always results in a fatigue failure of a restrained component and the latter will result in short term destruction of the valve/actuator assembly[8,9].

A number of common and repeated problems associated with the Design-Selection and Operation-Maintenance of control valves have been discussed. These problem valves, known to everyone in the operation, keep coming up plant after plant. They need to be addressed in a systematic way to avoid the reoccurring troublesome control valve problems. Many times the attempts to fix a problem in the field are doomed to fail because the dominant errors were made in the sizing and selection of the valve. To cover all the issues one must review each of the

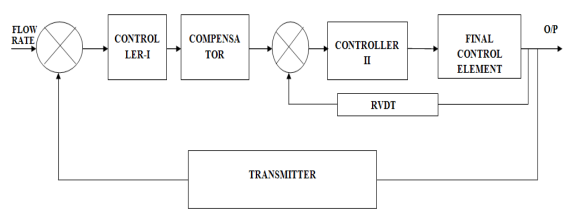


Figure 1. Block diagram of the proposed system with smart Positioner.

issues discussed to highlight all the root causes and take correction action[5].

2. Experimental Set-Up

The original existing system consisted of an ordinary two tank interacting system setup with two cylindrical tanks, control valve, rotameter, pump and the reservoir. This is a SISO system. The proposed system consists of the same with an additional rotameter and a pump connected for giving a variable disturbance. Hence now the system acts as a MISO system. This modified setup is connected to the second process tank. The opening or closing of control valves is usually done automatically by electrical, hydraulic or pneumatic actuators. Positioner is used to control the opening or closing of the actuator based on electric or pneumatic signals. These control signals, traditionally based on 3-15psi (0.2-1.0 bar), more common now are 4-20mA signals for industry. Figure 2 shows the control valve of pneumatic valve. A control valve consists of three main parts in which each part exist in several types and designs:

- Valve's actuator.
- Valve's Positioner.
- Valve's body.

Differential pressure level measurement technology infers liquid level by measuring the pressure generated by the liquid in the tank. The differential pressure transmitter consists mainly of a mechanical measuring system with elastic pressure element of Model 733.14, magnetic-field- dependent sensor (Hall sensor) with

Figure 2. View of control valve or pneumatic valve.

amplifier and case with the connecting parts for the electronics. A permanent magnet rigidly coupled to the pressure element influences the flow field of a sensor. The resulting differential voltage is amplified to a standard current signal. The final control valve automatically opens and closes by the use I/P conveter which converts the manipulated current into pressure this system uses A "Current to Pressure converter" (I/P) converts an analog signal (4 to 20 mA) to a proportional linear pneumatic output (3 to 15 psig). Its purpose is to translocation the analog output from a control system into precise, repeatable pressure valve to control pneumatic valves.

3. Proposed System

Figure 3 shows the modified system with a disturbance given to the tank 3. The flow is controlled using a rotameter. This in turn creates a disturbance in the interacting system. Now the level of the liquid in the second tank increases. The proposed controller controls the level of the liquid in the second tank and rejects the disturbance and brings back the level in the tank to the set level.

In this proposed system a RVDT and it is an one turn potential meter and it supports up to 24 volts supply. It has three terminals as anode (+) cathode (-) and common. In this anode and cathode are the input terminals. The output is taken between the common and the cathode terminals and it can be rotated in the 360^{o}.

In the shaft of the RVDT the pinion is connected and the pinion is interfaced with the Rack. During the movement of the rack the shaft of the RVDT can rotate either in the clockwise or in the anticlockwise direction according to the movement of the Rack.

The output of the RVDT is given to the DAQ 6008. During the change in RVDT the Resistance value can be changed and voltage level given to the DAQ is changed. In this we are using the 9v (or) 12v DC adapter for providing the external input to the RVDT. A Rack is connected with the Stem of the control valve with the help of the supporting steel bar for the purpose of upward and the downward movements. The rack is fixed in the horizontal direction. In the above diagram the hardware connections between the RVDT and the Rack and Pinion sets are shown[10,13].

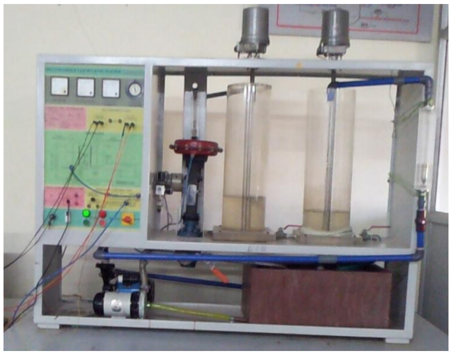


Figure 3. Proposed experimental set-up.

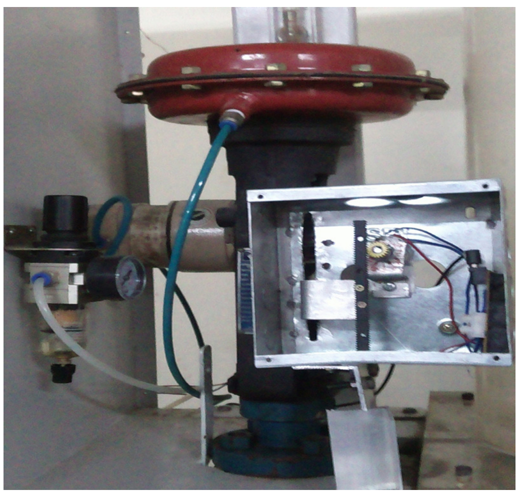


Figure 4. Final control element with RVDT.

4. Modelling of a Two Tank Interacting System

Finally the transfer function arrived is given by:

$H2(S)/Qi(S) = R2/(\tau 1\ \tau 2S2 + (\tau 1+ \tau 2+A1R2)S+1)$

5. Results and Dicussions

The Figure 7(a) below shows the response of the system at the start of the process without any disturbance applied to it. The output response of the process of the system with control valve stem position 100% open and with setpoint 50 is shown in Figure 7(b). The output response of the system with setpoint 75 and the control valve stem position 50 open is shown in the Figure 7(c). The output response of the system with the setpoint as 50 and the control valve stem position 50% open is shown in the Figure 7(d). Response of the system without disturbance for a regular invervals[15,17].

These are the responses of the system before introducing the smart positioner to the control valve. The output response of the system with disturbance for regular time intervals is shown in Figures 7(e) to 7.h). The output response of the system with set point as 50 and the control valve fully open is shown in Figure 7(e). The output response of the system with set point as 75 and the control valve stem position 50% open is shown in the Figure 7(f). The output response of the system with set point as 75 and the control valve stem position as 50% open is shown in the Figure 7(g). The output response of the system with set point as 50 and the control valve stem position as 50% open is shown in the Figure 7(h). The below responses are obtained after introducing the smart positioner to the control valve[14,16].

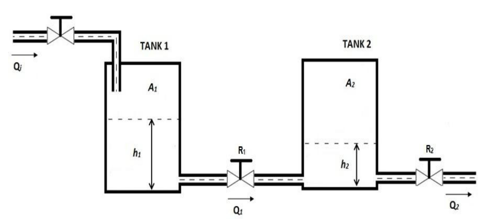


Figure 5. Interacting system with two tanks.

Table 1. Input parameters

Radius of the tank 1 and tank 2
Area of tank 1 and tank 2
Maximum Height

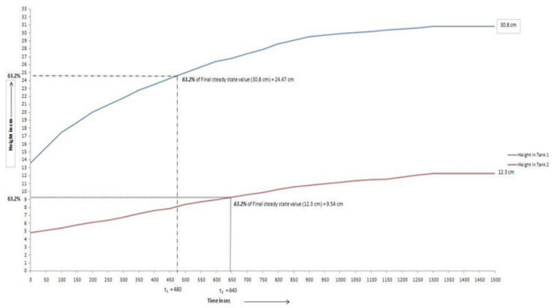


Figure 6. Output response of the system.

6. Performance Analysis of the System without Disturbance

Table 3 Shows the responses of the system without any disturbances using PID controllers in Lab VIEW software.

7. Analysis of the System with Disturbance

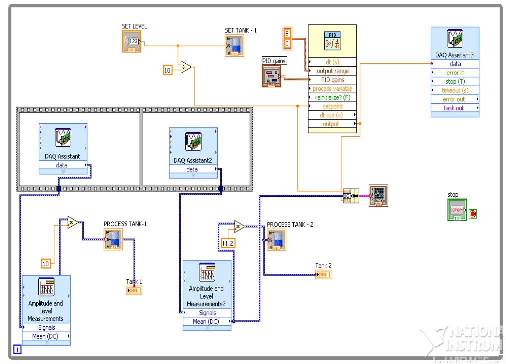
Table 4 shows the responses of the system without any disturbances using PID controllers in LabVIEW software.

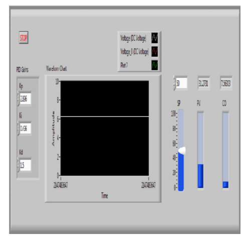
8. Output Response of the Feedback

The Figure 9 shows the responses of the system both before and after introducing the smart Positioner. The red color response states that after introducing the Smart positioned the time taken to settle is less when compared to the response without positioned.

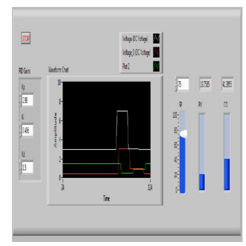
9. Conclusion and Future Scopes

Smart Positioner proves to be a great aid to predictive maintenance by providing a valve degradation analysis, which is important for critical valves in safety-related systems[4]. With the development of the 700 series control valve and but it can be able to success in 300 series with the help of monitoring the control valve functions through the LCD (Liquefied Crystal Display) and the 300 series to improve the customer values in the field but in

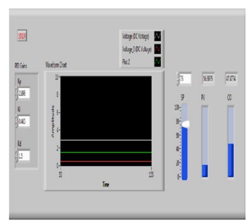




(a)



(b)



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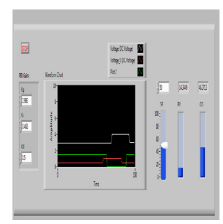
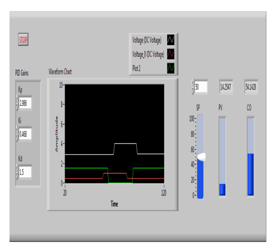
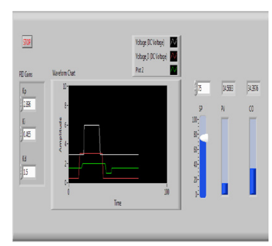


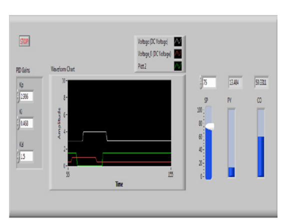
(d)



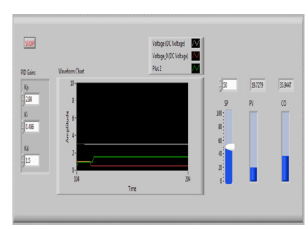
(e)



(f)



(g)



(h)

Figure 7. Shows the block diagram panel diagram designed in Lab VIEW for the system in real time.

Table 2.

	SP	PV	CO
Normal initial response	50	31.273	7.56
Response with stem position 100%	75	19.75	41.39
Response with stem position 50% open	75	16.38	47.47
Response with stem position 50% open	50		46.37

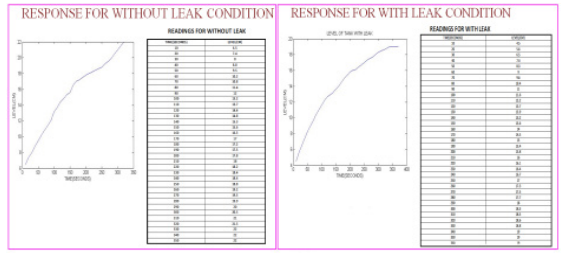


Figure 8. Responses with and without leak condition.

Table 3.

	SP	PV	CO
Response with stem position 100%	50	14.25	54.14
Response with stem position 50%	50	19.72	35.94
Response with stem position 50%	75	13.48	59.33
Normal response	75	14.56	34.39

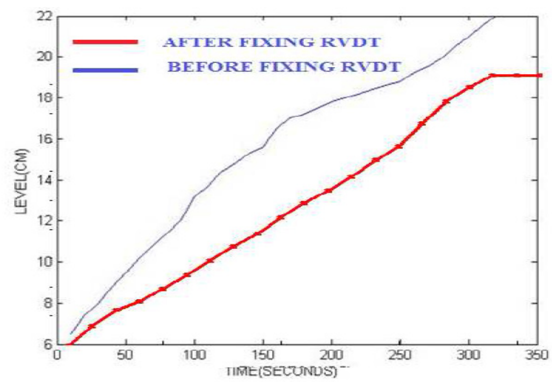


Figure 9. Output response with feedback.

the 700 series they will additionally required the 4-20mA device clock speed for the purpose of reducing the input current Rating to the Microprocessor[5].

This proposal focuses on improving the performance of the existing control valve by inserting a Smart Positioner. This Smart Positioner not only helps in optimizing the backlash effect but also help to reduce other problems that occur in the control valve such as aging of the stem and the spring, due to leak in the pressure inlet line and due to improper sealing of the control valve.

9.1 Future Scopes

The Smart Positioner in the control valve can be further improved to provide better results. The future improvements are:

- The accuracy of the control valve can be improved.
- This can be used for interacting system where the settling time is to be less when compared to the normal process without Positioner.
- This can also be implemented for other processes such as: Flow, pressure and temperature.
- It can be tuned using PID controller for large lag process.

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