Saad S. Alahmad, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 14, Issue 9, September, 2024, pp: 13-34

RESEARCH ARTICLE OPEN ACCESS

Practical approachin Industrial Training in close loop Control Systems, problems solution” Case of PID- Level Control”

Saad S. Alahmad*and Abdelkarim J. Ibreik**
**Eng. Saad S. Alahmad, Electrical Power Department, Public Authority for Applied Education and Training.*
***Eng. Abdelkarim J. Ibreik, Electrical Power Department, Public Authority for Applied Education and Training*
***Cooresponding Author*

Abstract
The necessity of training students in a way to gain skills in Instrumentation and control fields leads us to search and specify the difficulties appearing during the execution of industrial control experiments. As an example of an experimental approach, Level PID control was used to attend this goal, Furthermore, the results of the experiments will be recorded at different scenarios to choose the suitable values for the control system response. This research will apply a PID corrector to improve the Process Control under specific conditions and constraints using Basic Level Rigs (feedback) and ABB controller. Furthermore recording the confronted difficulties in the experiment, and find a proper solutions to meet the expected results according to related theorems. Examine the control system characteristic, behavior and reliability by applying external disturbance .

This study shows that producing accurate results are not simple, you need to consider many factors such as follow the instruction of equipment manufacturer explained in technical manuals, calibrate devices and Knowledge of theories. The main aim of the study to enrich technician and researchers with knowledge in the field of instrumentation and motivate them for further research. Finding the reasons behind un expected results of experiments and try to find solutions. The solutions were either by calibrating the sensors nor actuators in the system(hardware wise) or configuring the system parameters such PID coefficients in the controllers (software wise).

Keywords: Industrial Control, Training Process, PID control, Controllers, Sensors, Actuators, Kuwait Public Authority for Applied Education and Training.

Date of Submission: 29-08-2024 Date of acceptance: 08-09-2024

I. Introduction

Skilled Technicians are considered one of the valuable treasures in advanced countries that communities relay on them for construction, developments and progress.

Therefore, designing a proper training programs along with a continuous improvement and upgrading laboratory’s equipment and studying materials are considered one of the essential objects to achieve these goals and meet the needs of the work market.

Higher Institute of Energy (HIE) in Public Authority for Applied Education and Training (PAAET- KUWAIT) yearly graduating a qualified national technical staff in different aspect of industrial fields. These staffs can manage the operation of a sophisticated control systems and maintain the equipment and measuring devices related to automation of process control system.

Specialized trainers have big responsibility and challenge to choose a proper laboratories equipment and instruments with high-quality specification to prepare the practical experiment documents and get in touch with the problems might be faced in practical implementation. the main goals of applying these experiments summarized by:

1- Get experience in the field of study.
2- Gaining trust in implement the experiment safely.
3- Understanding the operation and connection of actual equipment in the field.
4- Able to recognize and solve the troubles by tracing the faults.

In this research, we will focus in the instrumentation part of close loop control system. Concentrating in Level Control system, using the PID corrector.

The Close Loop Control System was implemented and tested under different scenarios to confirm the expected behavior according to theoretical relations. In addition, the effect of disturbances and simulated malfunctions were examined the system stability.

The trainees must be familiar with available instruments and equipment to use and handle correctly without hazards. Moreover, a knowledge of dealing with relevant computer application that used to execute the necessary connections, monitoring the streams and record the results

To construct Level Control system using the PID technique we need to use an appropriate equipment to meet the best results.

Firstly a Float Level Transmitter is used with Float Level Sensor to measure and convert the mechanical displacement into electrical signal (mA) that can be read by the controller, the float level sensor is fixed over the liquid in the Process Tank. A process interface equipment used to provide the input and output with the necessary power supply. ABB controller was used to easily apply the parameters of PID corrector through computer application. The output devices and actuators such as (solenoid valve and servo-valve) used in two modes, either manually or automatically.

II. Literature Review

Any control system consists of three major components which are input, output and process, whereas the output is considered the most important part in the control systems that where continuous monitoring is required.

2.1 Control Systems

The process block represents the physical process being affected by the actuator, and the controlled variable is the measurable results of the process. For example, if the actuator is a servo-valve (Level Control Valve) which used to control the flow rate of the liquid to control the level in the tank, then the process is "level control" and the controlled variable is the Level in the tank

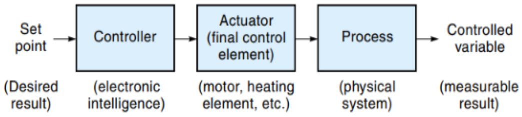


Fig.1 : A block diagram of control system

Open-Loop Control Systems

"Control systemscan be divided into two categories: open- loop and closed-loop systems. In an open-loop control system, the controller independently calculates exact voltage or current needed by the actuator to do the job and sends it. With this approach, however, the controller never actually knows if the actuator did what it was supposed to because there is no feedback. This system absolutely depends on the controller knowing the operating characteristic of the actuator"[1]

An example of open-loop system shown in Fig.2 controlling the direction (angle degree) of antenna by motor by selecting the setpoint of the angle as illustrated in Fig.3

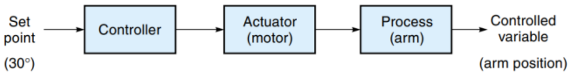


Fig. 2: Open loop control system (antenna case)

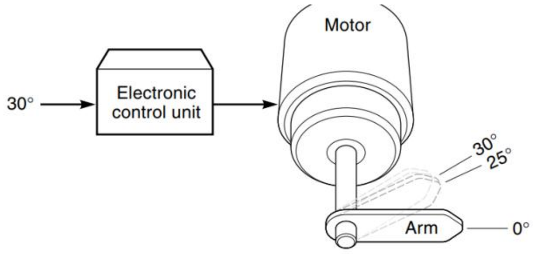


Fig.3: simple open loop control of antenna direction

"Open-loop control systems are appropriate in applications where the actions of the actuator on the process are very repeatable and reliable. Relays and stepper motors are devices with reliable characteristics and are usually open-loop operations. Actuators such as motors or flow valves are sometimes used in open-loop operations, but they must be calibrated and adjusted at regular intervals to ensure proper system operation. "[1]

Closed-Loop Control Systems

In a closed-loop control system, the output of the process (controlled variable) is continuously monitored by a sensor, as shown in Figure 4. The sensor measure the system output and converts this measurement into an electric signal that it feed back to the controller. Because the controller knows what the system is actually doing, so it can make any adjustments necessary to keep the output where it belongs. There is two signals directions, one signal from the controller to the actuator is called the forward path, and the second signal from the sensor to the controller is called feedback path which closed the loop of the control system. This measurement (controlled variable) is compared with the set point value in the comparator and the results of the difference is called error or deviation from the required value. According to this signal the controller send a proper signal to the actuator to maintain the required value in the output. See figure 5

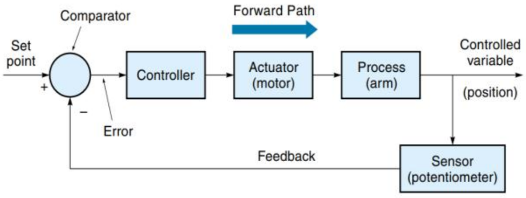


Fig. 5: close loop control system

A basic close control system is illustrated in Figure no. 6

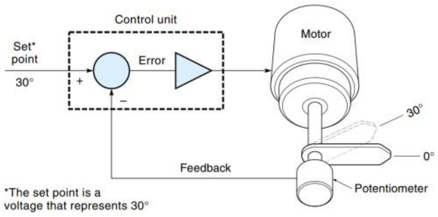


Fig. 6: Basic close loop control system example

To minimizes the error by the controller, using a control strategy, which can be basic or complex. A basic control strategy would be ON-OFF control by enable the controller to turn the actuator fully on or off. And the complex one by using PID and other advanced control strategies.

Transfer Functions

"Physically, a control system is a collection of components and circuits connected to perform a useful function. Each component in the system converts energy from one form to another" [1]; for example, we notice that a motor converting volts to speed revolutions per minute (rpm) and temperature sensor as converting degrees to volts or even to displacement as in bi-metal sensor. To describe this action and create a common formula to show the performance of the entire control system, we calculate the combined effects of the different components in the system. This need is behind the transfer function concept.

A transfer function (TF): is a mathematical relationship between the input and output of a control system component. Specifically, the transfer function is defined as the output divided by the input, expressed as

$$\mathrm{TF} = \frac{\text{output}}{\text{input}}$$

Transfer Function describe the condition of the system in time-dependent and steady state and both have different characteristics, while TF at steady state is called Gain expressed as

$$\mathrm{TF}_{\text{steady-state}} = \text{gain} = \frac{\text{steady-state output}}{\text{steady-state input}}$$

Such as a motor example at the beginning a huge current need to start up (Transient period) after that needs regular steady current (Steady-State period).

A simple example for the TF is the potentiometer which is commonly used in different application such as our Float sensor used in this research, the potentiometer give 10V if rotate 300° , so if we divide the output voltage by the rotation angle we get TF as explain here

$$\mathrm{TF} = \frac{\text{output}}{\text{input}} = \frac{10\ \mathrm{V}}{300^\circ} = 0.0333\ \mathrm{V/deg}$$

From this TF we can calculate the output directly the expected response in case of rotation angle is 150°

Output= TF x Input= 0.0333V/deg x 150° =5 V

But in our case of study the sensor output 4-20mA while the input of the level varies from 0-100%

So, if we have 50% input we will get

Output= 0.50 (20mA-4mA) +4mA=12mA

Analog and digital Control System

Normally the input (sensor / Set point)and output (command signal to actuator) signals using analog signals (4-20mA) these values convert into voltage by 100 ohm resistor and used by analog controller or interfaces, but in case of we need to use digital controller such as ABB controller we have to convert the input signal from analog to digital by (ADC), while converting the output signal from digital to analog by (DAC). Also we can generate the set point value (4-20mA) from Variable Current Source. See illustration in Fig. (7)

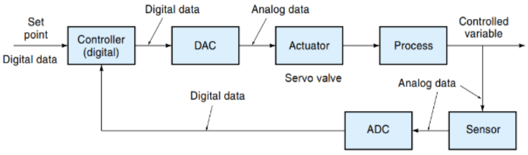


Fig. 7: Using ADC and DAC with digital controller

Feedback Control

The control law of the Feedback, is the relationship between the actual measured value and desired value of a process parameter.

Applying feedback loop to a process allows the control law to be operatedin auto-mode; now the control action is dependent on the measured value. And a system which employs feedback control has become error-driven. and able to deal with unexpected disturbances.[2]

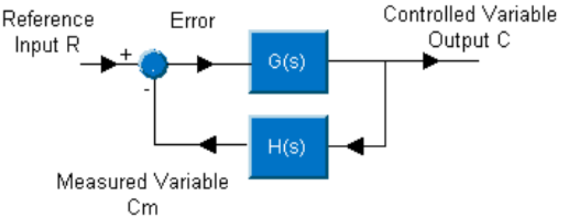


Fig. 8 : General Feedback Diagram

The above diagram shows the general feedback control system Fig. (8). This diagram applies to all systems incorporating a feedback loop. (general process control system, digital and analogue control systems) were all based on this general form.

It shows the forward path, encompassing the plant, represented by **G**. This function includes any controller dynamics. The feedback path is represented by **H**, and this includes the measurement system.

A system can bemodeled so that its behavior can be assessed before it is physically implemented. By using a block diagram of a Feedback system, the modelling of a system can be explained**.**

$$C = (R - C\,H)\,G \text{ or } C\,(1 + H) = R\,G$$

By rearranging this, a function of output over input can be produced:

$$\frac{C}{R} = \frac{G}{(1 + H)}$$

the transfer function of the whole system, shows the relation between output and input.

Controller Actions

Common control law types are the **P-type** (proportional), **I-type** (integral) or **D-type** (derivative), or a combination of these, i.e. PI, PID. And the control law represents the action of the controller.

Definitions Terminologies

“The control system design begins by defining the process output needs and performance. The measured response used to check the control system performance after applying the step function(set point). The measured output wave form characteristic guide us to understand the performance of the control system through its terminologies

1- Rise Time is the amount of time the system takes to go from 10% to 90% of the steady-stateor final value.

2- OvershootPercent is the amount that the process variable exceed the final value, expressed as a percentage of overshoot to the final value.

3- Settling time is the time required for the process variable to settle within a certain percentage (commonly 5%) of the final value. “

4- Steady-State Error is the difference between the set point and measured process variable . see fig.(9) “ [5]

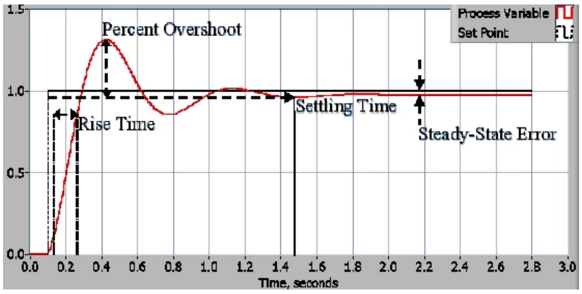


Fig. 9: Response of typical PID close loop system [5]

Abbreviations details

Some abbreviations used on the control diagram need to be cleared such as:

r - is reference value or set point (desired value)

MV- is measured value or process value

e - is error or the deviations between setpoint and measured value

Ctrl- controller

P - proportional control

I- Integral Control

D-differential control

Um- manual input

C-the output

Uc- Controlled input or control effort

U- is the total flow to the tank (control effort)

K- is the gain or sensitivity of the controller, represents how much the servo is open, and the output, C, is the tank level.

Ke - the automatic control effort, Uc, from the controller

Proportional Control (P)

The main function of proportional controller is to maintain a desired system performance, controlling the system disturbances (related to an steady drain of liquid).

The proportional control effort is directly proportional to the deviation between the setpoint and measured value(error). In our research we will notice that the control effort related to the command signal (percentage 1-100%, 4-20 mA), which controlling the flow rate of the Liquid passing through the servo-valve gate (Level Control Valve).

The following diagram shows a general proportional control system Fig.(10).

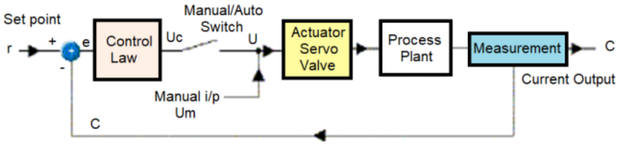


Fig. 10: close loop control system(proportional).

The error, **e**, is passed to the control law,producinga control effort is proportional to this error.

The control effort, **U**, will then determine how the process behave in the next time period.

By considering automatic proportional control, the following can be written:

U = Ke

This shows that the control effort, **U**, is directly proportional to error, e, where K is the gain or sensitivity of the controller.

The major disadvantage of proportional control is the unavoidable offset. And the **e**rror reduced by increasing the proportional effort and the system will lose the control if gain (or the control effort become beyond the limits).

This is the most basic equation describing this type of control, but it produces a problem: without an error there would be no input to the system. However, this is not strictly true because if there was no error the input would, in practice, be at a base or quiescent level. Applying this to the above equation gives:

U = Ke + Um

where Um is the quiescent point.

The total inflow can also be split up in the following way: Um is the water input needed to overcome any outflow and Uc, the change of inflow produced by a change in servo position (to counteract any deviation).

Now total inflow can be described as:

U = Uc + Um

Uc is the outcome of the control law and, for proportional control, this is simply:

Uc = Ke

Without reducing deviation to zero the controller would attempt to correct the output with a control effort and this would be seen as a bump when switching modes. The process would actually be driven away from the desired operating point.

Proportional Band

It is usual in industrial controllers to consider gain in terms of a proportional band (PB) or %PB. The proportional band represents the change in measured value (normally fractional change) that will generate 100% change in control effort. It can also be represented as the deviation that will generate 100% change in control effort.

$$PB = \frac{\text{Fractional deviation}}{\text{Fractional change in control effort}}$$

But this can be reduced....

Deviation is the error e divided by the measurement span, and the fractional change in control effort is the change in control effort divided by the output span of the controller. Therefore PB is:

$$PB = \frac{e}{\text{Measurement span}} \; \frac{\text{Controller output span}}{Uc}$$

Controller gain, K, is just Uc, the control effort, divided by error.

K= Uc / e ,

This reduces the equation to;

$$PB = \frac{1}{K} \quad \frac{\text{Controller output span}}{\text{Measurement span}}$$

The above equation shows the relationship between proportional band and controller gain, which is inverse proportionality.

A figure for gain alone is meaningless, since it will be dependent on the units used. Expressing PB as a percentage does have meaning, even if nothing is known about the process plant.

Proportional control alone is not normally used in process control because a steady state error must always exist for any control effort to be exerted. Proportional control is a form of deviation correction. However, without some deviation no corrective action will be produced.

Increasing gain will reduce this deviation, but a large gain increases the chance of *oscillation*.

Reverse Control Action

Simply put, an increasing water level requires a decreasing output from the controller to drive the valve.

This is what is called a Reverse Control Action.

Direct Control Action

Note that, with some processes, a rise in measured value needs a rise in controller output. This would be called Direct Control Action.

The major problem with proportional control, is the inherent offset produced by the controller.

The control effort needed to correct an error is directly proportional to that error and so the minimum error possible is finite.

The way to remove this error is to use a control action that will produce a control effort for zero error.

This is done by introducing an extra component into the control effort that is the integral of the error. This continue to change until the error is zero, thus removing the error entirely.

Controllers that employ integral action are described as *automatic reset* controllers.

Integral Control (I)

The amount of integral action is controlled by a constant, T_r, which is the *reset time*. The control effort to the process is now described by:

$U_c = U_p + U_r$

where U_p is the proportional term and U_r is the reset (integral) term.

From the previous assignments, you will already have met the expression for the proportional term:

$U_p = K\ e$

The reset term, U_r, is described by:

$$U_r = (K / T_r) \int e\ dt$$

which shows the position of the reset time constant, T_r.

The control effort can now be determined by the following expression:

$$U_c = K\ [e + (1 / T_r) \int e\ dt\ ]$$

This describes the action of an automatic reset controller.

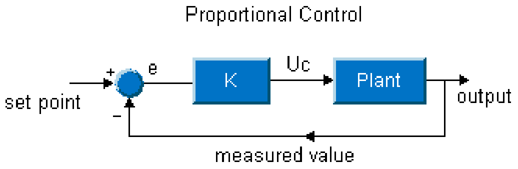


Fig. 11: Proportional Control system diagram

The diagram above Fig.(11) is the previous proportional control example, where:

$U_c = K\ e$

The following diagram Fig.(12) shows the new control effort arrangement to produce PI control. The summation of two distinct elements ($U_r + U_p$)give the total control effort U_c , where U_r is the reset term and U_p is the proportional term.

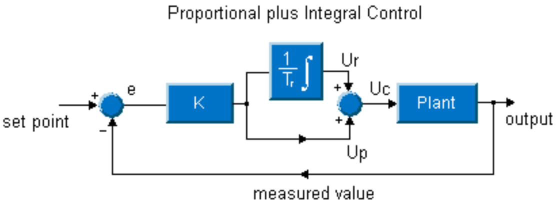


Fig.12: PI control system diagram

The reset time constant, T_r, is a very important variable as it controls the contribution of the integral action to the control effort over a given length of time.

If an integrator is given a step input of fixed duration, its response is a ramp. The slope of the ramp is controlled by T_r: the smaller T_r is, the steeper the ramp. With a steep ramp, the contribution of the integral term will be large in a given time and the time taken to reduce the error present will be short.

Unfortunately it is not possible to keep reducing T_r, increasing the integral action, to remove all error. As with the proportional band, there will be a minimum level of reset time constant that makes the system unstable. This should be avoided. At this minimum level, the integral action will be too large for the system and oscillation (our old friend) will result.

Derivative Action and Proportional plus Integral (PID) Control

Proportional control on its own reacts immediately to any deviation but it is insensitive to the rate of change of deviation. By adding an integral action, the control law now removes long term errors (offset). But if the error was increasing very rapidly a very large control effort would be desired (much larger than simple direct proportionality can provide) to halt this. PID control adds a derivative term which is proportional to the rate of change of error.

Considering the control effort in a similar way to the theory on Integral action, it can be split up into the following terms:

$U_c = U_p + U_r + U_d$

where U_p is the proportional term, U_r is the reset term and U_d is the derivative term.

The proportional and integral terms have already been met;

$$U_p = K\ e \qquad\qquad U_r = (K / T_r) \int e\ dt$$

The derivative term is described by the following expression:

$U_d = K\ T_d\ (de / dt)$

where T_d is the derivative time.

This derivative time, T_d, is very similar to the reset time, T_r, of the integral term. It controls the contribution of the derivative term to the overall control effort.

The control effort produced by a PID controller is as follows:

$$U_c = K\ [e + (1/T_r) \int e\ dt + T_d\ (de / dt)]$$

See the the PID diagram in Fig.(13).

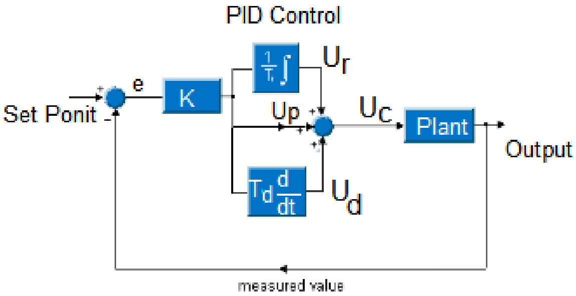


Fig. 13: PID control system diagram

The time constant of the derivative term appears in the numerator but the time constant of the integrating term appears in the denominator. This means that a derivative time of zero will remove any derivative action, but an infinite reset time is needed to remove all reset action.

As briefly mentioned, the derivative contribution is directly proportional to the rate of change of deviation between measured value and set point. As a result, the derivative term will be positive whilst the deviation is increasing and negative whilst the deviation is decreasing.

"Considering the action of the controller, while the error is increasing the derivative term will increase the control effort, with the size of the increase determined by the rate of change of the error. When the error is decreasing the derivative term will reduce the control effort as the rate of change of the error decreases. Coupled with the proportional action, this produces a braking effect as the measured value approaches the set point". [2]

"The overall effect of the derivative term is to increase the speed of response, to improve damping of oscillation and to reduce the size of the overshoot." [2]

"Derivative action will play no part in removing the offset present in proportional control. This offset is a steady state error, it has no rate of change since it is not time dependent, and the derivative of this will be zero. "[2]

Unfortunately, derivative action cannot be applied to every control situation, as it is not suitable for systems with noisy environments. Noisy signals contain high frequency components, which are amplified by the derivative action. These amplified high frequency components will appear at the controller output and will cause large changes in the position of the actuator.

While these may not affect the plant to a large extent (since plant dynamics will usually act as a filter to high frequencies), the rapid changes will almost certainly shorten the life of the actuator. The high frequencies may also cause fluctuations in the power supply.

Also, it must be understood that derivative action is most successfully employed in systems with fast changing variables. The reaction speed of the level and flow variables in this system are not sufficiently fast to *show-off* the potential of derivative action. This fact will be demonstrated later during the controller self-tune. The controller decides upon the most appropriate levels of proportional band, integral and derivative to control the process connected to it. The level of derivative action required will be seen to be extremely small.

The servo valve does not allow the flow rate to change fast enough to require much of the characteristic *braking* action of the derivative component.

However, there are certain situations where the derivative term is of great use. A servo motor is designed to respond to input signals relating to speed to direction almost immediately. A square-wave input to a servo motor exercises the reactions of the motor to the full.

2.2 Calibration

There are four steps required before start the running the control system:

1- Physical Link
2- Termination
3- Parameters
4- Scale adjustments

Some instrumentation devices need to be calibrated regularly, such as float level sensor, level transmitters, digital displays and gauges. moreover, the output devices such as servo-valve, due the nature of its mechanism and its internal position-er.

In the Float Level Sensor the calibration should by done by adjusting the potentiometer value, pulley and float device to meet the following specification where a Level of 0% should give 4mA (0.4V), a level of 50% give 12mA(1.2V) and a level of 100% give 20mA(2V). While the Level Transmitter should be calibrated by adjusting the Zero/Span values. The digital display can be checked and calibrated by accurate current meters with current generator used for these purposes.

Where the output devices such as Servo-Valve which receive a command signal from 4mA-20mA should be opened from 0%-100%.

It is to be noted that not all equipment need calibration such as ABB Controller 38-300 which is already calibrated to high accuracy but if we need very high accuracy equipment, we need a calibrator which has more accuracy.

2.3 Signaling

Signaling is necessary in control system installations.

Consider, for example, that a controller is located in a control room and its transmitter and control valve are mounted locally(site) to a process tank. In order for the controller to get information from the transmitter, and also to be able to change the position of the control valve (to control the flow rate or the level in the tank for example), it is necessary for the units to be able to communicate with each other.

Signaling have different types of transmission means, in our laboratories, signaling may either be done pneumatically (compressed air signaling) or electrically (current signaling). A great advantage with signaling is that standard signals can be used, which means that instruments can be bought from different suppliers and still remain compatible. For Pneumatic control signals, the standard range used for control purpose are the value of (0.2 bar to 1 bar). Electrical signals in a control system are usually dc (direct current) signals and can be divided into current (4mA-20mA) and voltage signals (0V-10V) .
Current signals are used for signaling over long distances and voltage signaling is used for shorter distances.
Nowadays, computers are increasingly taking over control room instrumentation and there has been a corresponding increase in the use of current signaling.
Current signaling is very often used between transmitters, controllers and signal transducers
In some cases, we need to use signal converter such as
1- Current to pressure converters (I/P)
2- Pressure to current converters (P/I)
3- Current to voltage converter (I/V)

2.4 Input devices (Sensors and Transmitters)

The sensing device is converting a physical quantity (e.g level, flow rate, pressure, etc.) into a current signal.
In the signal transmitter, sensor current is compared with the outgoing current, and the difference is amplified and is used to modify the setting of the generator current. see schematic diagram of signal transmitter Fig.(15).
In the Signal transmitter, The output current signal changes in proportion to the signal from the sensing device. While, in the sensing device, the current changed proportion to rotational movement of potentiometer (fixed in the pulley), and the pulley rotation based on the raising the level of water in tank and the float. see illustrated diagram in. Fig. (14)

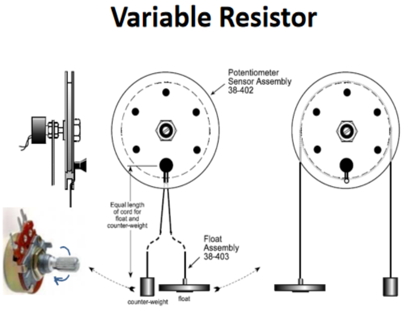


Fig.14: Potentiometer sensor assembly

Signaling between the transmitter and a number of instruments sited in the control room often requires a current-to-voltage conversion, that takes place in the instruments by passing the current through their resistors (resistor connected in series). Due to that the transmitter using the comparator.

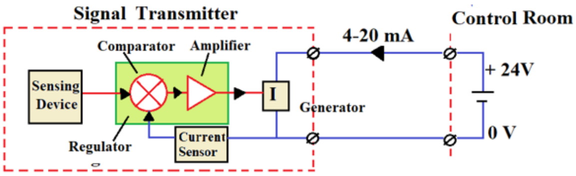


Fig.15: Signal Transmitter

From an electrical point of view, a transmitter can be regarded as a current generator, which in our case is powered by the Process Interface (PI), placed in a remote control room. This means that it is the transmitter that determines the current, independently of the line resistance. However, Ohm's law still applies:

$I_{max} = E/R$

Simply, the Float Level Transmitter providing information about the Level in tank as feed-back signal to show the state of the process by using standard protocol that the controller can utilize .
This paper discussed a calibration of sensing device and transmitter and emphasis on the importance of applying calibration process before the implementation of any experiment.

An accurate feedback (coming from sensing device and transmitter) will be the key point of getting accurate results when apply different strategies to the control system,

2.5 Output devices (Servo-valve)

The output device which used to control the level or rate of flow is the servo-valve. Consisting of four main components:
1- The electrical motor.
2- Comparator with positioner (Variable Resistor)
3- Gear.
4- Rotating valve (convert the rotating movement to linear displacement movement).
Simple diagram for the servo valve shown in Fig.(16).

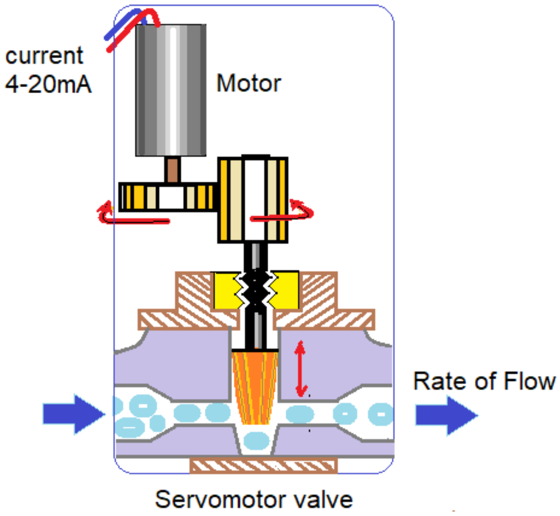


Fig. 16 : Mechanism of servo valve

due to the existence of moving mechanical parts in the servo-valve (like gear and the position-er or variable resistor), it has to be checked before any practical experiment by injecting current (mA) and checking the expected response of opening (percentage).
The relation between the input current and the output % of position of the valve or rate of flow is illustrated in the following graph . see Fig.(17)

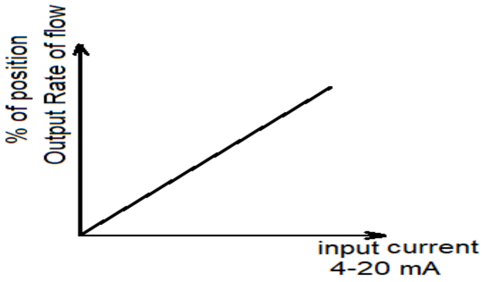


Fig. 17: relation between input and output for servo valve

Its important to understand that the motor of the servo valve needed time to response when receiving a large amplitude control signal, for example a signal of 20mA (open 100%) received after 4mA (close 0%) . This response appeared with an overshoot. see Fig.(18)

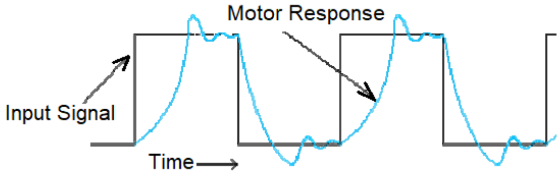


Fig. 18: Time response for large amplitude graph for the motorized control valve.

Moreover, it is observable that overshoot is appeared in in case of no derivative action is applied, but if derivative action is applied the overshoot reduced to minimum, and the remaining small overshoot cleared by adding breaking effect. See the illustration graph Fig.(19)

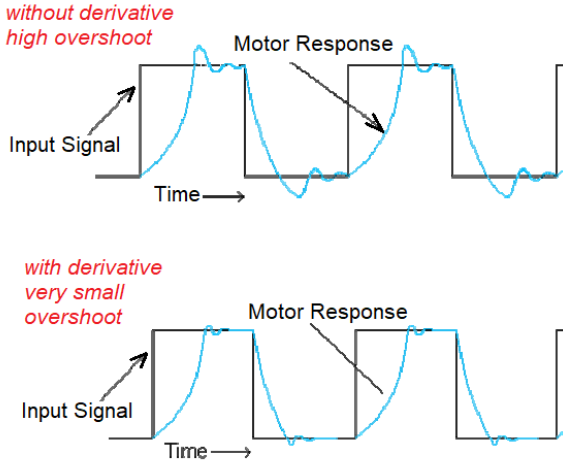


Fig.19: Effect of derivative action on overshoot response on motorized control valve.

2.6 Controller

The controller is the vital part of the control system, which has terminals for the input and output devices. It is responsible to control the processes based on the selected control strategies (ON-OFF control, P, PI, PID).

ABB controller is an accurate and dose not need calibration, only configure the parameters and run the system.

III. The Methodology

Introduction

After making the proper connection and certify the accuracy of the components and devices. We move to the monitor the response under different circumstances of applying disturbances and changing the PID parameters settings (PB,Tr,Td).

The implementation of the PID control on fluid level in process tank, produce a response with a regulated output without disturbance. It is easy to set or change the value of variables for Proportional Band (controlling the gain of the proportional action on the servo-valve), Integral Action Time Tr (Reset Time) and Derivative Action Time Td (Derivative Time). the following diagram show the effect of disturbances on the process output. Fig.(20)

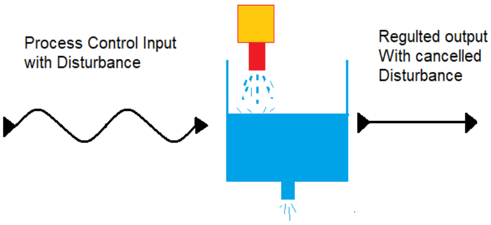


Fig. 20: Importance of process control

“The control effort of the derivative component enables a controller to identify a rapidly changing in error and take extra action to reveal it and the response of the plant will be improved accordingly. There is now an element of the control action that is proportional to the rate of change of error. Practically we chose a proper value for (Td) Derivative Action Time.

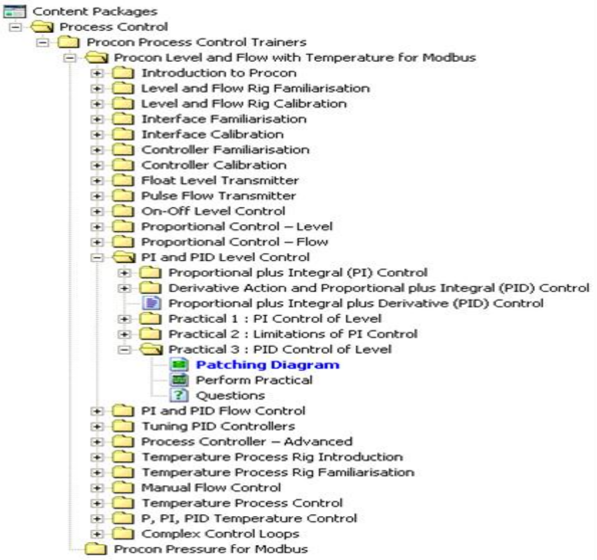
A large increase of the inflow to the tank will result in overflow. By applying large control effort, the time to reverse the direction of the system will be reduced. And producing an overcompensation to control increasing of extra error.

Furthermore, as the measured value (process value) approaches the set point, the rate change of error will decrease as proportional action reduced, this will result a negative contribution in derivative action causing in reducing the control effort and reduce the chance of appearing overshoot.”[2]

“So by other words we can say that The derivative action will prevent a system from failure by producing an very large control effort and slow down its approach to the set point with the aim of avoiding overshoot.”[2]

The procedure of execution the experiment

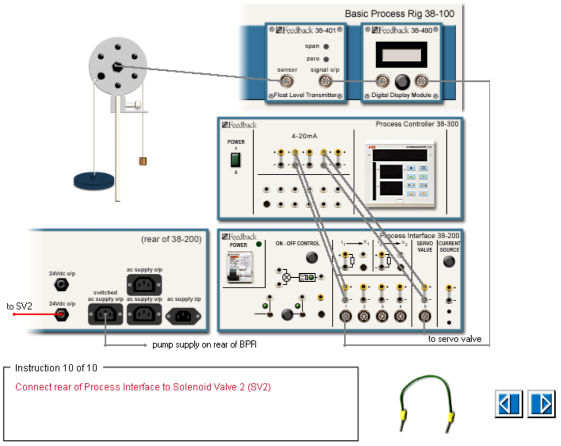
The procedure of implementing this practical experiment begins with running the software related to control types required, see Fig.(21)



- Content Packages
  - Process Control
    - Procon Process Control Trainers
      - Procon Level and Flow with Temperature for Modbus
        - Introduction to Procon
        - Level and Flow Rig Familiarisation
        - Level and Flow Rig Calibration
        - Interface Familiarisation
        - Interface Calibration
        - Controller Familiarisation
        - Controller Calibration
        - Float Level Transmitter
        - Pulse Flow Transmitter
        - On-Off Level Control
        - Proportional Control – Level
        - Proportional Control – Flow
        - PI and PID Level Control
          - Proportional plus Integral (PI) Control
          - Derivative Action and Proportional plus Integral (PID) Control
          - Proportional plus Integral plus Derivative (PID) Control
          - Practical 1 : PI Control of Level
          - Practical 2 : Limitations of PI Control
          - Practical 3 : PID Control of Level
            - **Patching Diagram**
            - Perform Practical
            - Questions
        - PI and PID Flow Control
        - Tuning PID Controllers
        - Process Controller – Advanced
        - Temperature Process Rig Introduction
        - Temperature Process Rig Familiarisation
        - Manual Flow Control
        - Temperature Process Control
        - P, PI, PID Temperature Control
        - Complex Control Loops
      - Procon Pressure for Modbus

Fig.21: content packages of process control folders

By clicking the patching Diagram 0f PID control for Level Process and follow the given steps we can make our connections ready. As shown in patching diagram Fig.(22). __________



Instruction 10 of 10

Connect rear of Process Interface to Solenoid Valve 2 (SV2)

Fig. 22 :Patching Diagram

The control system consists of two directions (Measuring/controlling). First direction, is measuring direction which start by the Level Sensor (floating device with potentiometer fixed in pulley) connected to Level Transmitter, Digital Display (which consist of 2 modes, %percentage/ current in mA), Process Interface and finally the ABB Process Controller. By this sequence the measuring current loop will be closed.

Second direction, is the control direction, the command signal released from The Process Controller to the Process interface to the servo-valve (the control signal start from 4mA to 20 mA).

Make sure that MV2 (Manual Valve 2) is fully opened MV3 is closed Pump is switched on see Fig.(23) for detail connection diagram.

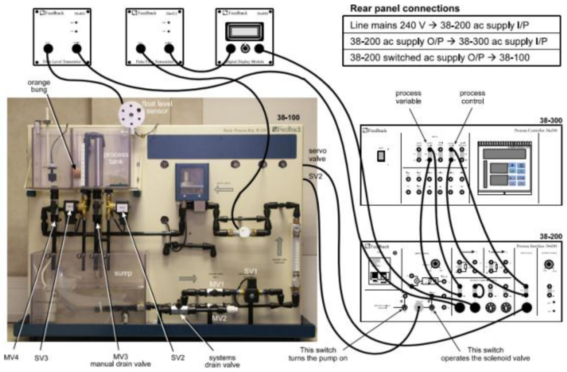


Fig. 23: detailed connections of control system

As shown in attached charts in appendix, chart No. 2 the red color line represent the set point and the yellow color line represent the measured value of the process.

Table No.1 in the appendix show the sequence of operation and scenarios of execution the experiment to fulfil the aim of this paper.

Charts in chart No.2 show the evidence of the recorded data with some explanation of the action done and the resulted response in the Level Process control.

IV. Discussions

4.1 Experiments and Technical works

This paper concentrate on the system response of a level control process, and discover the problems might affect the expectations. Which conflict with the theoretical concepts, besides finding solutions for the problems appear during the implementation.

Before starting the experiment, you should have an idea about the behaviors of each correction component of PID by changing its values.

"The behavior of Proportional Band (PB) which in inversely related to the gain, and determine the control effort, offset, oscillation and steady state."[2]

Here the offset is reduced by high a gain. But more increase in gain will increase overshoot and the system will be unstable.

The smaller value of PB the large value of gain, the larger control effort will exerted to the system , the faster response. The produced results from the experiment was recorded during the execution and confirmed, refer to the table no.1.

The Integral Action is control term which delete and integral the error, it will present until error is zero, removing offset. The Coefficient used for integral, Tr (is the reset time) to control the length of the integral time and the contribution of integral action. refer to the table no.1 scenario no.s 1 to 4.

If the value of Tr reduce and become very small the system will start oscillation.

The integral action must be large if PB is also large because a large integral action means small Tr. PB large mean small gain, small proportional control effort, so large OFFSET. So small Tr for large integral action will decrease or delete the OFFSET.

The Deviation Action is a contribution to the rate of change of deviation the control effort of Deviation control effort will increase when deviation increased.

We can say that the PB is direct proportional with error. And Integral Time Action Tr is controlling the OFFSET and Derivative T_d is controlling the deviation of rate of change in the OFFSET.

A larger change in deviation (between process value and the set point) will produce a much greater derivative control effort than before, because of the derivative action. And a Large control effort encourage oscillation. refer to the table no.1 item 5 to 12.

from the results found in table no.1, Proportional action will be increased by increasing gain and Proportional Band PB decreased. Integral action will delete the error at certain value of Tr, but if we move to more smaller value of Tr will create oscillation. Derivative action decreases as Td decrease. And derivative is dealing with rate of change in the deviation related to the difference between process value and set point.

During the implementation, some problems raise up and need fast solutions. Such as bad connectors (need replacements), alignment of mechanical parts of the sensor (reel with potentiometer)and servomotor (gear with position-er) to meet the actual physical requirement of these parts, This was discussed in calibration part. moreover the Electrical problems coming from the current source and process transmitters which also has to calibrated before any thing.

One more very important factor has to be considered in training is the time of execution during the class session

The study was interested to evaluate the response of the PID process control system under different scenarios, and provide the trainees and trainers with valuable information of working in the instrumentation field, motivating them to take more attentions during execution of practical experiments. And to figure out other problems in future researches.

4.1 Experiment Results

A table was created to write the setting values of PB,Tr and Td in the first columns. Then the output process values were recorded in next columns followed by the observations and remarks.see table no.1 .

The results of control system responses were filled in table no.1 attached in appendix. The work was demonstrated as scenarios consist of many actions each actions has remark shows the experiment changes. These scenarios were based on applying different PID coefficient values to capture the changes in response. These collected results in table no.1were compared with theories of PID characteristic in table no.2 .

Referring to the data gathered in table No.1, we found that this experiment need time to observe the changes in the response of the control system output. Finally the recorded data will not gives any meaning if you didn't compare it with the expected results in table no.2 and expected response in fig. no.9 .

V. Results of Discussion

Base on the results and the steps of execution which discussed, the importance of taking care in execution any process control system guide us to summaries the key points of handling it and avoiding malfunctions :

1-Making sure that input/output devices is calibrated in proper way to meet the specification.
2-All terminals connected properly with connectors having the same numbers of pins.
3- comparing the results with theoretical values and take your decision to continue your progress in take more results
4-Apply different disturbances to confirm the stability of the control system.
5- find proper solution for the problems.
6-"Trained employee results in less wastages and increase productivity so it is beneficial to employer. On the other hand it's beneficial to employee because it improves the skill, knowledge and ability of employees. The result is help to achieve the goals of organization."[6]

VI. Conclusion

This paper shows that, practical experiments are necessary for understanding the ideas and theories which was given in lectures, recognizing that there is no experiment free from troubles and needs to rectify and tune . The need of applying the pre defined steps for the first time is important for practicing by using the computer application. The researches should be able to explain the behavior of the system under different circumstances and conditions.

Encourage the instrumentation technical staff to not give up from finding the proper solution to obtain the accurate results, and forward there researches to publishers for sharing there thoughts and experience.

References

Books and reference manuals

[1.] Modern Control Technology. Components and systems, Dimlar 2nd edition
[2.] PROCON Level, Flow & Temperature Process Control Trainers Reference Manual 38-001-3, Feedback Instrument Limited, http:www.fbk.com
[3.] PROCON Process Control Trainers Level, Flow & Temperature 38-901-M, Feedback Instrument Limited, http:www.fbk.com
[4.] Feedback equipment, Instrumentation Laboratory, Paaet, Higher Institute of Energy.

Internet

[5.] National Instrument (Internet) https://www.ni.com/en/shop/labview/pid-theory-explained.html?srsltid=AfmBOoonBHApRGw2tlylL3eeI3bHfeLSCQHwzrMULHpeSsiNOpjtZRWZ

Researches

[6.] SUPRAJA A, D/O A SAMBAIAH. International Journal of Engineering Research and Applications www.ijera.com ISSN: 2248-9622, Vol. 14, Issue 8, August, 2024, pp: 38-41

Appendix

Table no.1 " PID Response of control system with different scenarios "

Charts 1: “Feedback standalone application for steps of running Level control system responses for the PID correction mode”

Charts 2: “sequence of time response charts with different actions of setting for the parameters”

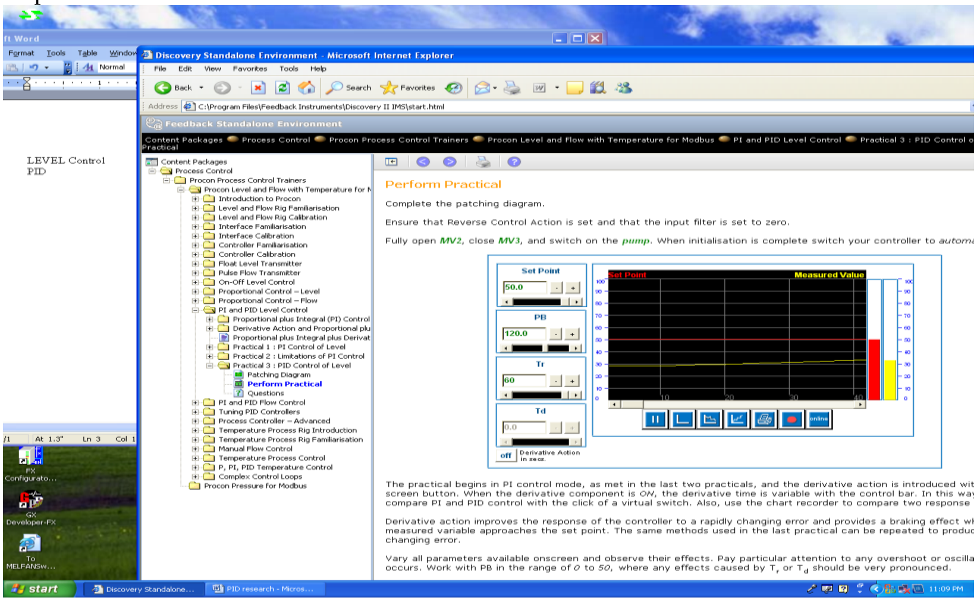
Table 1: PID Response of control system with different scenarios

	Responses to different scenarios (Actions) Level Process was set to 50% of the Tank (12mA)								
No.	**Scenario (Action)**	**PB**	**Tr**	**Td**	**Measured (Max. value)**	**Measured (Min. value)**	**Stability**	**Control effort**	**Monitoring period In chart**
1	Using small gain and large resetting time	120	60	0	53.8%	48.7%	Fluctuate	slow Response for servo valve -small control effort	From 140s to 540s
2	Change PB 120 to 10 Large gain	10	60	0	50%	49.9%	Stable Error almost 0	Fast Response for servo valve -big control effort	From 570s-720s
3	Apply disturbance by opening drain valve	10	60	0	50% **system recovered** at 845s	40% direct *after drain at* 823s	**Stable** Error=0	Fast Response for servo valve	823s-845s
4	Change Tr from 60 to 2	10	2	0	52%	48%	Start oscillating & Overshoot	Fast Response for servo valve	950 s -1230 s
5	add Derivative Action T_d=16	10	2	16	53%	49.8%	oscillating & Overshoot	Fast Response for servo valve	1440 s-1460 s
6	Change T_d from 16 to 64	10	2	64	57.6%	53.1%	oscillating & Overshoot	Fast Response for servo valve	1620s-1650s
7	Change T_d from 64 to 96	10	2	96	57.7%	53.1%	oscillating & Overshoot	Fast Response for servo valve	1660s-1870s
8	Change T_d from 96 to 1	10	2	1	51.2%	48.7%	Small oscillating & Overshoot	Fast Response for servo valve	1880s-2000s
9	Change T_r only from 2 to T_r=10	10	10	1	50.3%	49.7%	Very Small oscillating & Overshoot	Fast Response for servo valve	2060s-2140s
10	Change Pb=1	1	10	1	50.4%	49.7%	Very Small oscillating & Overshoot	Fast Response for servo valve	2270s-2290s
11	Change Pb=30	30	10	1	50.3%	49.7%	Very Small oscillating stable	Fast Response for servo valve	2510s-2660s
12	After changing PB ,T_r ,T_d	30	30	10	49.9%	49.9%	stable	Fast Response for servo valve	4540s -4570s
14	After changing T_d Open drain solenoid valve	30	30	5	49.9% After some time at 5130 S	49.9% After some time at 5130 S	The servo valve adjust its opening to substitute the drained water	Fast Response for servo valve	4980s-5130s
15	Last case	30	30	5	49.9%	49.9%	stable	Fast Response for servo valve	5130s -5140s

Table 2: P, I ,D and PID control system characteristic by increasing the value of Coefficient

Quality of transient response	(Error %)	Time of steady (Ts) state	(Overshoot)	Raise Time-T_r (10%-90%)	Type of control
Small change	Decrease	Small change	Increase	Decrease	Kp Proportional
worst	Delete	Increase	Increase	Decrease	Ki Integral
Best	Small change	Decrease	Decrease	Small change	K_D Diffrential
good	Delete	Decrease	Decrease	Decrease	PID

Charts 1: Standalone application used for running the steps of Level control system connections and chart's responses- PID correction mode



Perform Practical

Complete the patching diagram.

Ensure that Reverse Control Action is set and that the input filter is set to zero.

Fully open *MV2*, close *MV3*, and switch on the *pump*. When initialisation is complete switch your controller to *automa*

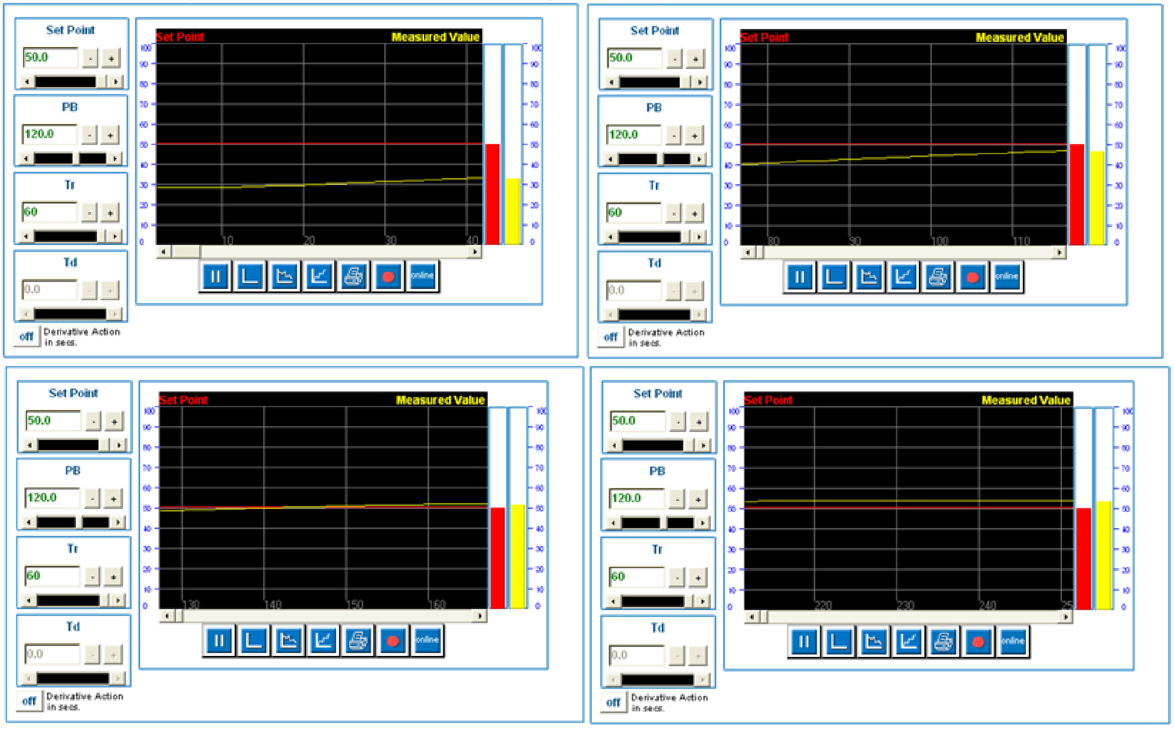
The practical begins in PI control mode, as met in the last two practicals, and the derivative action is introduced wit screen button. When the derivative component is *ON*, the derivative time is variable with the control bar. In this way compare PI and PID control with the click of a virtual switch. Also, use the chart recorder to compare two response

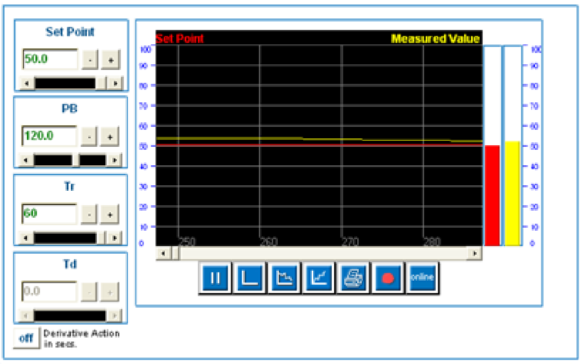
Derivative action improves the response of the controller to a rapidly changing error and provides a braking effect wh measured variable approaches the set point. The same methods used in the last practical can be repeated to produc changing error.

Vary all parameters available onscreen and observe their effects. Pay particular attention to any overshoot or oscilla occurs. Work with PB in the range of *0* to *50*, where any effects caused by T_r or T_d should be very pronounced.

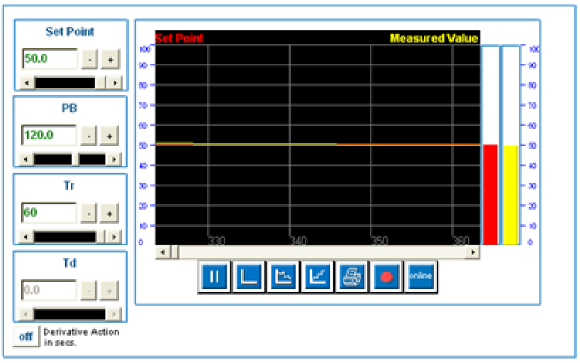
Charts 2: sequence of time response charts with different actions of setting for the parameters

Action No.1: setting PB=120, Tr=60, Td=0
Results: need long time to finish oscillation and to go to steady state period

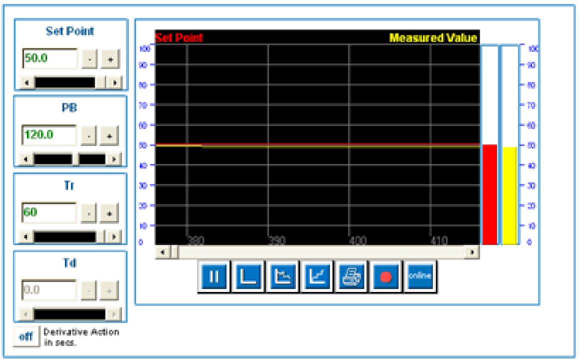




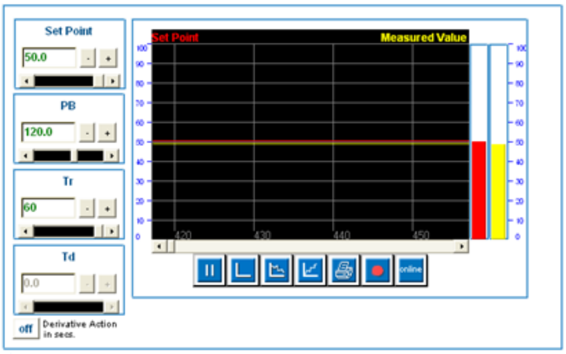
Set Point 50.0
PB 120.0
Tr 60
Td 0.0



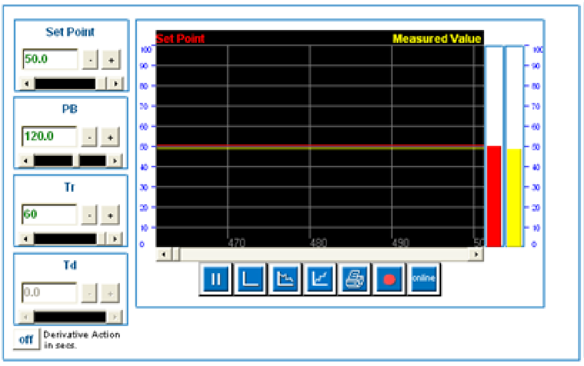
Set Point 50.0
PB 120.0
Tr 60
Td 0.0



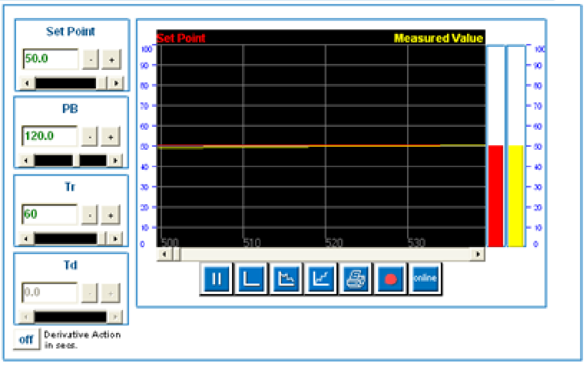
Set Point 50.0
PB 120.0
Tr 60
Td 0.0



Set Point 50.0
PB 120.0
Tr 60
Td 0.0

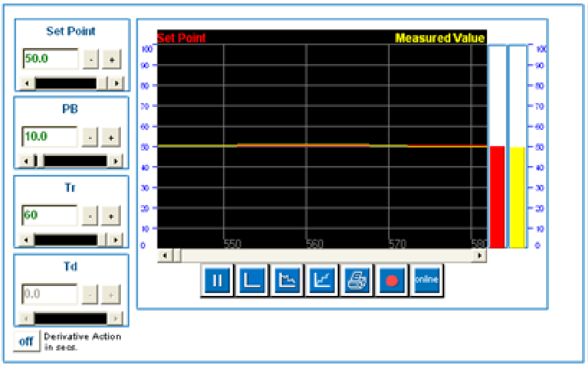


Set Point 50.0
PB 120.0
Tr 60
Td 0.0

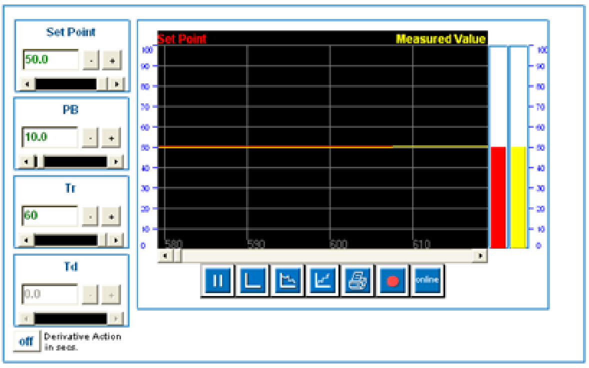


Set Point 50.0
PB 120.0
Tr 60
Td 0.0

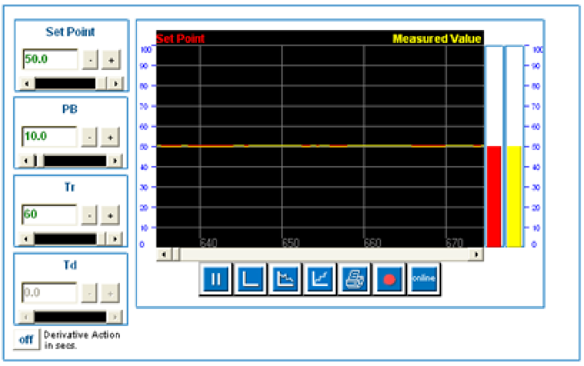
Action No.2: Changing PB=10, Tr=60, Td=0
Results: you will find more effort applied by servo-valve to clear the error fast (high response). Error become very small, PV=50% or 49.9% Error=0

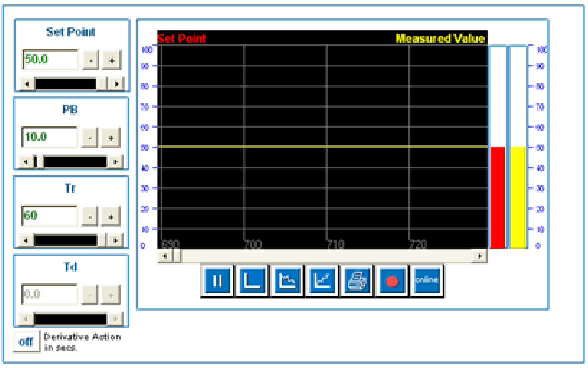


Set Point 50.0
PB 10.0
Tr 60
Td 0.0

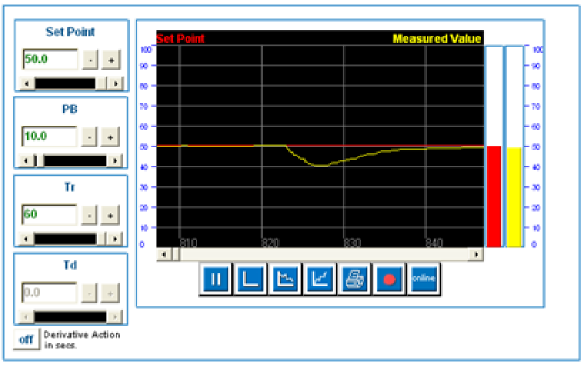


Set Point 50.0
PB 10.0
Tr 60
Td 0.0

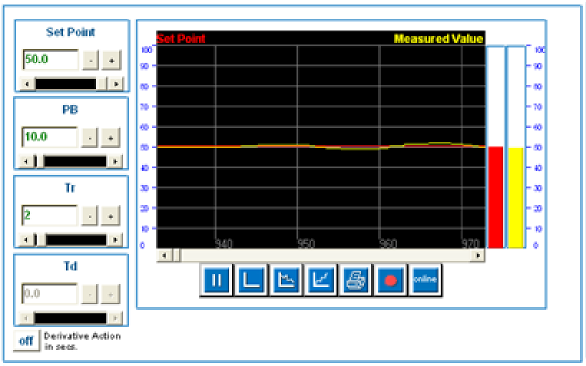

Set Point 50.0
PB 10.0
Tr 60
Td 0.0
off Derivative Action in secs.

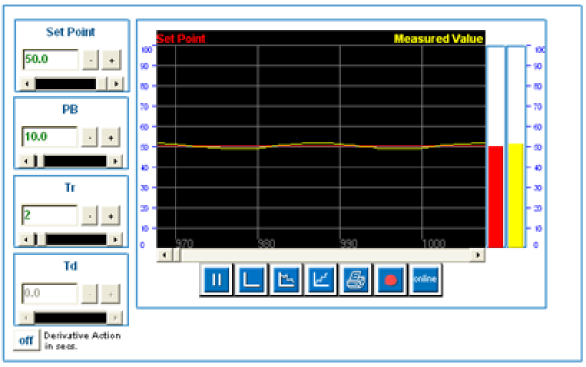

Set Point 50.0
PB 10.0
Tr 60
Td 0.0
off Derivative Action in secs.

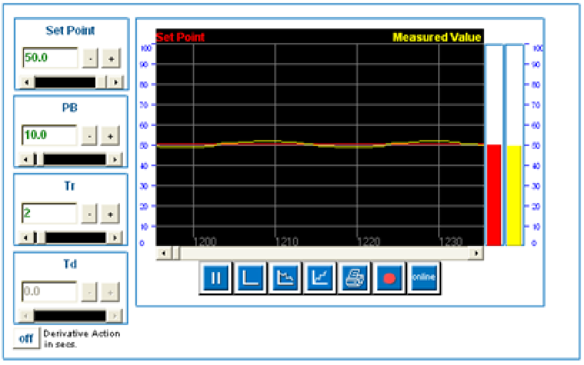
Action No.3: Apply external disturbance by open drain Valve at PB=10, Tr=60, Td=0
Results: the PV went down for a wile till the servo-valve substitute the quantity loss by drain and back to normal with error=0


Set Point 50.0
PB 10.0
Tr 60
Td 0.0
off Derivative Action in secs.

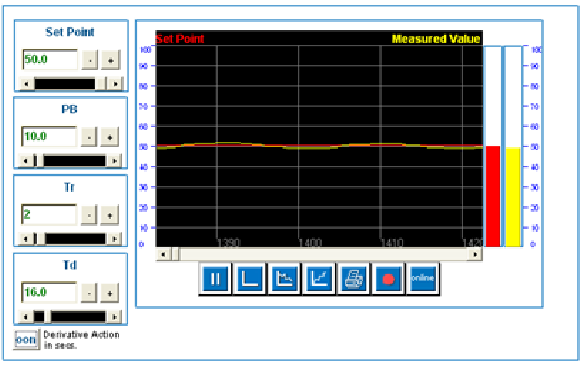
Action No.4: Changing PB=60, Tr=2, Td=0
Results: Start overshoot


Set Point 50.0
PB 10.0
Tr 2
Td 0.0
off Derivative Action in secs.

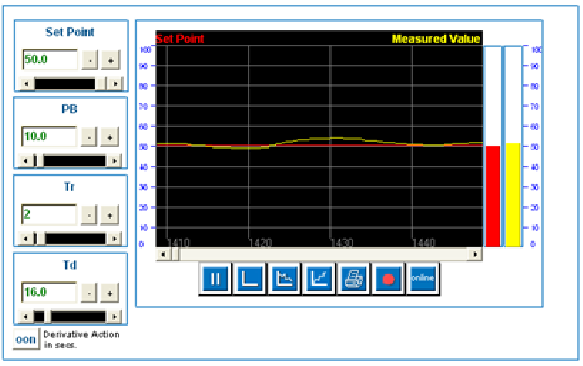

Set Point 50.0
PB 10.0
Tr 2
Td 0.0
off Derivative Action in secs.


Set Point 50.0
PB 10.0
Tr 2
Td 0.0
off Derivative Action in secs.

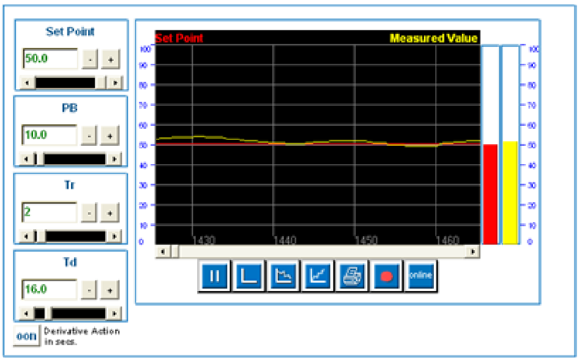
Action No.4: add Derivative Action, Changing PB=10, Tr=2, Td=16
Results:Range from 53% - 49.8%



Set Point 50.0
PB 10.0
Tr 2
Td 16.0

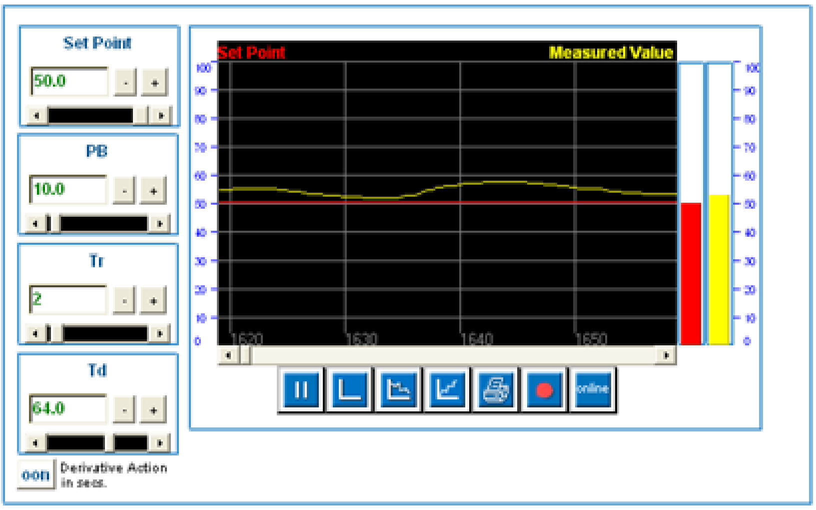


Set Point 50.0
PB 10.0
Tr 2
Td 16.0



Set Point 50.0
PB 10.0
Tr 2
Td 16.0

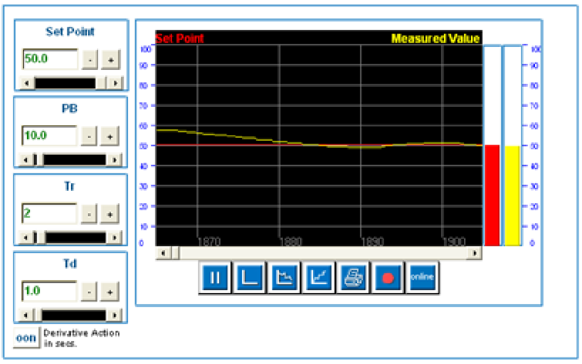
Action No.5: Changing PB=10, Tr=2, <u>Td=64</u>
Results:Range from 57.6% - 53.1%



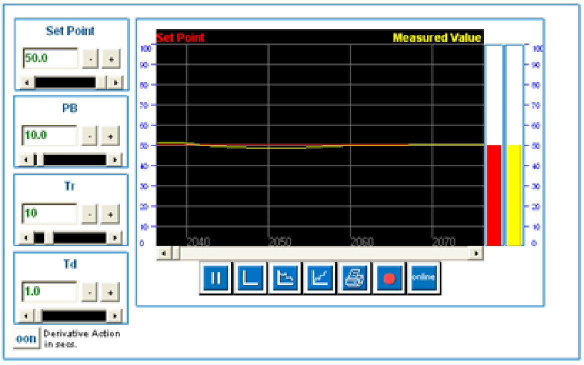
Set Point 50.0
PB 10.0
Tr 2
Td 64.0

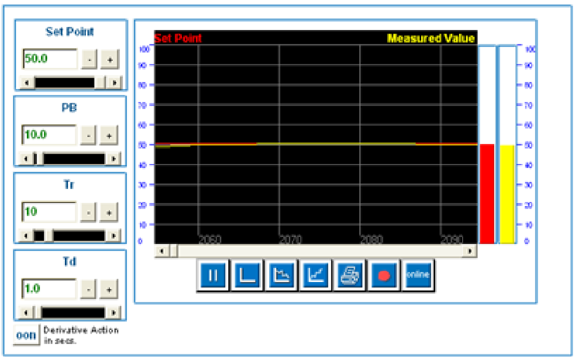
Action No.6: Changing PB=10, Tr=2, <u>Td=96</u>
Results:Range from 57.3% - 53.6% small change

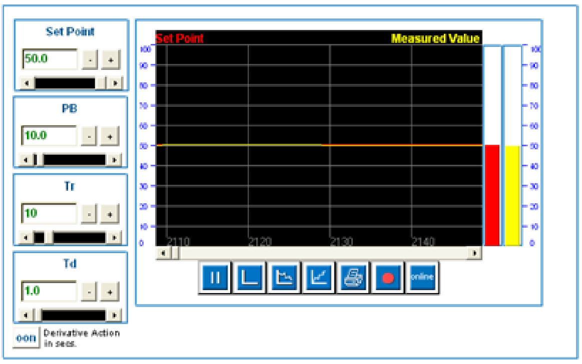
Action No.7: Changing PB=10, Tr=2, <u>Td=1</u>
Results:Range from 51.2% - 48.7% reduce the overshoot


Set Point 50.0
PB 10.0
Tr 2
Td 1.0

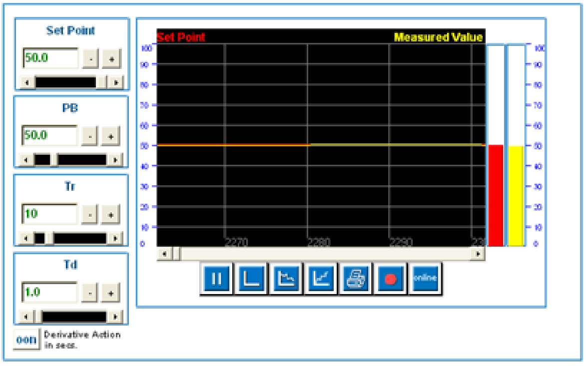
Action No.8: Changing PB=10, Tr=10, Td=1
Results:Range from 50.3% - 49.7%


Set Point 50.0
PB 10.0
Tr 10
Td 1.0


Set Point 50.0
PB 10.0
Tr 10
Td 1.0

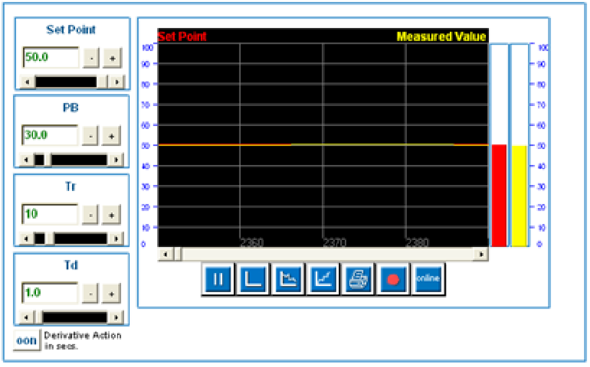

Set Point 50.0
PB 10.0
Tr 10
Td 1.0

Action No.9: Changing PB=1, Tr=10, Td=1
Results:Range from 50.4% - 49.7% worst than before

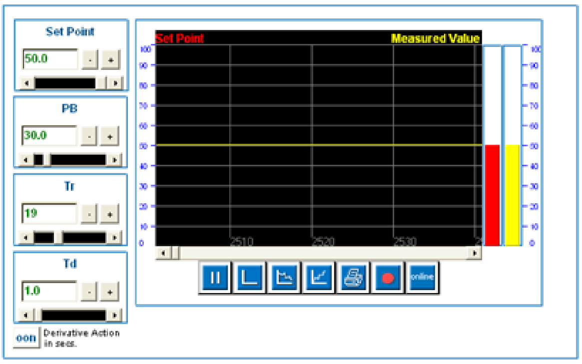

Set Point 50.0
PB 50.0
Tr 10
Td 1.0

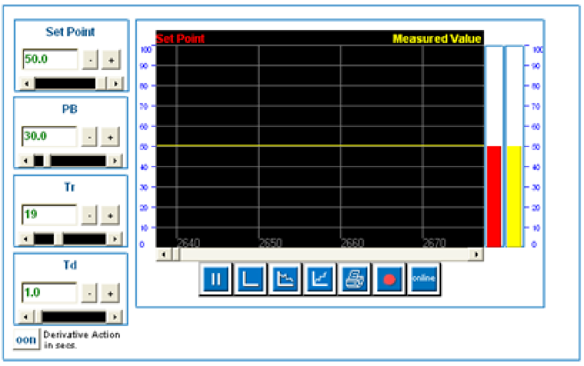
Action No.10: Changing Pb=30, Tr=10, Td=1

Results: the output level or Process Value =between 50.4% & 49.7% Very Small error

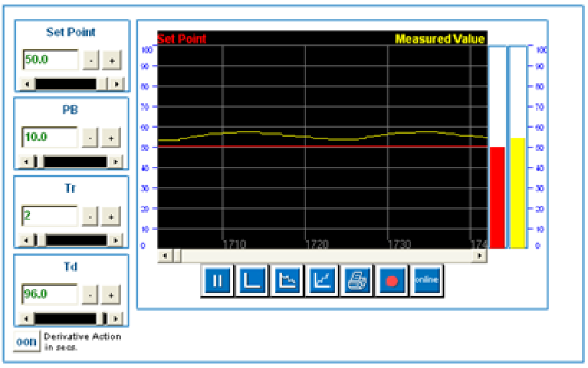

Set Point 50.0
PB 30.0
Tr 10
Td 1.0

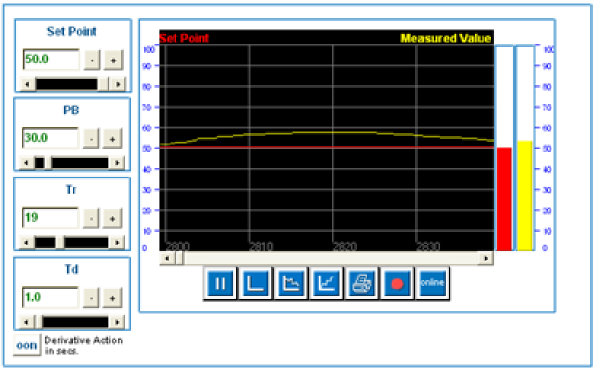
Action No.11: Changing pb=30, Tr=19, Td=1
Results: Process Value =between 50.3% & 49.7% System more Stable


Set Point 50.0
PB 30.0
Tr 19
Td 1.0

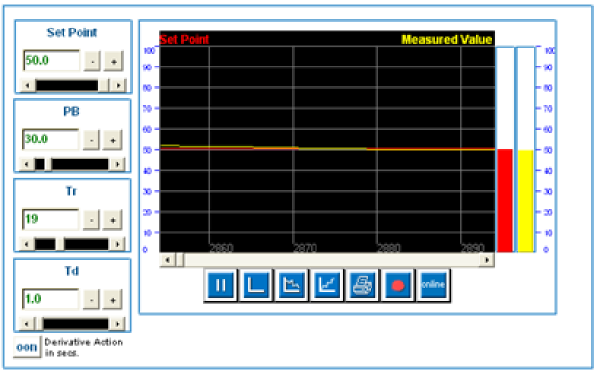

Set Point 50.0
PB 30.0
Tr 19
Td 1.0

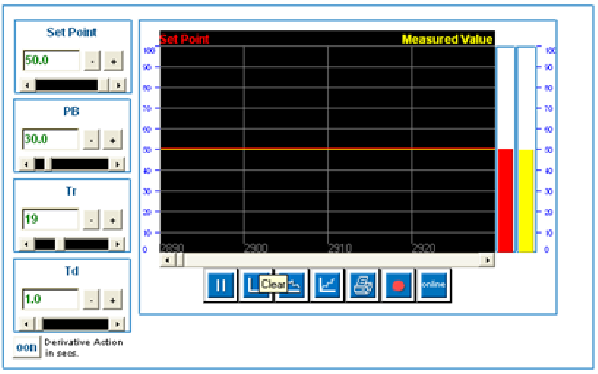
Action No.12: Changing the parameters to PB=10 high gain, Tr=2 small, Td=96 big.
Results: Servo-valve output changed from 20 % to 100% then start closing


Set Point 50.0
PB 10.0
Tr 2
Td 96.0

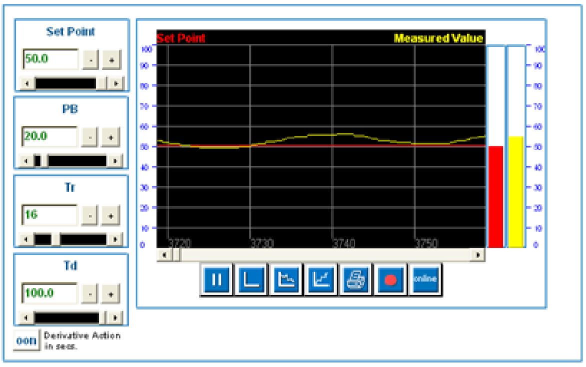

Set Point 50.0
PB 30.0
Tr 19
Td 1.0

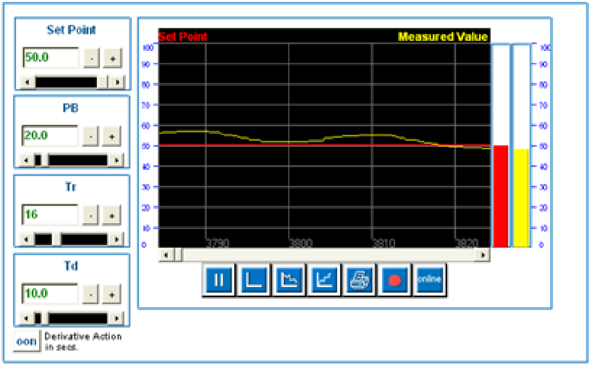
Action No.13: After setting back (PB=30, Tr=19, Td=1)
Results: the system return back to its stability

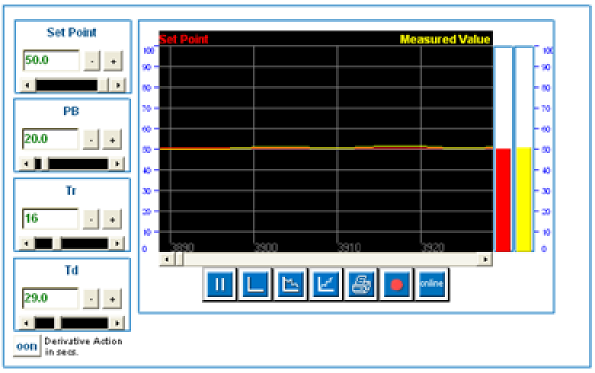

Set Point 50.0
PB 30.0
Tr 19
Td 1.0

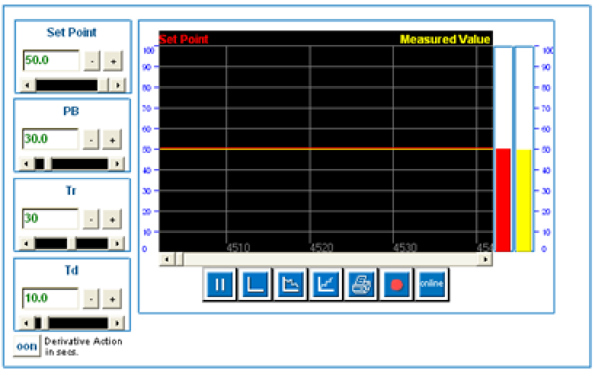

Set Point 50.0
PB 30.0
Tr 19
Td 1.0

Action No.14: open the drain outlet valve to certain value
Results: the servo-valve output changed from 40% to 96% to substitute the loss of water to main the process value equal to set point 50%
after finish the transient period the system move to steady state as shown in the following charts


Set Point 50.0
PB 20.0
Tr 16
Td 100.0


Set Point 50.0
PB 20.0
Tr 16
Td 10.0


Set Point 50.0
PB 20.0
Tr 16
Td 29.0


Set Point 50.0
PB 30.0
Tr 30
Td 10.0