PROCESS DYNAMICS &CONTROL

QUESTION BANK UNIT – I

PROCESS DYNAMICSAND CONTROL

(PART A)

1 Distinguish between batch process and continuous process.

A)

Batch process	Continuous process
1. A process in which the materials or work are stationary at one physical location while being treated. Eg. Thermal type process.	A process in which the materials or work flows more or less continuously through a plant apparatus while being treated. Eg. Storage vessel control.
2. This is suitable for different kinds for Product	Suitable for one or two products
3. The quantity of product is less	Quantity of product is large
4. The control system is simple.	The control system is complicated.
5. The Process variables are lumped	The pv is distributed over the entire system.

2. Define degrees of freedom?

The Degree of freedom is defined as the number of independent variable that must be specified in order to define the process completely. The number of degree of freedom can be found by the equation

f = V – E Where

V = Number of independent variable describing a process

E - Number of independent equation physically relating the V variables.

3. What are the different mathematical models used in process control?

Experimental approach: In this case the physical equipment of the chemical process is available and the various values of input (disturbance, manipulated variable) are change and through appropriate measuring devices the outputs of process change with time. Such a procedure is time and effort consuming and it is usually quite costly because a large number of such experiments have to be performed.

Theoretical approach:

This is given in terms of mathematical equations (differential, algebraic) whose solution yields the dynamic or static behavior of the chemical process that is examined.

4.What is meant by self-regulation?

Self regulation of a process is defined as the process is one in which either inflow and outflow is dependent to the controlled variable. Most of the causes the flow is self regulating because of its steady state is increased by increasing the outflow.

5.What is non-self regulation? Give an example.

A non-self regulating process is one in which both inflow and outflows are independent of the controlled variable this type of process has no steady state gain. The example of the non self process is a simple liquid level system with constant outflow.

6.Distinguish between servo and regulator operation of control system.

Servo problem	Regulator problem
1.The set point is variable and load disturbance are kept constant This method is desired by operator.	1.The load disturbance is variable and set point is kept constant this may happen any time in the system
Tracking of missiles and automatic machining are examples of this type.	Controlling of temperature and flow rate are examples of this type.

7. Write any two characteristics of first order process

- Capacity to store material, energy or momentum.
- The resistance associated with the flow of mass, energy or momentum in reaching the capacity

8. List any four objectives of process control.

i.) Safety
ii.) Product specification.
iii.) Environmental regulations.
iv.) Operational constraints
v.) Economics.

9. Define interacting system and give an example.

The term interacting is often referred as loading. When two tanks are connected at same datum level if level of any one tank increases simultaneously another tank head also increase.

Example: Two tank systems connected in series

10. A tank operating at 10 ft head, 5 lpm outflow through a valve and has a cross section area of 10 sq. ft. calculate the time constant.

Given h = 10 ft. Q = 5 lpm, A = 10 ft^2. Time constant T = AR but R = h / q = 10 / 5 = 2

T = 10 x 2 = 20 min.

11.Define non interacting system and give an example

The dynamic behavior one tank is affected by the other, but the reverse isn't true, then it is non-interacting system. Here the liquid heads are independent of each other Example: Two tanks one below the other.

12.What is the need for mathematical model?

To optimize process design and operating condition

To design a control strategy

To understand the behavior of a process, mathematical representation of physical and chemical phenomenon taking place in it is essential

13.What is a second order system? Write its general form of transfer function.

A second order system is one in which output is described by a second order differential Equation

$$a_2 \, d^2y/dt^2 + a_1 \frac{dy}{dt} + a_0 y = b\, f(t)$$

$b, a_0, a_1, a_2 \rightarrow$ constant.

14.What is the need for process automation?

Process automation is employed to maintain a controlled variable at a desired value. The main advantage of automatic control is that a machine can perform the task more rapidly and consistently than a human being. It requires closed loop of action and reaction without human intervention.

15.A Self regulatory system doesn't require a controller. True/False. Justify the answer.

True. It doesn't need any external intervention for its stabilization

16.What is the significance of "degree of freedom"?

The desired control of a process will be achieved when and only when all the degree of freedom has been specified. A good understanding of degree of freedom is inherent in a process and they are very good for the design of effective controllers

17.What is the need for servo operation?

To make the process follow changes in the set point as closely as possible, servo operation is necessary. Example: normally in batch process changes in load variables such as temperature and pressure causes large errors than the set point change, in that case servo operation is necessary.

18.How the mathematical modeling of higher order process obtained?
The mathematical modeling of higher order process are obtained in three ways:

a. N first order processes in series
b. Processes with dead time
c. Processes with inverse response.

19. *Define process variable, load variable and manipulated variable.*

Process variable: It is the quantity or condition of the control system which is directly measured and controlled.

Load variable: the load variables of a process are all other independent variables except the control variable and manipulated variable.

Manipulated variable: it is the quantity or condition which is varied by the automatic controller so as to affect the value of control variable.

20 Name different sets of test inputs that can be given to a process.

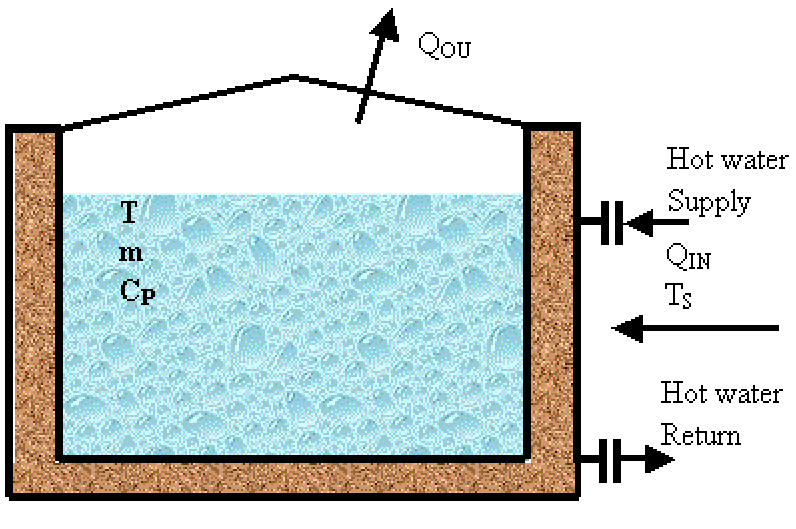
Step, Ramp, Impulse, Parabolic, Sinusoidal input

PART-B

1. Describe a simple thermal system in which incoming liquid is heated by the heater in the tank and going out with higher temperature. Develop first order transfer function of the thermal process(NOV/DEC 2012) .

Modeling a Process - A Tank Heating System

Think about the tank below. It could be the hot water cylinder in your home which is a hot water tank heated by a heating coil that is connected to the central heating system (it can also be heated electrically like a kettle by an electric heater immersed in the water in the tank).



Hot water is used to heat the contents of a reactor. It is supplied to the jacket at a temperature of Ts. Heat is transferred at a rate of Qin (J/sec = Watts) from the jacket to the reactor contents. This input causes a change in the reactor temperature, T. The liquid in the reactor has a mass, m (kg), and a specific heat capacity of Cp (kJ/kgK). Heat is removed from the reactor at a rate of Qout (W).

The input to the system is the temperature of the hot water, T_S. This variable determines how much heat is added to the system, i.e. Q_{in}.

The output from the system is the temperature of the reactor, T. This variable determines how much heat is removed from the system in Q_{out}.

Any difference between the heat added and removed will result in an accumulation of energy (either positive or negative). A mass/energy balance on the system gives:

$$In - Out = Accumulation$$
$$Q_{in} - Q_{out} = Rate\ of\ Change\ in\ Internal\ Energy$$
$$Q_{in} - Q_{out} = \frac{Change\ in\ Internal\ Energy}{\Delta t}$$

Internal energy is a function of the mass of liquid, its specific heat capacity and its temperature and is equal to mC_pT. m and C_p are constants. The ***change*** in internal energy is equal to mC_p x the ***change*** in temperature.

$$Q_{in} - Q_{out} = \frac{mC_p \Delta T}{\Delta t}$$
$$\Delta t \rightarrow 0$$
$$\Rightarrow Q_{in} - Q_{out} = mC_p \frac{dT}{dt}$$

If the top of the reactor is sealed and insulated the heat loss becomes minimal, i.e. Qout = 0.

The heat added to the system, Qin, is a function of the overall heat transfer coefficient, U (W/m^{2}K), the area available for heat transfer, A (m^2), the driving force for heat transfer which is the difference between the jacket temperature and the reactor temperature. Qin is given by:

$$Q_{in} = UA(T_S - T)$$

Rearranging the above equation, we get:

$$UA(T_S - T) - 0 = mC_p \frac{dT}{dt}$$
$$T_S - T = \frac{mC_p}{UA}\frac{dT}{dt}$$
$$\frac{mC_p}{UA}\frac{dT}{dt} + T = T_S$$

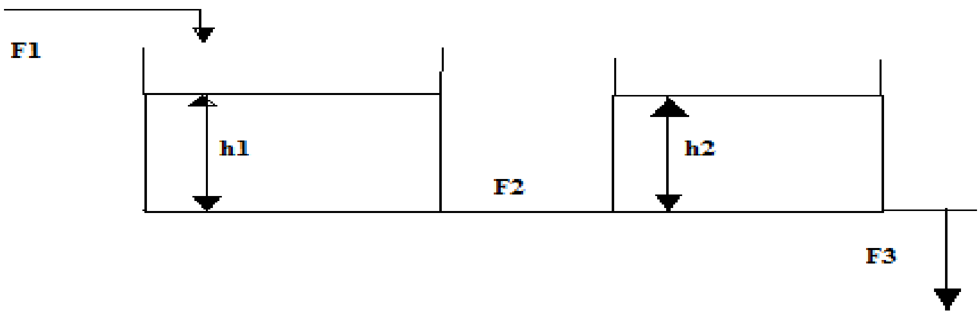
This is a first order differential equation which means that this is a first order system. The time constant is equal to mC_p/UA and the steady state gain is 1, i.e. the reactor temperature will eventually reach the temperature of hot water in the heating coil if left for long enough.

So the transfer function of the process can easily be obtained as

$$\frac{h(s)}{q(s)} = \frac{R}{\tau s + 1}$$

The steady state temperature is a combination of the hot water temperature and the outside temperature. The contribution of the hot water temperature is reduced. The higher the outside temperature the higher the tank temperature will be.

2. Consider the system shown in fig. Develop a mathematical model for the system. Assume that the effluent stream from a tank is proportional to the hydrostatic liquid pressure that causes the flow of liquid. Cross-sectional area of tank 1 is A_1 (ft^2) and of tank 2 is A_2 (ft^2). The flow rates F_1, F_2, $F_3$are in ft^2/min. take necessary assumptions. (MAY/JUNE 2012)



3. (a) Derive a mathematical model of a first order thermal process.
(b)What is the inverse response? Explain the inverse response noticed in the level control of feed water in the boiler.(MAY/JUNE 2012).

(a) **Heat Flow Rate:**

Thermal systems are those that involve the transfer of heat from one substance to another.

Mathematical model of thermal system:

The **model of thermal systems** are obtained by using thermal resistance and capacitance which are the basic elements of the **thermal system**.The thermal resistance and capacitance are distributed in nature.But for simplicity in analysis lumped parameter models are used.

In lumped parameter model it is assumed that the substances that are characterized by resistance to heat flow have negligible heat capacitance and the substances that are characterized by heat capacitance have negligible resistance to heat flow.The thermal resistance, R for heat transfer between two substances is defined as the ratio of change in temperature and change in heat flow rate.

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$$\text{Thermal resistance, } R = \frac{\text{Change in Temperature}, {}^\circ C}{\text{Change in heat flow rate, Kcal / sec}}$$

For conduction or convection,

Heat flow rate, $q = K\,\Delta\theta$

On differentiating we get,

$$dq = K\ d(\Delta\theta)$$

$$d(\Delta\theta)/dq = 1/K$$

But thermal resistance, $R = d(\Delta\theta)/dq$

Thermal resistance, $R = 1/K$ for conduction

$$= 1/K = 1/HA = \text{for convection}$$

For radiation,
Heat flow rate, $q = Kr\theta^4$

On differentiating we get

$$dq = Kr\ 4\ \theta^3\ d\theta$$

$$d\theta/dq = 1/Kr4\ \theta^3$$

But thermal resistance, $R = d\theta/dq$

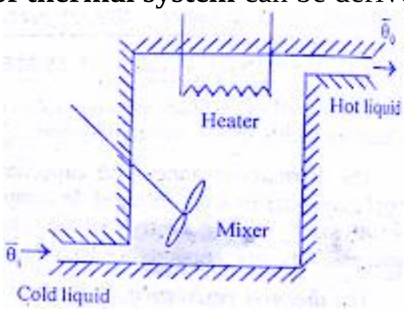
Thermal resistance, $R = 1/4Kr\ \theta^3$ (for radiation)

Thermal Capacitance, C is defined as the ratio of change in heat stored and change in temperature.

Let M = Mass of substance considered, Kg
c = Specific heat of substance, Kcal/Kg -°C
Now, Thermal capacitance, C = Mcp

Transfer function of Thermal system:

Consider a simple **thermal system** shown in the below figure.
Let us assume that the tank is insulated to eliminate heat loss to the surrounding air, there is no heat storage in the insulation and liquid in the tank is kept at uniform temperature by perfect mixing with the help of a stirrer.Thus, a single temperature is used to describe the temperature of the liquid in the tank and of the out flowing liquid.The **transfer function of thermal system** can be derived as shown below.



Let $\theta 1$ = Steady state temperature of inflowing liquid, °C
$\theta 0$ = Sandy state temperature of outflowing liquid, °C
G = Steady state liquid flow rate, Kg/sec
M = Mass of liquid in tank, Kg
c = Specific heat of liquid, Kcal/Kg °C
R = Thermal resistance, °C - sec/Kcal
C = Thermal capacitance, Kcal/°C
Q = Steady state heat input rate, Kcal/Sec

Let us assume that the temperature of inflowing liquid is kept constant. Let the heat input rate to the **thermal system** supplied by the heater is suddenly changed from Q to Q + q1.Due to this, the heat output flow rate will gradually change from Q to Q + q0.The temperature of the outflowing liquid will also be changed from θ0 to θ0 + θ.

For this system the equation for q0, C and R are obtained as follows,

$$\left.\begin{array}{l}\text{Change in output}\\ \text{heat flow rate,}\end{array}\right\} q_0 = \begin{array}{c}\text{Liquid flow}\\ \text{rate, G}\end{array} \times \begin{array}{c}\text{Specific heat of}\\ \text{liquid, c}\end{array} \times \begin{array}{c}\text{Change in}\\ \text{temperature, } \theta\end{array}$$

$$= Gc\theta$$

Thermal capacitance, C = Mass, M x Specific heat of liquid, c = Mc

$$\text{Thermal resistance, } R = \frac{\text{Change in temperature, } \theta}{\text{Change in heat flow rate, } q_0} = \frac{\theta}{q_0}$$

On substituting for qo from equation (1) in equation (3) we get,

$$R = \frac{\theta}{Gc\theta} = \frac{1}{Gc}$$

In this **thermal system**,rate of change of temperature is directly proportional to change in heat input rate.

$$\therefore \frac{d\theta}{dt} \ \alpha \ q_i - q_0$$

$$\therefore C\frac{d\theta}{dt} = q_i - q_0$$

The constant of proportionality is capacitance C of the system.

Equation (5) is the differential equation governing system.Since equation (5) is of first order equation, the system is first order system.

From equation (3) , R = θ/q0

q0 = θ/R

On substituting for q0 from equation (6) in equation (5) we get,

$$C\frac{d\theta}{dt} = q_i - \frac{\theta}{R} \quad \Rightarrow \quad C\frac{d\theta}{dt} = \frac{Rq_i - \theta}{R} \quad \Rightarrow \quad RC\frac{d\theta}{dt} = Rq_i - \theta$$

$$\therefore RC\frac{d\theta}{dt} + \theta = Rq_i$$

Let, L {θ} = θ(s); L{dθ/dt} = sθ(s) ; L{q1} = Q1(s)

On taking Laplace transform of equation (7)

RC s θ(s) + θ(s) = R Q1(s)

$$\theta(s)\,[sRC + 1] = R\,Q1(s)$$

$\theta(s)/Q1(s)$ is the required **transfer function of thermal system**.

$$\therefore \frac{\theta(s)}{Q_i(s)} = \frac{R}{sRC+1} = \frac{R}{RC\left(s+\frac{1}{RC}\right)} = \frac{\frac{1}{C}}{s+\frac{1}{RC}}$$

4. (a) Differentiate servo and regulatory operation with the help of suitable example.

(b) Explain with suitable examples, the difference between the interacting and non- interacting processes.(NOV/DEC 2010).

(a)SERVO VS. REGULATORY CONTROL

Control system essentially ensures the output of a system to behave in a desired way by prescribing an input. Broadly, the objective of control system is one of the following.

- Elimination of disturbances: Regulatorycontrol
- Makingthecontrolledvariablefollowthechangesinsetpoint:Servocontrol

Regulatory Control

In this case, deviation of the output from the set point is minimized in the face of changing circumstances by adjusting the inputs to the system. Controlling the temperature in a room in spite of the ambient temperature variation is an example of regulator operation. A regulatory control system will normally have a fixed reference or set point. This does not mean that the set point cannot be changed. Set points do change, but the changes are not very frequent. Set points remain constant for relatively longer periods of time. In regulatory process control sys- tems, load variations usually present the primary problem. Electrical power gen- eration is a typical example of a regulatory system. Reference or set point of 220 V and 50Hz is fixed. The problem is to maintain this set point in spite of continuously changing load demands.

Servo Control

In this case, the aim is to get the output to follow a desired trajectory specified by the input. The problem of controlling the motion of a machine tool according to the shape of a desired template is an example of servo control. In plastic manu- facturing process, switching from one grade to another grade with minimum production of off-specification products is an example of “follow up” or “servo- mechanism”.

In servomechanism, the main concern is the determination of controlled vari- able response according to the changes in reference. A typical example of servo- mechanism is—numerical control of a milling machine. The reference is con- tinuously changing and the milling cutter must duplicate this change to produce a satisfactory product. In batch control of reactors, after the reactor has been charged with the reactants, a certain temperature-time pattern has to be fol- lowed—another example of servo control. In this type of system, few, if any, external or load disturbances affect the system. The Second World War provided the impetus for the development of control theory. The applications were mainly of servo type, for example, tracking of missiles and air crafts, and guiding the direction of space ship. In most servo control applications, the position, speed or acceleration of an object is made to follow the set point closely.

In process control, the focus is mainly on regulator operation, although all closed-loop control systems have provision for carrying out both servo and regulatory control operation.

(b) Interacting vs. Noninteracting Systems

- Consider a process with several invariables and several output variables. The process is said to be interacting if:
    - Each input affects more than one output.
- or
    - A change in one output affects the other outputs.
    - Otherwise, the process is called non interacting.
- As an example, we will consider the two liquid-level storage systems shown in Figs. 1 and Fig 2
- In general, transfer functions for interacting processes are more complicated than those for non interacting processes.

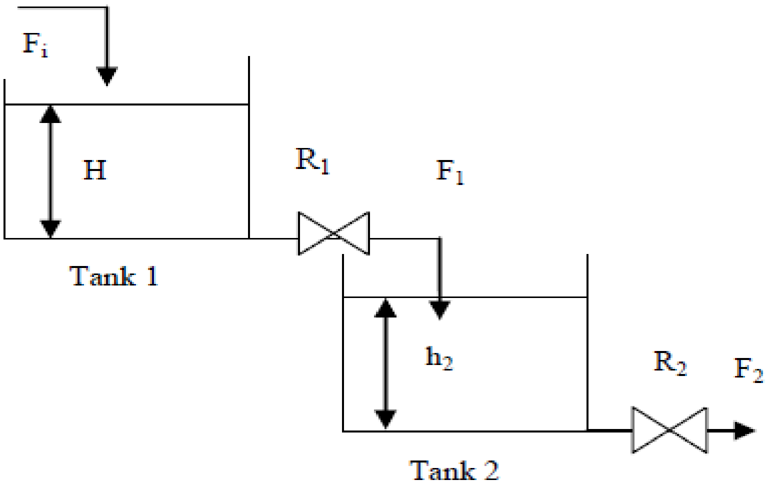


FIG 1.Schematic diagram of Non interacting Process

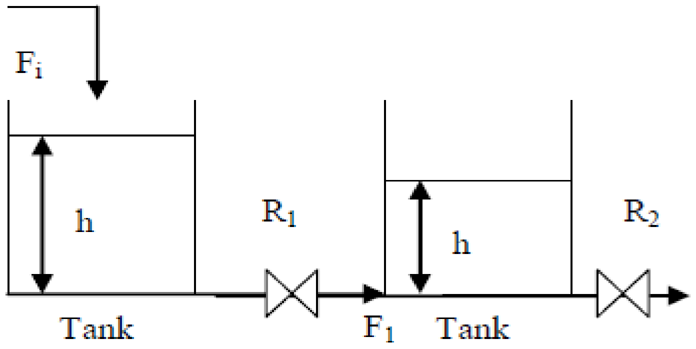


Figure 2. Schematic diagram of Interacting process

5. (a) Bring out the difference between the continuous and batch process with the help of neat diagrams.

   (b) List the merits and demerits of the continuous and batch process (APR/MAY 2010).

6. (a) Derive the mathematical model of a thermal process from fundamentals.

   (b) Explain with suitable examples, the difference between the interacting and non- interacting processes.(APR/MAY 2010).

7. (a) what are the dynamic components of the loop that may exhibit significant time delays in their

response?

(b) How are the effects of dead time compensated? What are the important features of dead time compensators? (MAY/JUNE 2009).

8. (a) what is the inverse response? Explain its behaviour with dynamic system.

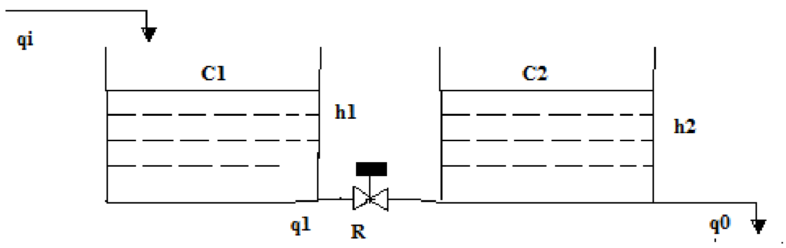
(b) What is the need for mathematical modeling for process control?

(c) Explain the mathematical model for the first order thermal process(MAY/JUNE 2009).

9. (a) Distinguish between servo and regulator operation.

(b) explain the self regulation process with an example(NOV/DEC 2013)

10. Derive the mathematical model for the given process (NOV/DEC 2013)



Refer to Interacting system derivation in my notes.

UNIT II

CONTROL ACTIONS AND CONTROLLERS

PART A

1. What are the basic control actions in process control?

The basic control actions used in process control is

a).On – off control b) Proportional control c).Proportional – Integral control
d).Proportional - Integral - Derivative control

2 Define proportional band.

Proportional band (PB) is defined as the error (expressed as a percentage of the range of measured variable) required to move the valve from fully closed to fully open. The Pb and Proportional gain (K_p) is given by PB = 100 / K_p.

3 Define reset time

The time required for the output of a proportional – Integral controller to change an amount equal to the amount of proportional response provided by a step change of actuating signal.

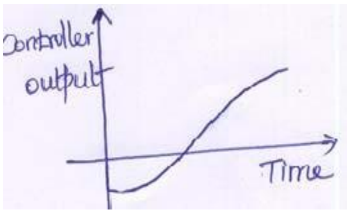
4 Define differential gap. Why is it introduced in a process?

A differential gap in two-position control causes the manipulated variable to maintain its previous value until the controlled variables has moved slightly beyond the set point. In actual operation it is the same as hysteresis. A differential gap is caused in the two-position controller if small friction exists at the bearing on the float arm.

5 Identify two parameters of ON-OFF controller

- Cycling: when control variable does not remain at set point(SP) value it keeps oscillating around SP.
- Differential gap: to overcome cycling

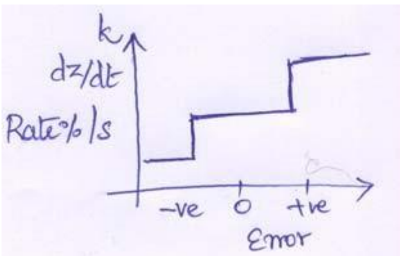
6 Draw the open loop response of an inverse response process when excited with unit step input



7. What is meant by neutral zone in ON-OFF controller?

It is known as differential gap. A small range of value through which control variable must pass in order to change from maximum to minimum or vice verse

8. Sketch the input, output characteristics of single speed floating controller



9. Define integral windup and Anti reset windup.

Windup occurs when PID system has constant error. The difference between set point and control variable never gets to zero; the integral term grows to a very large number. This is called integral windup.

Anti- reset windup is a system to stop the I term from growing without bound

Reset windup is to set the reset interval to a very large number

10 What are the advantages and disadvantages of PI control?

Advantages:

1. It removes or reduces the steady state error without the need for manual reset.
2. It removes or reduces the steady state error without the need for manual reset.

Disadvantages:

1. It may lead to oscillatory response of increasing or decreasing amplitude which is undesirable and the system may become unstable.
2. Constant steady state error.

11 What is meant by single speed floating control?

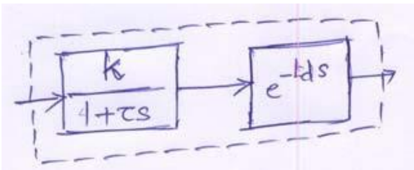
The output will not change but remains (floats) at whatever previous setting it is, when the error goes to zero. The output of the control element changes at a fixed rate when the error exceed the neutral zone

12 Derivative controls cannot be used alone. Justify your answer.

When the error is constant the derivative action is zero. The derivative action Anticipates future errors and introduces appropriate Action. When the process has noise the derivative control amplifies the noise and makes the noisy one. It introduces a stabilizing effect on the Closed –loop control response of a process

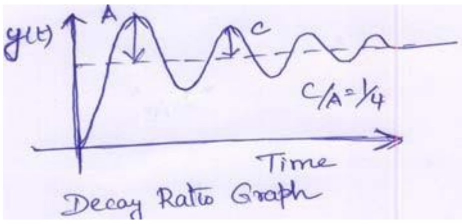
13 What is dead time?

Dead time is a fixed interval of time between the change of an input to an element and the beginning of response to the input.



14 Define ¼ decay ratio.

The ratio of the amounts above the ultimate value of two successive peaks is called as decay ratio. The decay ratio is expressed as, **Decay ratio: C/A= exp ($-2\zeta\pi / \sqrt{1-\zeta^2}$). If C/A=1 then it is called ¼ decay ratio.**



15 What are the advantages and disadvantages of 2-position control?

Advantages: Easy to design, Low cost

Disadvantages: Cycling behavior of the control valve, FCE is subjected to high frequency of oscillation if neutral zone is not used

16. Why derivative mode of control is not recommended for a noisy process?

The derivative control mode is not recommended for a noisy process because even when the process variable(pv) settles down at the set point the derivative control gives the control action for noises that are at higher frequencies, so the pv moves around the set point.

17. *What are the advantages, disadvantages and applications of PD controller?*

Advantages: Offset can be reduced without reducing settling time.

Disadvantages: Offset is not eliminated. At steady state PD acts as a P controller (i.e.) Steady state error is not eliminated

18. What is meant by differential gap? What are its effects? Is it a desirable factor?

A differential gap in two-position control causes the manipulated variable to maintain its previous value until the controlled variables has moved slightly beyond the set point. In actual operation it is the same as hysteresis. A differential gap is caused in the two-position controller if small friction exists at the bearing on the float arm.

19. Design an electronic p-controller with a proportional gain 5.

Given: $k_p = 5$ $K_p = r_2/r_1$

$5 = r_2/r_1$

Ans: $r_2 = 10k\Omega$ and $r_1 = 2K\omega$

20. *What are the advantages and disadvantages of PID control* actions? P-control

Adv: it amplifies the error signal which increases the loop gain. This improves the steady state tracking accuracy, disturbance signal rejection and relative stability. It makes the system less sensitive to parameter variations.

Disadv: constant steady state error. I-control.

Adv: it removes or reduces the steady state error without the need for manual reset. *Disadv:* it may lead to oscillatory response of increasing or decreasing amplitude which is undesirable and the system may become unstable.

D-control.

Adv: controller gives 90 degree phase shift.

Settling time decreases.

Disadv: No control action for steady error. Not suitable for noisy processes.

PART B

1. With neat schematic diagram explain the single speed floating control.(nov13)

Floating Control Mode

In floating control, the specific output of the controller is not uniquely determined by error. If the error is zero, the output does no t change but remains (floats) at whatever setting it was when error went to zero. When error moves of zero, the controller output again begins to change. Similar to two-position mode, there will be a neutral zone around zero error where no change in controller output occurs. Popularly there are two types:

(a)Single Speed

(b) Multiple Speed

(a)Single Speed: In this mode, the output of the control element changes at a fixed rate when the error exceeds the neutral zone. The equation for single speed floating mode is:

$$\frac{dp}{dt} = \pm K_F \qquad |e_p| > \Delta e_p \qquad (1)$$

...

where dp/dt = rate of change of controller output with time
K_F = rate constant (% / s)
Δe_p = half the neutral zone

If the equation (5) is integrated for actual controller output, we get

$$p = \pm K_F t + p(0) \qquad |e_p| > \Delta e_p \qquad (2)$$

where $p(0)$ = controller output at $t = 0$

The equation shows that the present output depends on the time history of errors that have previously occurred. Because such a history is usually not known, the actual value of p floats at an undetermined value. If the deviation persists, then equation (6) shows that the controller saturates at 100% or 0% and remains there until an error drives it toward the opposite extreme. A graph of single speed floating control is shown in Fig. (1)

The single- speed controller action as output rate of change to input error is shown in Fig.1 (a). The graph in Fig.1 (b) shows a reverse acting controller, which means the controller output decreases when error exceeds neutral zone, which corresponds to negative K_F in equation (1). The graph shows that the controller starts at some output p(0). At time t_1, the error exceeds the neutral zone, and the controller output decreases at a constant rate until t_2 , when the error again falls below the neutral zone limit. At t_3 , the error falls below the lower limit of neutral zone, causing controller output to change until the error again moves within the allowable band.

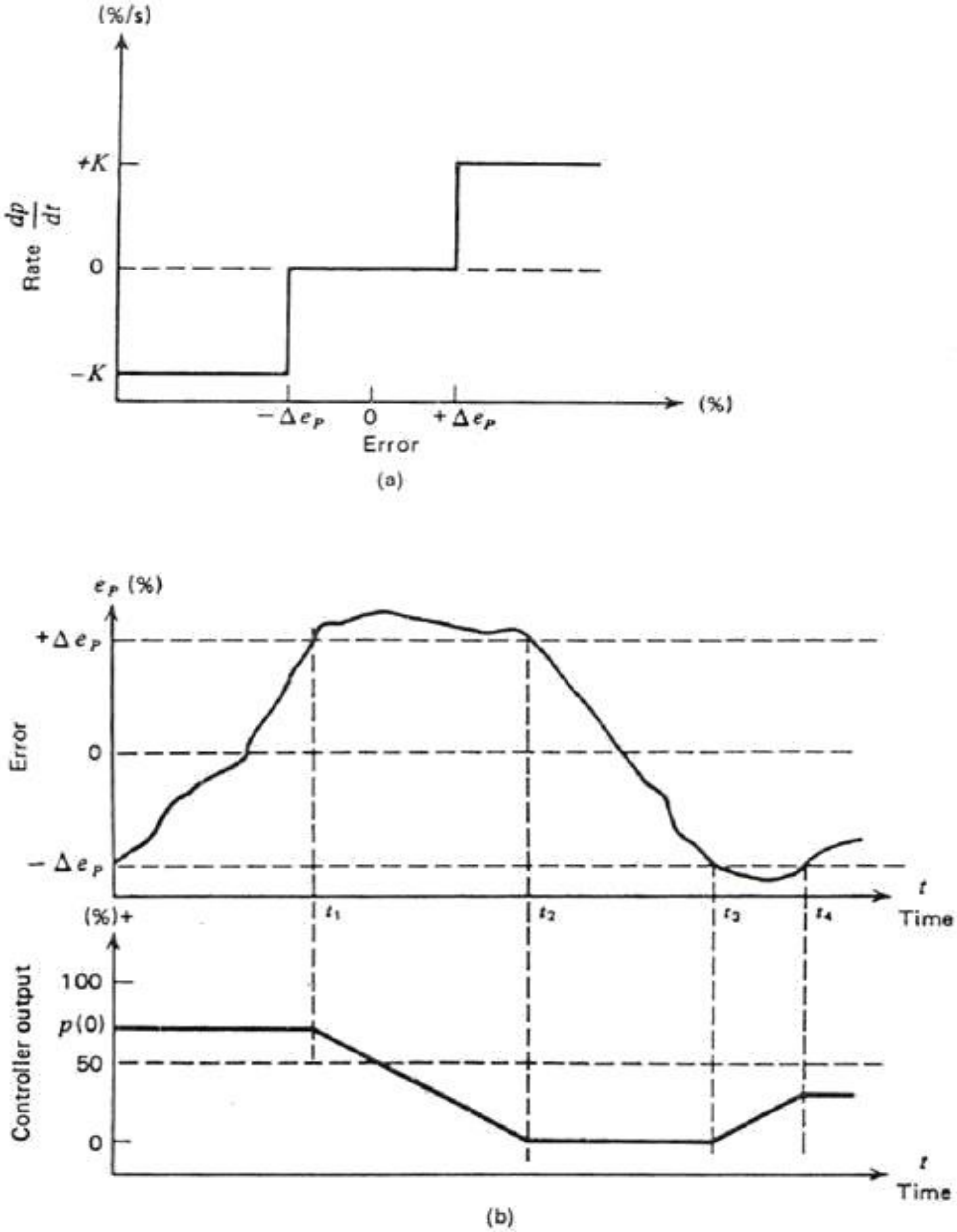


Fig. 1. Single speed floating controller (a) Controller action as output rate of change to input error, and (b) Error versus controller response.

2. With neat sketch explain the function of P+I pneumatic controller.(nov13)

Types of pneumatic controllers

Following is the list of variants of pneumatic controllers.

- Proportional only (P) controller
- Proportional-Derivative (PD) controller
- Proportional-Integral (PI) controller
- Proportional-Integral-Derivative (PID) controller

2.1 Proportional only (P) controller

The simplest form of pneumatic controller is proportional only controller. Figure 2.1 shows the pneumatic circuit of 'proportional only' controller. The output signal is the product of error signal multiplied by a gain (K).

Output = (Error * gain)

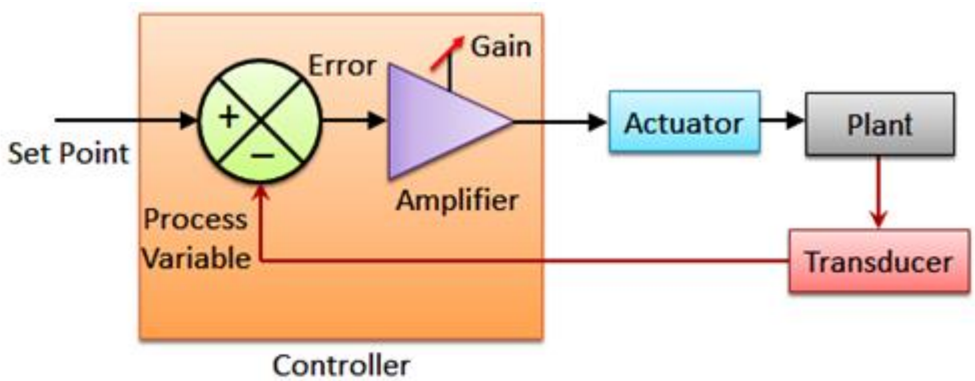


Fig (2.1) Proportional only controller

Consider the pneumatic system consisting of several pneumatic components, viz. flapper nozzle amplifier, air relay, bellows and springs, feedback arrangement. The overall arrangement is known as a pneumatic proportional controller as shown in Figure 2.1.2

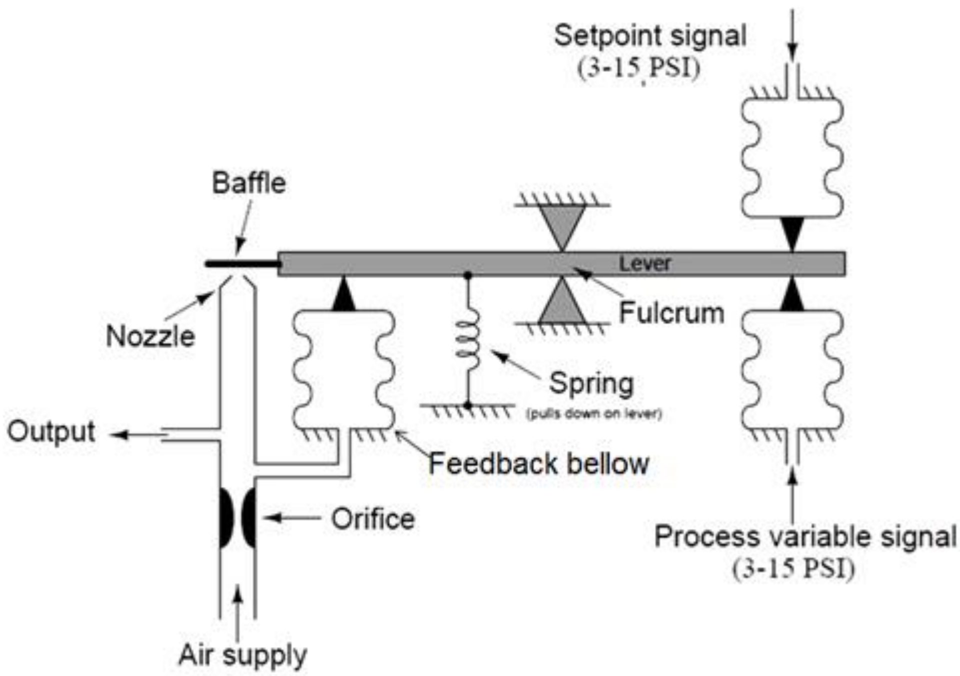


Fig 2.1.2 Proportional only (P) controller elements

It acts as a controller in a pneumatic system generating output pressure proportional to the displacement at one end of the beam. The action of this particular controller is direct, since an increase in process variable signal (pressure) results in an increase in output signal (pressure). Increasing process variable (PV) pressure attempts to push the right-hand end of the beam up, causing the baffle to approach the nozzle. This blockage of the nozzle causes the nozzle's pneumatic backpressure to increase, thus increasing the amount of force applied by the output feedback bellows on the left-hand end of the beam and returning the flapper (very nearly) to its original position. If we wish to reverse the controller's action, we need to swap the pneumatic signal connections between the input bellows, so that the PV pressure will be applied to the upper bellows and the SP pressure to the lower bellows. The ratio of input pressure(s) to output pressure is termed as a gain (proportional band) adjustment in this mechanism. Changing bellows area (either both the PV and SP bellows equally, and the output bellows by itself) influences this ratio. Gain also affects by the change in output bellows position. Moving the fulcrum left or right can be used to control the gain and in fact is usually the most convenient to engineer.

2.2 Proportional-Derivative (PD) controller

A proportional-derivative (PD) controller is shown in Figure 2.2 To add derivative control action to a P-only controller, all we need to place a restrictor valve between the nozzle tube and the output feedback bellows, causing the bellows to delay filling or emptying its air pressure over time.

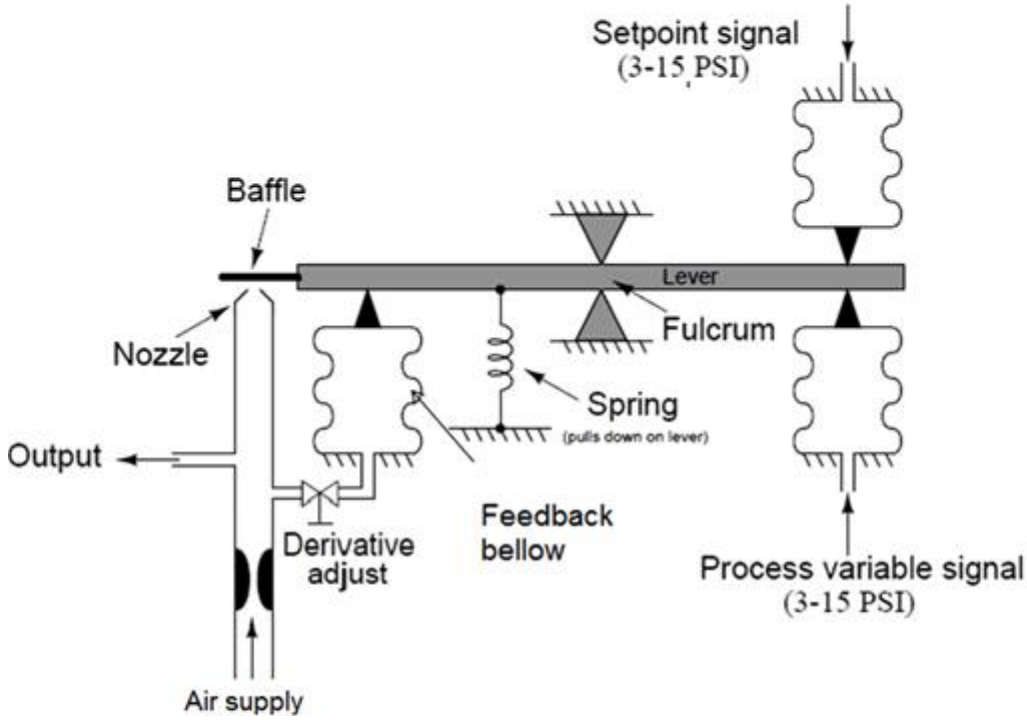


Fig 2.2 Proportional-Derivative (PD) controller

If any sudden change occurs in PV or SP, the output pressure will saturate before the output bellows has the opportunity to equalize in pressure with the output signal tube. Thus, the output pressure "spikes" with any sudden "step change" in input: exactly what we would expect with derivative control action. If either the PV or the SP ramps over time, the output signal will ramp in direct proportion (proportional action). But there will be an added offset of pressure at the output signal in order to keep air flowing either in or out of the output bellows at a constant rate to generate the necessary force to balance the changing input signal. Thus, derivative action causes the output pressure to shift either up or down (depending on the direction of input change) more than it would with just proportional action alone in response to a ramping input.

2.3 Proportional-Integral (PI) controller

In some systems, if the gain is too large the system may become unstable. In these circumstances the basic controller can be modified by adding the time integral of the error to control the operation (Fig 2.4). Thus the output can be given by an equation,

$$\mathrm{OP} = \mathrm{K}\left(\mathrm{error} + \frac{1}{\mathrm{T_i}}\int \mathrm{error\,dt}\right) \tag{2}$$

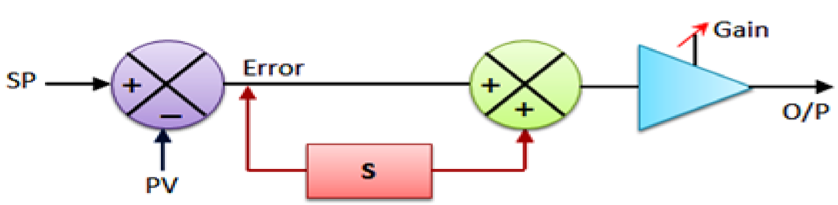


Fig. 2.4 Block diagram of P-I controller

The T_i is a constant called integral time. As long as there is an error the output of the controller steps up or down as per the rate determined by T_i. If there is no error then the output of the controller remains constant. The integral term in the above equation removes any offset error.

Figure 6.5.8 shows the configuration of pneumatic proportional plus integral controller. Integral action requires the addition of a second bellows (a "reset" bellows, positioned opposite the output feedback bellows) and another restrictor valve to the mechanism.

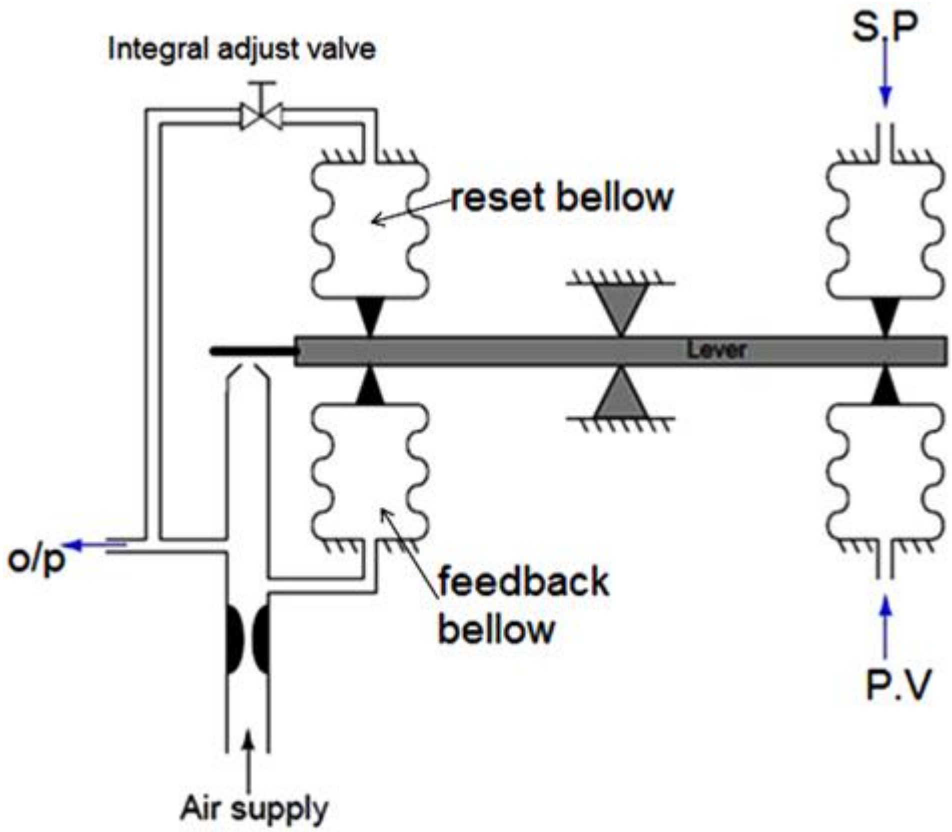


Fig. 2.5 Proportional-Integral (P-I) controller

As the reset bellows fills with pressurized air, it begins to push down the left-hand end of the force beam. This forces the baffle closer to the nozzle, causing the output pressure to rise. The regular output bellows has no restrictor valve to impede its filling, and so it immediately applies more upward force on the beam with the rising output pressure. With this greater output pressure, the reset bellows has an even greater "final" pressure to achieve, and so its rate of filling continues.

2.4 Proportional-Integral-Derivative (PID) controller

Three term pneumatic control can be achieved using a P-I-D controller. Here the action of the feedback bellows is delayed. The output is given by,

$$\mathrm{OP} = \mathrm{K}\left(\mathrm{error} + \frac{1}{\mathrm{T_i}}\int \mathrm{error}\,\mathrm{dt} + \mathrm{T_d}\frac{\mathrm{d\,error}}{\mathrm{dt}}\right) \tag{6.5.3}$$

The terms gain K, derivative time T_d, integral time T_i which can be set by beam pivot point and two bleed valves (Fig. 2.6). This is a combination of all the three controllers described above. Hence it combines the advantages of all three. A derivative control valve is added to delay the response at feedback bellow. Addition of derivative term makes the control system to change the control output quickly when SP and PV are changing quickly. This makes the system more stable.

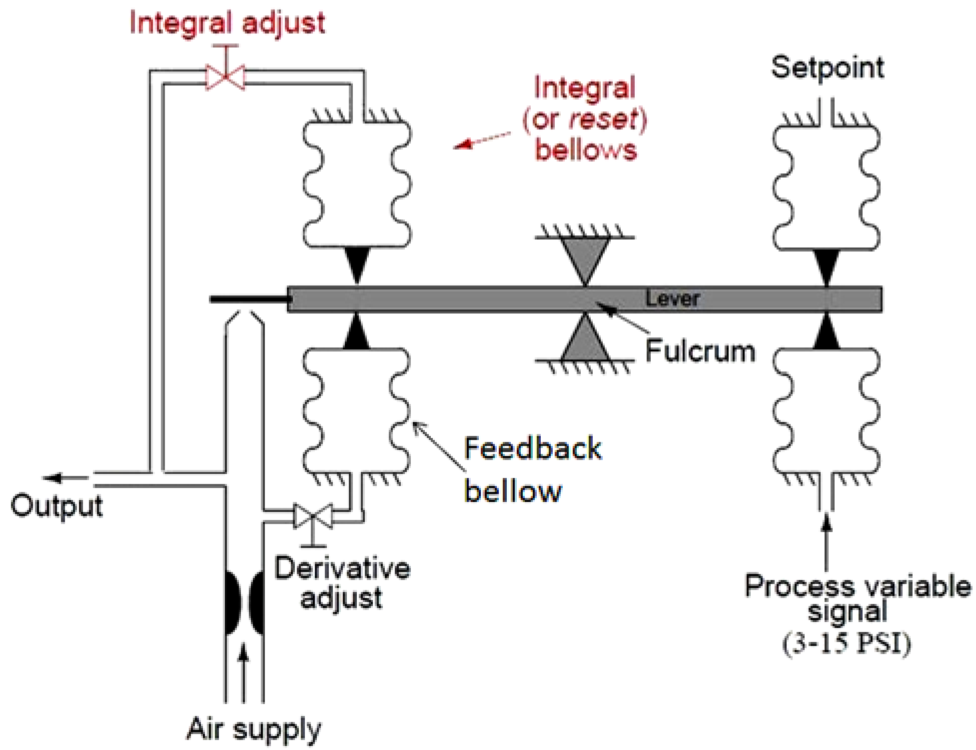


Fig. 2.6 Proportional-Integral-Derivative (P-I-D) controller

Advantages of pneumatic controllers

- Simplicity of the components and no complex structure
- Easy maintainability
- Safe and can be used in hazardous atmospheres
- Low cost of installation
- Good reliability and reproducibility
- Speed of response is relatively slow but steady
- Limited power capacity for large mass transfer

Limitations of pneumatic controllers

- Slow response
- Difficult to operate in sub-normal temperatures
- Pipe-couplings can give rise to leaks in certain ambient conditions
- Moving parts - more maintenance

3.Explain with neat diagram the working of electronic PID controller.(nov13)

INTRODUCTION TO ELECTRONIC CONTROLLERS

A controller is a comparative device that receives an input signal from a measured process variable, compares this value with that of a predetermined control point value (set point), and determines the appropriate amount of output signal required by the final control element to provide corrective action within a control loop. An Electronic Controller uses electrical signals to perform its receptive, comparative and corrective functions. Electronic PID Controllers Electronic PID controllers can be obtained using operational amplifiers and passive components like resistors and capacitors

Two Position controller using OPAMP

Fig. 1 represents the OPAMP implementation of ON/OFF controller with adjustable neutral zone.

Fig 1.

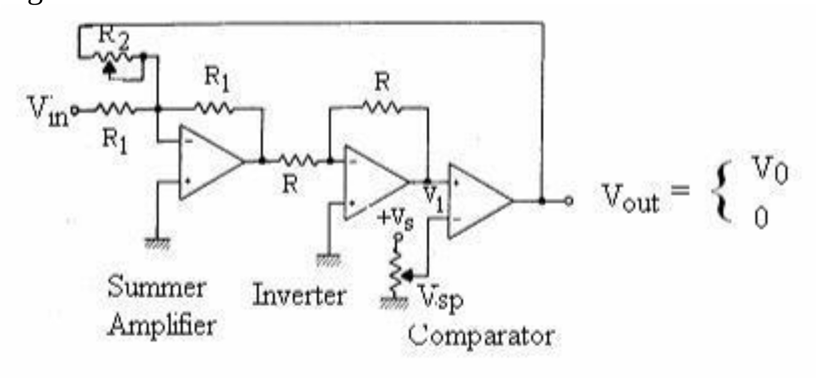


Fig 1. A two position controller with neutral zone made from op amps and a Comparator

Assume that, if the controller input voltage, Vin reaches a value VH then the comparator output should go to the ON state, which is defined as some voltage V0. When the input voltage falls bellow a value VL the comparator output should switch to the OFF state, which is defined as 0 V.

This defines a two position controller with a neutral zone of

NZ= VH - VL as shown in the Fig. 1.1

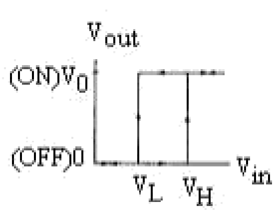


Fig. 1.1. Two position controller response in terms of voltages

Assume that, in the beginning, the comparator is in the OFF state. i.e. the voltage, V1 at the input of the comparator is less than the setpoint voltage, Vsp. Hence,

Vout = 0 (2.17)

The comparator output switches states when the voltage on its input, V1 is equal to the set point value Vsp Analyzing this circuit,

$$V_1 = V_{in} + \frac{R_1}{R_2} V_{out} \tag{2.18}$$

Substituting Eq. 2.17, in Eq. 2.18, yields

V1 = Vin

The comparator changes to ON state when V1 = Vin = VH. Thus, the high (ON) switch voltage is

VH = Vsp (2.19)

and the corresponding output voltage Vout is

Vout = V0 (2.20)

With this V1 changes to

$$V_1 = V_{in} + \frac{R_1}{R_2} V_0$$

(2.21) If Vin = VL the comparator changes to OFF state, giving the relation,

$$V_1 = V_{sp} = V_L + \frac{R_1}{R_2} V_0 \qquad (2.22)$$

This gives the low (OFF) switching voltage of

$$V_L = V_{SP} - \frac{R_1}{R_2} V_o \qquad (2.23)$$

As mentioned before, Fig 2.31 shows typical two position relationship between input and output voltage for the circuit. The width of the neutral zone between VL and VH can be adjusted by variation of R2. The relative location of the neutral zone is calculated from the difference between the equations (2.19) and (2.23).

The inverter resistance value in Fig. 2.30 can be chosen as any convenient value.

Typically it is in the 1 to 100 K Ω range.

Three position Controllers

Fig. 2.2 shows how a simple three position controller can be realized with op amps and comparators.

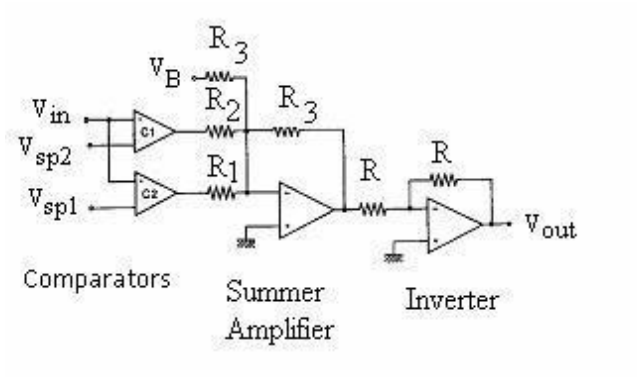


Fig 2.2 Three Position Controller

Fig. 2.2 A three position controller using two comparators and op amps Assume that, the output of the comparators is 0 V for the OFF state and V0 volts for the ON state. The summing amplifier also includes a bias voltage input, VB which allows the three position mode response to be biased up or down in voltage to suit particular needs. The inverter is needed to convert the sign of the inverting action of the summing amplifier.

When Vin < VSP1 ,

Comparator C1 is OFF, C2 is OFF (Because VSP1< VSP2) Outputs of both comparators are 0 V. Thus,

Vout = VB

When VSP1 < Vin< VSP2 , Comparator C1 is OFF, C2 is ON Outputs of comparator

C1 = 0 and Output of Comparator $C2 = \frac{R_3}{R_1} V_0$ Volts. Thus,

Thus,

When $V_{in} < V_{SP1}$, $\quad V_{out} = V_B$

Volts. Thus,

$V_{SP1} < V_{in} < V_{SP2}$, $\quad V_{out} = V_B + \frac{R_3}{R_1} V_0$

$V_{in} > V_{SP2}$, $\quad V_{out} = V_B + \frac{R_3}{R_1} V_0 + \frac{R_3}{R_2} V_0$

Here, the output need not be symmetric. (e.g. 0%, 50% and 100%). Fig. 2.33 shows the response of this circuit for a particular case VB = 0

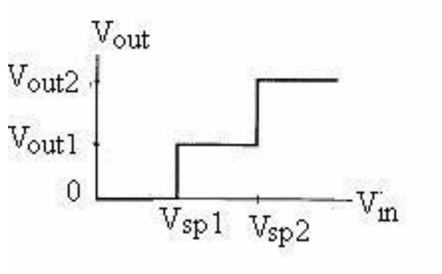


Fig. 2.33. Response of the three position controller with VB = 0

Proportional Mode

Implementation of this mode requires a circuit that has the response given by:

P = Kpep + P0 (2.24)

Where P = controller output 0 – 100 %

Kp = Proportional gain

ep = error in percent of variable range

P0 = Controller output with no error

Implementation of P – Mode controller using OPAMP

If both the controller output and error expressed in terms of voltage, then the above Eq. 2.24 is a summing amplifier. Fig.2.34 shows such an electronic proportional controller.

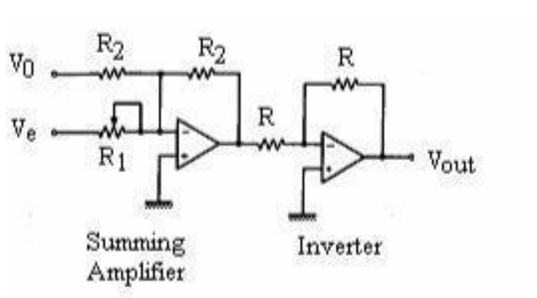


Fig.2.34. An op amp proportional mode controller

Now, the analog electronic equation for the output voltage is:

Vout = GpVe + V0 (2.25)

Where, Vout = output voltage

Gp = R2/R1 = gain

Ve = Error voltage

V0 = output with zero error

To use the circuit of Fig.2.34 for proportional mode, a relationship must be established with the characteristics of the mode, defined already, in chapter 1. In Eq. 2.35, the error is expressed as the percent of measurement range, and the output is simply 0 % to 100%. Yet Fig. 2.34 deals with voltage on both the input and output.

Thus, first identify that the output voltage range of the circuit, whatever it is, represents a swing of 0% to 100%. Thus, if a final control element needs 0 to 5 V, then a Zener is added as shown in the Fig.2.35 so that the op amp output can swing only between 0 and 5V

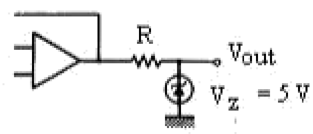


Fig.2.35. A zener diode used to clamp the output swing of an op amp controller

Integral Mode

The general representation of integral controller is

$$P(t) = K_I \int_0^t e_p(t)dt + P_I(0) \quad (2.26)$$

Where, P(t) = controller output in percent of full

scale KI = integration gain (s-1)

ep(t) = deviations in percent of full scale variable

value PI(0) = Controller output at t = 0

Implementation Using OPAMP

Integral controller implemented using OPAMPs is shown in Fig.

2.36 Analysis of the circuit gives,

$$V_{out} = G_I \int_0^t V_e dt + V_{out}(0) \quad (2.27)$$

Vout(0) = Initial output voltage.

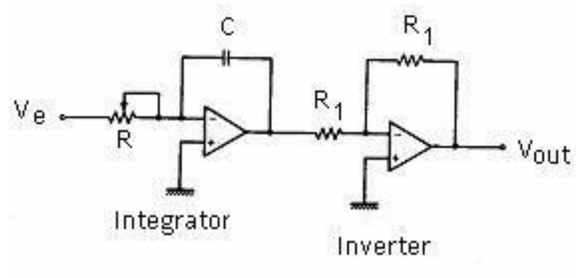


Fig. 2.36. An op amp integral mode controller

The values of R and C can be adjusted to obtain the desired integration time. The initial controller output is the integrator output at t = 0.If K_I is made too large, the output rises so fast that overshoots of the optimum setting occur and cycling is produced.

Determination of G_I

The actual value of G_I and therefore R and C, is determined from KI and the input and output voltage ranges. Integral gain says that, an input error of 1 % must produce an

output that changes as K_I % per second. Or if an error of 1 % lasts for 1 s, the output must change by KI percent.e.g. Consider an input range of 6 V Output range of 5V

KI = 3.0 %/(%- min)

Note: Integral gain is often given in minutes because industrial processes are slow, compared to a time of seconds. This gain is often expressed as integration time, TI, which is just the inverse of the gain.

Solution

First convert the time units to seconds. Therefore, [(3 %)/(%- min)][(min/60s)]

= 0.05%/(%-s) Error of 1 % for 1

sec = (0.01)(6V)(1s) = 0.06 V-s

KI % of the output = (0.0005)(

5V) = 0.0025 V

The integral gain GI = (KI % of the output) / (Error of 1 % for 1 sec)

= (0.0025V)/(0.06 V-s)

= 0.0417 s-1

Values of R and C can be selected from this.

Derivative mode

The derivative mode is never used alone because it can not provide a controller output when the error is zero or constant. The control mode equation is given by

$$P(t) = K_D \frac{de_p}{dt} \tag{2.28}$$

where, P = Controller output in percent of full output KD = Derivative time constant (s)

ep = error in percent of full scale range

where, P = Controller output in percent of full output

KD = Derivative time constant (s)

ep = error in percent of full scale range

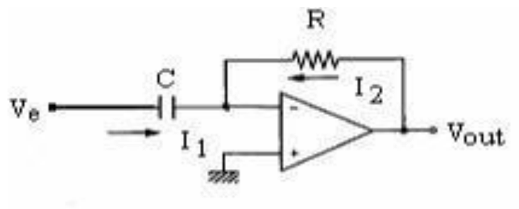
Implementation of derivative controller using OPAMP:

Consider an OPAMP differentiator circuit shown in Fig. 2.37 The theoretical transfer function for this circuit will be given by

$$V_{out} = -RC \frac{dV_e}{dt} \tag{2.29}$$

where, the input voltage has been set equal to the controller error voltage

Fig 2.37 OPAMP differentiator circuit



Composite controller modes

Composite modes combine the advantages of each mode and in some cases eliminate the disadvantages. Composite modes are implemented easily using opamp techniques. **Proportional – Integral mode**

PI controller is the combination of proportional and integral controller defined by:

$$P = K_p e_p + K_p K_I \int_0^t e_p dt + P_I(0)$$

Where, P = controller output in percent of full scale ep = process error in percent of the maximum Kp = Proportional gain

KI= Integral gain

PI(0) = initial controller integral output

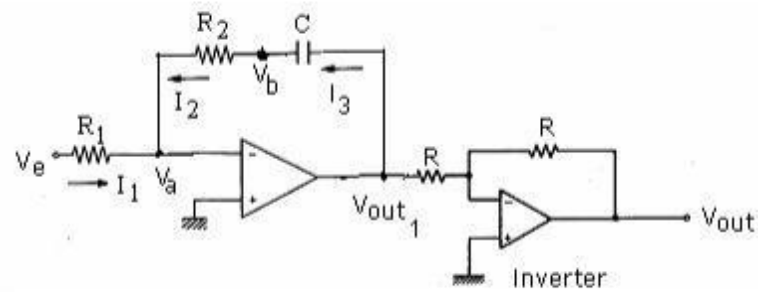
Implementation of PI controller using opamps

Figure 2.38 a shows one method of implementation of the PI controller using opamps.

Fig. 2.38 a. An op amp

proportional integral (PI) mode controller

To derive an expression for the output



voltage of this circuit, first define nodes and currents as shown in the Fig. 2.38 b.

Fig.2.38 b. An op amp proportional integral (PI) mode controller

Note that, there is no current through op amp input terminals and no voltage across the input terminals.

Therefore, Va = 0 and

I1 + I2 = 0 (2.31)

I3 – I2 = 0 (2.32)

The relationship between the voltage across the capacitor and current through a capacitor is given by

$$I_c = C\frac{dV_C}{dt} \qquad (2.33)$$

Where Vc is the voltage across the capacitor. Combining this with Ohm‟s law allows the preceding current equations (2.31 and 2.32) to be written in terms of voltage as

$$C\frac{d}{dt}[V_{out_1} - V_b] - \frac{V_b}{R_2} = 0$$

$$\frac{V_e}{R_1} + \frac{V_b}{R_2} = 0$$

The Eq. 2.34 can be solved for Vb as:

$$V_b = -\frac{R_2}{R_1} V_e$$

Substituting this in to Eq. 2.35

(2.34) (2.35)(2.36)(2.37)

$$C\frac{dV_{out_1}}{dt} - C\frac{d}{dt}\left(-\frac{R_2}{R_1}V_e\right) - \frac{1}{R_2}\left(-\frac{R_2}{R_1}V_e\right) = 0$$

$$C\frac{dV_{out_1}}{dt} + C\frac{R_2}{R_1}\frac{d}{dt}V_e + \frac{1}{R_1}V_e = 0$$

$$\text{Or, } \frac{dV_{out_1}}{dt} + \frac{R_2}{R_1}\frac{d}{dt}V_e + \frac{1}{R_1 C}V_e = 0$$

In order to solve for Vout, integrate this equation to eliminate the derivative on Vout. i.e.:

$$V_{out_1} = -\frac{R_2}{R_1}V_e - \frac{1}{R_1 C}\int_0^t V_e dt + V(0) \tag{2.38}$$

$$V_{out_1} = -\frac{R_2}{R_1}V_e - \frac{R_2}{R_1}\frac{1}{R_2 C}\int_0^t V_e dt + V(0)$$

After inverting

$$V_{out} = \frac{R_2}{R_1}V_e + \frac{R_2}{R_1}\frac{1}{R_2 C}\int_0^t V_e dt + V(0)$$

$$\text{Or, } V_{out} = G_p V_e + G_p G_I \int_0^t V_e dt + V(0) \tag{2.39}$$

Where, Proportional gain, Gp = R2/R1 and integral gain GI = 1/ (R2C)

Proportional Derivative Mode of controller

PD controller is the combination of proportional and derivative mode of controllers. The general definition of PD controller is

$$\mathrm{P(t)} = K_p \mathrm{e_p} + \mathrm{K_p K_D}\frac{\mathrm{de_p}}{\mathrm{dt}} + P(0) \tag{2.40}$$

Where, P = Controller output in percent of full output

Kp = Proportional gain

KD = Derivative time constant (s)

ep = error in percent of full scale range

P(0) = Zero error controller output

Implementation of PD controller using opamps.

Fig. 2.39 a shows how a PD controller can be implemented using op amps. Where the quantities are defined in the figure and the output inverter has been included. This circuit includes the clamp to protect against high gain at high frequency in the derivative term.

$$R = \frac{R_1 R_3}{R_1 + R_3}$$

Then the condition becomes as usual, 2π fmax RC = 0.1. Assuming this criterion has been met, while deriving the equation for the PD response given below

$$V_{out} = \left(\frac{R_2}{R_1 + R_3}\right)V_e + \left(\frac{R_2}{R_1 + R_3}\right)R_3 C \frac{dV_e}{dt} + V_0$$

$$V_{out_1} = G_p V_e + G_p G_D \frac{dV_e}{dt} + V_0$$

Where the proportional gain is

And the derivative gain is GD = R3 C

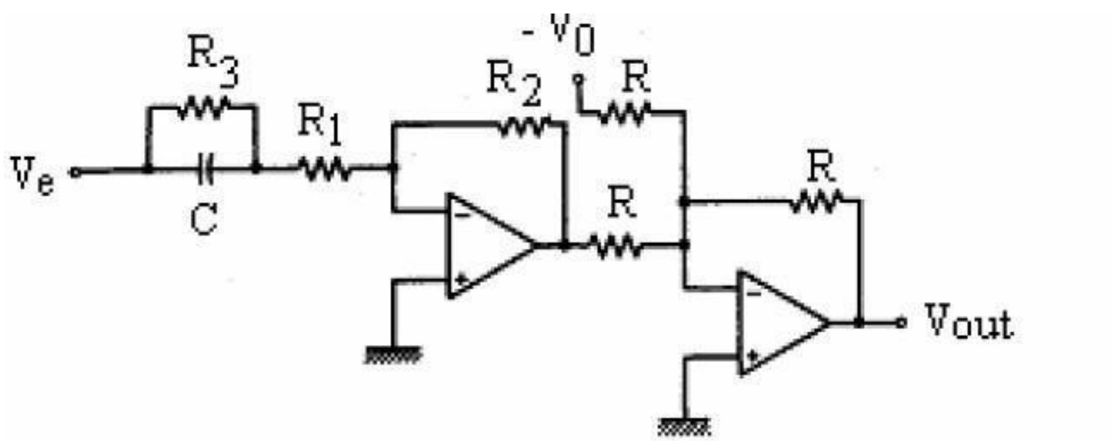


Fig.2.39 a An op amp Proportional Derivative (PD) mode controller

Derivation of PD controller response:

Analysis of PD circuit can be performed using the circuit shown in Fig. 2.39b showing currents and nodes. The voltage across the op amp input terminals, Vb = 0. Also there is no current in to the op amp inputs.

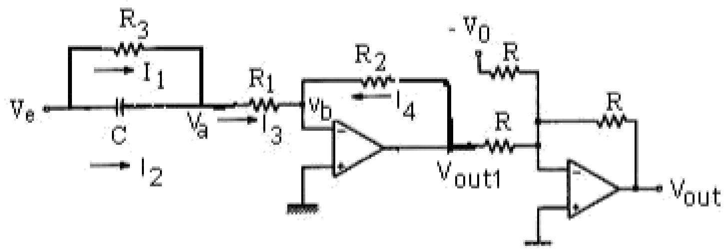


Fig.2.39 b An op amp Proportional Derivative (PD) mode controller

PD controller still has the offset error of a proportional controller because the derivative term cannot provide reset action.

Application of KCL, to the two active nodes provides the equations:

$I_1 + I_2 - I_3 = 0$

$I_4 + I_3 = 0$

Ohm's law and the differential relation between current and voltage for a capacitor can be used to express these equations in terms of voltage.

$$\frac{V_e - V_a}{R_3} + C\frac{d}{dt}[V_e - V_a] - \frac{V_a}{R_1} = 0$$

$$\frac{V_{out_1}}{R_2} + \frac{V_a}{R_1} = 0$$

$$V_a = -\frac{R_1}{R_2}V_{out_1}$$

$$\frac{V_e}{R_3} + \frac{R_1}{R_2 R_3}V_{out_1} + C\frac{dV_e}{dt} + \frac{R_1}{R_2}C\frac{dV_{out_1}}{dt} + \frac{1}{R_2}V_{out_1} = 0$$

Or, $V_e + \frac{R_1}{R_2}V_{out_1} + R_3C\frac{dV_e}{dt} + \frac{R_3R_1}{R_2}C\frac{dV_{out_1}}{dt} + \frac{R_3}{R_2}V_{out_1} = 0$

After rearranging and some more algebra, this reduces to:

$$V_{out_1} + \left(\frac{R_1}{R_1 + R_3}\right)R_3C\frac{dV_{out_1}}{dt} = -\left(\frac{R_2}{R_1 + R_3}\right)V_e - \left(\frac{R_2}{R_1 + R_3}\right)R_3C\frac{dV_e}{dt}$$

After inverting

$$V_{out} + \left(\frac{R_1}{R_1 + R_3}\right)R_3C\frac{dV_{out_1}}{dt} = \left(\frac{R_2}{R_1 + R_3}\right)V_e + \left(\frac{R_2}{R_1 + R_3}\right)R_3C\frac{dV_e}{dt}$$

Or, $V_{out} = \left(\frac{R_2}{R_1 + R_3}\right)V_e + \left(\frac{R_2}{R_1 + R_3}\right)R_3C\frac{dV_e}{dt} + V_0$

$$V_{out} = G_pV_e + G_pG_D\frac{dV_e}{dt} + V_0$$

Where the proportional gain is $G_p = \left(\frac{R_2}{R_1 + R_3}\right)$

And the derivative gain is $G_D = R_3C$

Three Mode Controller

Three mode controllers is the combination of proportional, integral and derivative mode of controllers. Characterized by

$$P = K_p e_p + K_p K_I \int_0^t e_p dt + K_p K_D \frac{de_p}{dt} + P_I(0)$$

Where, P = controller output in percent of full

scale ep = process error in percent of the maximum

Kp = Proportional gain

KI= Integral gain

KD= Derivative gain

PI(0) = initial controller integral output

The zero error term of the proportional mode is not necessary because the integral automatically accommodates for offset and nominal setting.

Implementation of three mode controller using op amps

Three mode controller can be implemented by a straight application of op amps as shown in Fig. 2.40a.

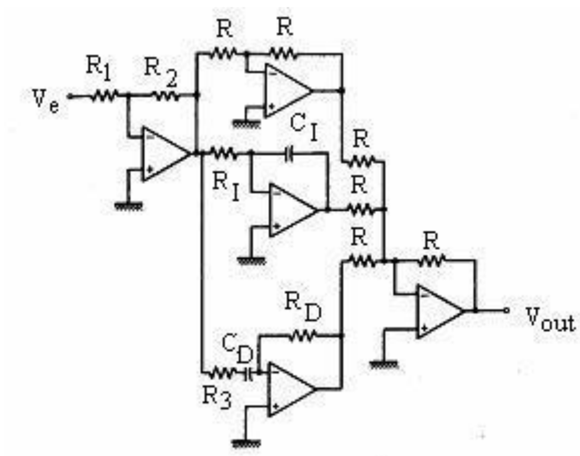


Fig. 2.40a. Implementation of a three mode (PID) controller with op amps

For the analysis, assume the voltages as indicated in Fig. 2.40b

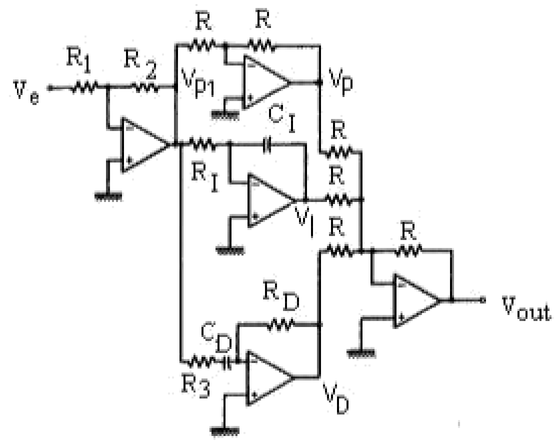


Fig. 2.40b. Implementation of a three mode (PID) controller with op amps

$$V_{p1} = -\frac{R_2}{R_1} V_e$$

$$V_p = \frac{R_2}{R_1} V_e$$

$$V_I = -\frac{1}{R_I C_I} \int_0^t V_{p1} dt \quad \text{or, } V_I = \frac{R_2}{R_1} \frac{1}{R_I C_I} \int_0^t V_e dt$$

$$V_D = -R_D C_D \frac{d}{dt} V_{p1} \quad \text{or, } V_D = \frac{R_2}{R_1} R_D C_D \frac{d}{dt} V_e$$

$- V_{out} = V_p + V_I + V_D$

$$-V_{out} = \left(\frac{R_2}{R_1}\right) V_e + \left(\frac{R_2}{R_1}\right) \frac{1}{R_I C_I} \int V_e dt + \left(\frac{R_2}{R_1}\right) R_D C_D \frac{dV_e}{dt} + V_{out}(0)$$

R_3 has been chosen from $2\pi f_{max} R_3 C_D = 0.1$ for stability. Comparing equations

$$G_p = \left(\frac{R_2}{R_1}\right), \; G_I = \left(\frac{1}{R_I C_I}\right) \quad \text{and } G_D = R_D C_D$$

$$-V_{out} = G_p V_e + G_p G_I \int V_e dt + G_p G_D \frac{dV_e}{dt} + V_{out}(0)$$

Adding an inverter at the output stage,

$$V_{out} = G_p V_e + G_p G_I \int V_e dt + G_p G_D \frac{dV_e}{dt} + V_{out}(0)$$

3. When an on-off controller is recommended? How its performance affected by process dead time.(may12)

4. A pi controller has 20% and integral time of 10sec.for a constant error of 5%.determine the controller output after 10sec.the controller offset is 25%.(may12)

5. Compare the features of ON & OFF,P,I,D control modes and draw their characteristics.(nov10)

Two-Position (ON/OFF) Mode

The most elementary controller mode is the two-position or ON/OFF controller mode. It is the simplest, cheapest, and suffices when its disadvantages are tolerable. The most general form can be given by

$$P = \begin{cases} 0\ \% & e_p < 0 \\ 100\ \% & e_p > 0 \end{cases} \qquad (2.2)$$

The relation shows that when the measured value is less than the setpoint (i.e. $e_p > 0$), the controller output will be full (i.e. 100%), and when the measured value is more than the setpoint (i.e. $e_p < 0$), the controller output will be zero (i.e. 0%).

Neutral Zone: In practical implementation of the two-position controller, there is an overlap as e_p increases through zero or decreases through zero. In this span, no change in the controller output occurs which is illustrated in Fig. 2.1

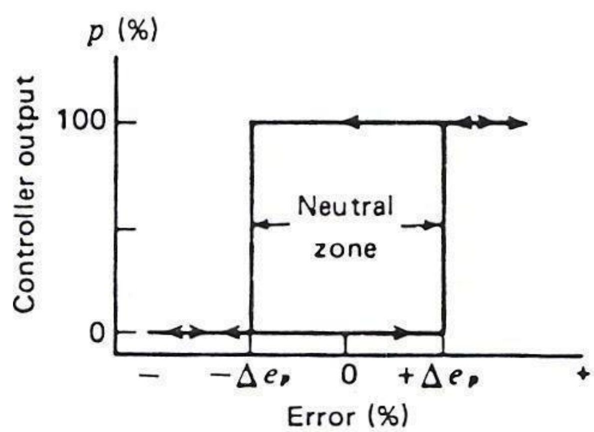


Fig. 2.1 Two-position controller action with neutral zone.

It can be observed that, until an increasing error changes by Δe_p above zero, the controller output will not change state. In decreasing, it must fall Δe_p below zero before the controller changes to 0%. The range $2\Delta e_p$ is referred to as *neutral zone or differential gap*. Two-position controllers are purposely designed with neutral zone to prevent excessive cycling. The existence of such a neutral zone is an example of desirable hysteresis in a system.

Applications: Generally the two-position control mode is best adapted to:

- Large-scale systems with relatively slow process rates

Example: Room heating systems, air-conditioning systems.

Systems in which large-scale changes are not common

Examples: Liquid bath temperature control, level control in large-volume tanks.

Proportional Control Mode

In this mode a linear relationship exits between the controller output and the error. For some range of errors about the setpoint, each value of error has unique value of controller output in one-to-one correspondence. The range of error to cover the 0% to 100% controller output is called proportional band, because the one-to-one correspondence exits only for errors in this range. The analytical expression for this mode is given by:

$$p = K_p e_p + p_0 \qquad (2.8)$$

where K_p = proportional gain (% per %)

p_0 = controller output with no error or zero error (%)

The equation (8) represents reverse action, because the term $K_p e_p$ will be subtracted from p_0 whenever the measured value increases the above setpoint which leads negative error. The equation for the direct action can be given by putting the negative sign in front of correction term i.e. - $K_p e_p$. A plot of the proportional mode output vs. error for equation (8) is shown in Fig.2.9

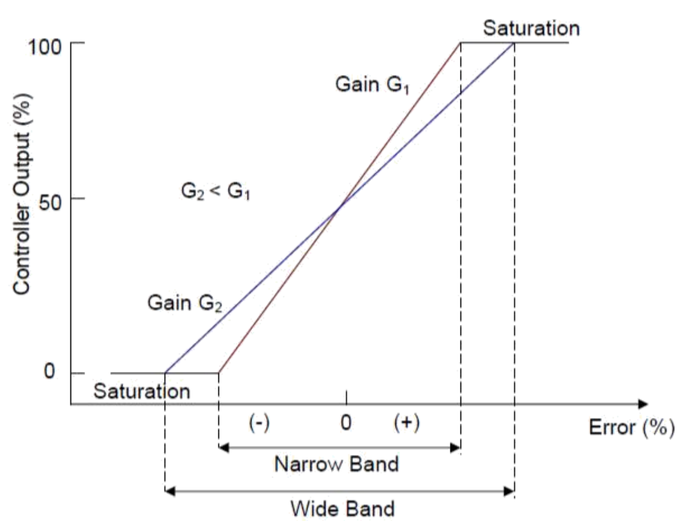


Fig. 2.9 Proportional controller mode output vs. error.

In Fig.2.9, p_0 has been set to 50% and two different gains have been used. It can be observed that proportional band is dependent on the gain. A high gain (G_1) leads to large or fast response, but narrow band of errors within which output is not saturated. On the other side a low gain (G_2) leads to small or slow response, but wide band of errors within which output is not saturated. In general, the proportiona l band is defined by the equation:

$$PB = \frac{100}{K_p} \qquad (2.9)$$

The summary of characteristics of proportional control mode are as follows:

1. If error is zero, output is constant and equal to p_0.

2. If there is error, for every 1% error, a correction of K_p percent is added or subtracted from p_0, depending on sign of error.

3. There is a band of errors about zero magnitude PB within which the output is not saturated at 0% or 100%.

Offset: An important characteristic of the proportional control mode is that it produces a permanent residual error in the operating point of the controlled variable when a load change occurs and is referred to as offset. It can be minimized by larger constant K_p which also reduces the proportional band. Figure 2.10 shows the occurrence of offset in proportional control mode.

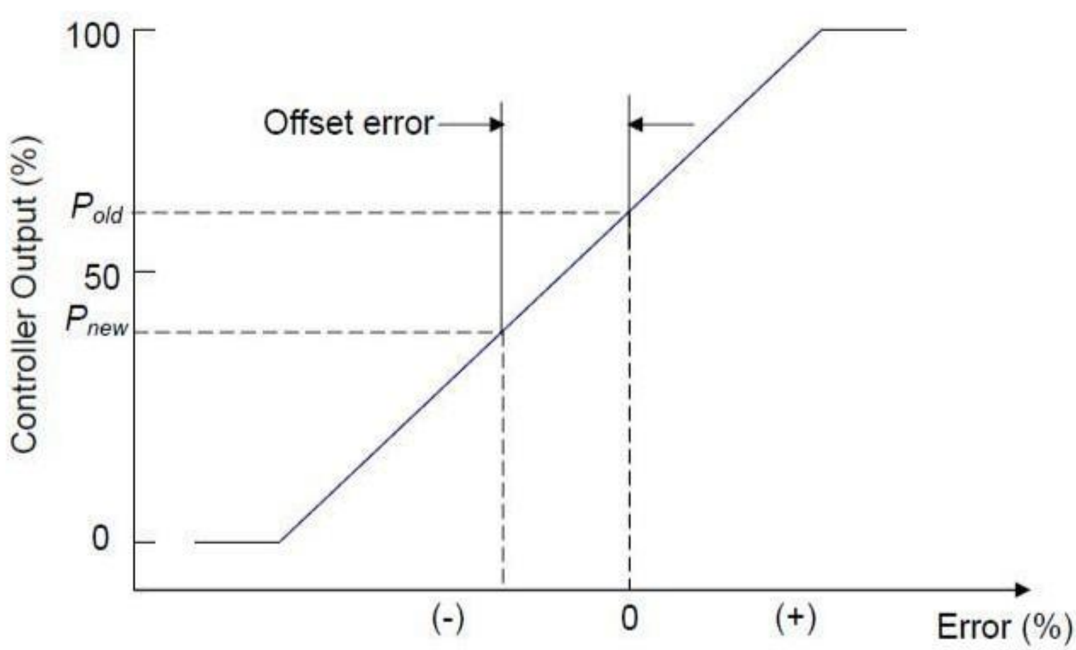


Fig. 2.10 Occurrence of offset error in proportional controller for a load change.

Consider a system under nominal load with the controller output at 50% and error zero as shown in Fig.2.10 If a transient error occurs, the system responds by changing controller output in correspondence with the transient to effect a return-to-zero error. Suppose, however, a load change occurs that requires a permanent change in controller output to produce the zero error state. Because a one-to-one correspondence exists between controller output and error, it is clear that a new zero-error controller output can never be achieved. Instead, the system produces a small permanent offset in reaching compromise position of controller output under new loads.

Applications:

- Whenever there is one-to-one correspondence of controller output is required with respect to error change proportional mode will be ideal choice.

- The offset error limits the use of proportional mode, but it can be used effectively wherever it is possible to eliminate the offset by resetting the operating point.
- Proportional control is generally used in processes where large load changes are unlikely or with moderate to small process lag times.

- If the process lag time is small, the PB can be made very small with large K_p, which reduces offset error.

- If K_p is made very large, the PB becomes very small, and proportional controller is going to work as an ON/OFF mode, i.e. high gain in proportional mode causes oscillations of the error.

Integral Control Mode

The integral control eliminates the offset error problem by allowing the controller to adapt to changing external conditions by changing the zero-error output.

Integral action is provided by summing the error over time, multiplying that sum by a gain, and adding the result to the present controller output. If the error makes random excursions above and below zero, the net sum will be zero, so the integral action will not contribute. But if the error becomes positive or negative for an extended period of time, the integral action will begin to accumulate and make changes to the controller output. The analytical expression for integral mode is given by the equation

$$p(t) = K_I \int_0^t e_p \, dt + p(0) \qquad (2.10)$$

where *p(0)* = controller output when the integral action starts (%)

K_I = Integral gain (s^{-1})

Another way of expressing the integral action is by taking derivative of equation (10), which gives the relation for the rate of change of controller output with error.

$$\frac{dp}{dt} = K_I \, e_p \qquad (2.12)$$

The equation (12) shows that when an error occurs, the controller begins to increase (or decrease) its output at a rate that depends upon the size of the error and the gain. If the error is zero, controller output is not changed. If there is positive error, the controller output begins to ramp up at a rate determined by Equation (12). This is shown in Fig.2.13 for two different values of gain. It can be observed that the rate of change of controller output depends upon the value of error and the size of the gain. Figure 2.14 shows how controller output will vary

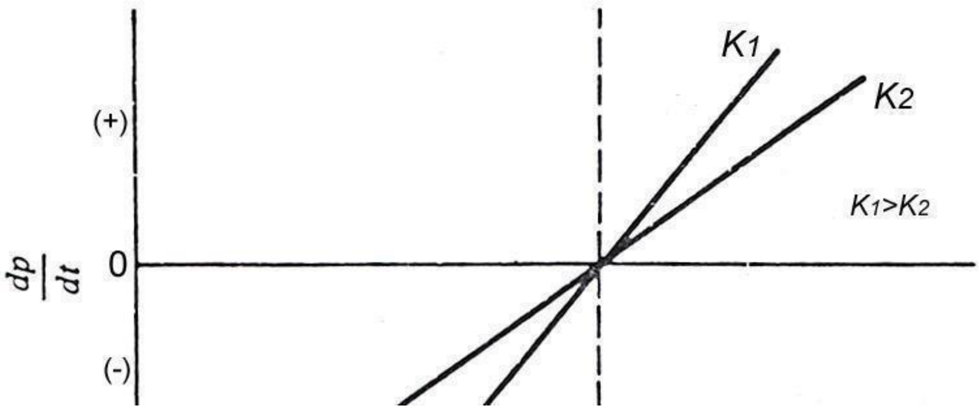


Fig. 2.13 Integral control action showing the rate of output change with error & gain

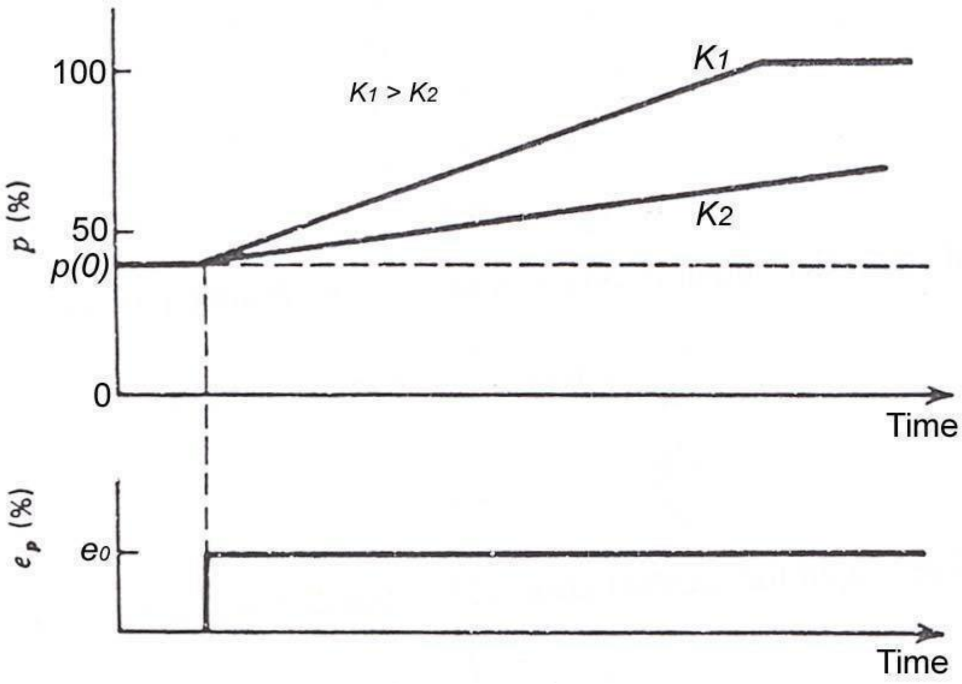


Fig. 2.14 Integral controller output for a constant error

It can be observed that the controller output begins to ramp up at a rate determined by the gain. In case of gain K_1, the output finally saturates at 100%, and no further action can occur.

The summary of characteristics of integral control mode are as follows:

1. If the error is zero, the output stays fixed at a value equal to what it was when the error went to zero (i.e. *p(0)*)
2. If the error is not zero, the output will begin to increase or decrease at a rate of K_I %/sec for every 1% of error.

Area Accumulation: It is well known fact that integral determines the area of the function being integrated. The equation (1.12) provides controller output equal to the net

area under error- time curve multiplied by K_I. It can be said that the integral term accumulates error as function of time. Thus, for every 1%-sec of accumulated error-time

area, the output will be K_1 percent.The integral gain is often represented by the inverse, which is called the integral time or reset action, i.e. $T_I = 1 / K_I$, which is expressed in minutes instead of seconds because this unit is more typical of many industrial process speeds. The integral operation can be better understood by the

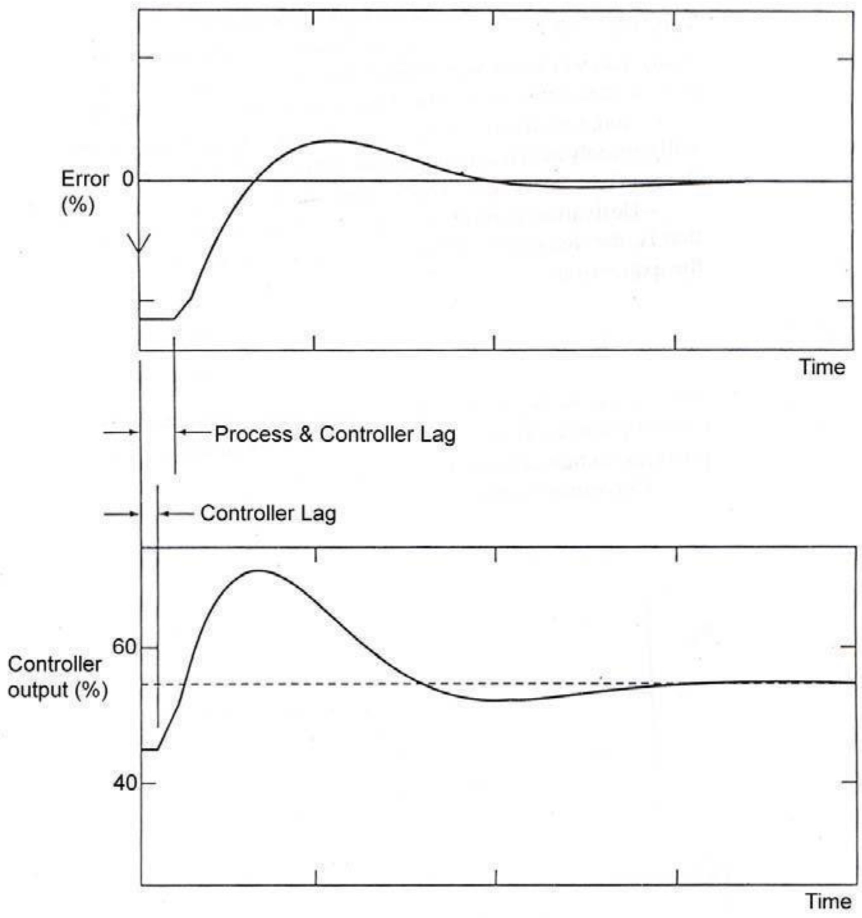


Fig. 2.15 Integral mode output and error, showing the effect of process and control lag.

A load change induced error occurs at t = 0. Dashed line is the controller output required to maintain constant output for new load. In the integral control mode, the controller output value initially begins to change rapidly as per Equation (12). As the control element responds and error decreases, the co ntroller output rate also decreases. Ultimately the system drives the error to zero at a slowing controller rate. The effect of

process and control system lag is shown as simple delays in the controller output change and in the error reduction when the controller action occurs. If the process lag is too large, the error can oscillate about zero or even be cyclic.

Applications: In general, integral control mode is not used alone, but can be used for systems with small process lags and correspondingly small capacities

UNIT III

CONTROLLER SETTINGS

PART A

1. How tuning is done in process control?

To adjust the controller parameters is referred as tuning. The controller may tune using the simple criteria such as ¼ decay ratio, minimum setting time, and minimum error. Using time integral performance such as ISE, IAE, ITAE the controller may tune. The popular method of controller tuning is Process reaction curve and Z-N method.

2. What is a process reaction curve?

This is a plot drawn between the measurement output and time when the closed loop system is disconnected between the controller and final control element and is manually operated with step change.

3 State the relation between maximum overshoot and decay ratio.

The relation between maximum overshoot and decay ratio is, **decay ratio = (overshoot)** $^{\mathbf{2}}$

4 What do you meant by controller tuning?

A procedure of finding the optimum controller setting by conducting a simple experimental test. It means adjusting the controller parameters.

5 Give an example for Discontinuous and Continuous mode of controller.

Discontinuous-ON-OFF controller.

Continuous – Proportional Controller

6 How to choose evaluation criteria for an application

ISE- to suppress large errors

IAE- to suppress small errors

ITAE- to suppress long time errors

7 What is ITAE and when to go for it?

ITAE is integral of the time weighted Absolute error and it is defined as ITAE = $\int t\, |\, e(t)\, |\, dt$.To suppress errors that persist for long times, the ITAE criterion will tune the controllers better because the presence of large t amplifies the effect of even small errors in the value of the integral.

8 Write Ziegler Nichols tuning formulae.

	Kc	τ_I (min)	τ_D (min)
P only	K_u / 2		
P-I	K_u / 2	P_u / 1.2	
P-I-D	K_u / 2	P_u / 2	P_u / 8

where K_u = ultimate gain, P_u = ultimate period of oscillation

9 Why is it necessary to choose controller settings that satisfy both gain margin and phase margin?

It is necessary to choose controller settings that satisfy both gain margin &phase margin in order to avoid unstable behavior by the closed loop of a process. The stability of the system is decided by the appropriate gain and phase margins

10 What is tuning a controller based on quarter – decay ratio?

It's the tuning of parameters of the controller so as to obtain a step change in the load (error).The response gives decay ratio of ¼.it is defined as the ratio of successive amplitude of the peaks decay ratio=C/A.

11 Write the Cohen – Coon controller settings PID controller.

For the PID controllers the parameters are,

$K_c = \tau / K\, t_d\ (4/3 + t_d / 4\ \tau)$

$\tau_I = t_d\ ((32 + 6t_d)/ \tau / (13 + 8t_d/\tau)\ \tau_D = 4t_d /$
$(11 + 2t_d / \tau)$

where τ ratio of steady state output and slope of the sigmoidal response K = ratio of steady state output to the steady state in t_d – time elapsed until the system responded.

12 When do you go Process reaction curve method for controller tuning.

- For the multi capacity processes whose response is sigmoid
- Process with very short time delay
- The process whose response is over damped
-

13 What is cycling?

An important mode of dynamic variable error is the oscillation of an error about zero. This means the variables is cycling above or below zero set point.

14 Briefly explain about Damped oscillation method

Using only proportional action and starting with low gain adjust the gain adjusted until the transient response of the closed loop shows a decay ratio of 1 / 4. The optimum setting of damped oscillation method is more accurate than ultimate method

15 Write two limitations of derivative controller?

- For a response with constant non zero error it gives no control action as the controller output goes to zero
- For a noisy response with almost zero error it can compute large derivatives and thus yield large control action, although it is not needed

16 Explain the function of a controller

Controller is the most important part of the process control which generates a control signal to the final control element based on the deviation of set point variable and process variable.

17 What are the parameters required to design a best controller?

- Keep the maximum errors as small as possible.
- Achieve short settling time.
- Minimize integral of errors until the process has settled to set point value

18 Define time constant of a process

It is a measure of the time necessary for the process to adjust to a change in its input

19 Write any two significance of gain margin

If gain is slightly greater than 1 at 180 shift system becomes unstable When the phase lag is 180 and if gain is slightly less than 1 system is stable.

20 Write *the Cohen – Coon controller settings PI controller.*

For the PI controllers the parameters are, $K_c = \tau / K t_d (0.9 + t_d / 12\tau)$

$\tau_I = t_d ((30 + 3t_d / \tau) / (9 + 20t_d/\tau)$

PART B

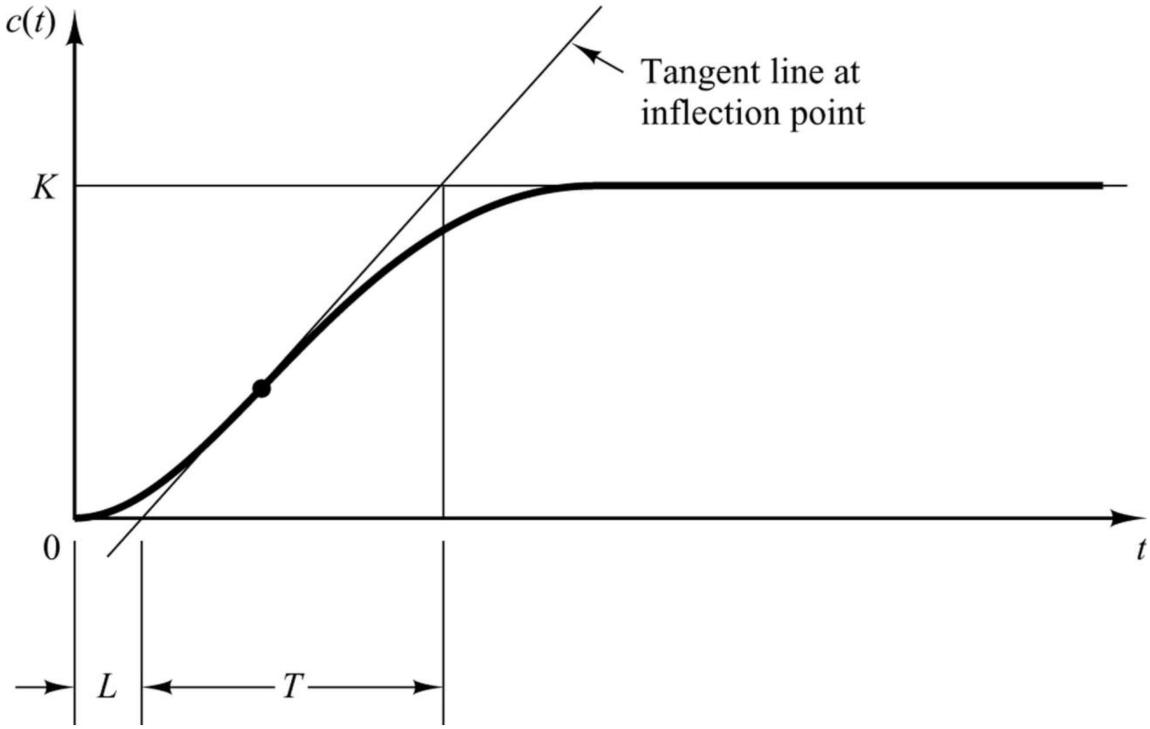
1.Explain the procedure for tuning of pid controller using ziegler Nicholas method.(nov10)

Closed loop tuning by Ziegler and Nichols:

Ziegler and Nichols conducted numerous experiments and proposed rules for determining values of K_P, K_I and K_D based on the transient step response of a plant.

They proposed more than one methods, but we will limit ourselves to what's known as the first method of Ziegler-Nichols in this tutorial. It applies to plants with neither integrators nor dominant complex-conjugate poles, whose unit-step response resemble an S-shaped curve with no overshoot. This S-shaped curve is called the reaction curve.

Ziegler–Nichols Tuning 1st Method S-shaped Step Input Response Curve



The S-shaped reaction curve can be characterized by two constants, delay time *L* and time constant *T*, which are determined by drawing a tangent line at the inflection point of the curve and finding the intersections of the tangent line with the time axis and the steady-state level line.

Ziegler–Nichols Tuning Rule Based on Step Response of Plant (First Method)

Type of Controller	K_p	T_i	T_d
P	$\frac{T}{L}$	∞	0
PI	$0.9\frac{T}{L}$	$\frac{L}{0.3}$	0
PID	$1.2\frac{T}{L}$	$2L$	$0.5L$

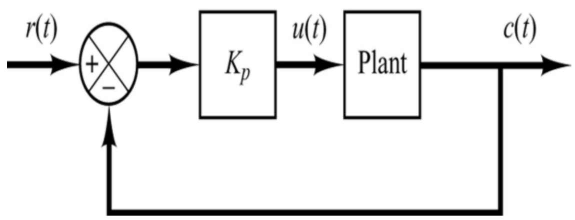
Ziegler-Nichols Method: More than six decades ago, P-I controllers were more widely used than P-I-D controllers. Despite the fact that P-I-D controller is faster and has no oscillation, it tends to be unstable in the condition of even small changes in the input set point or any disturbances to the process than P-I controllers. Ziegler-Nichols Method is one of the most effective methods that increase the usage of P-I- D controllers.

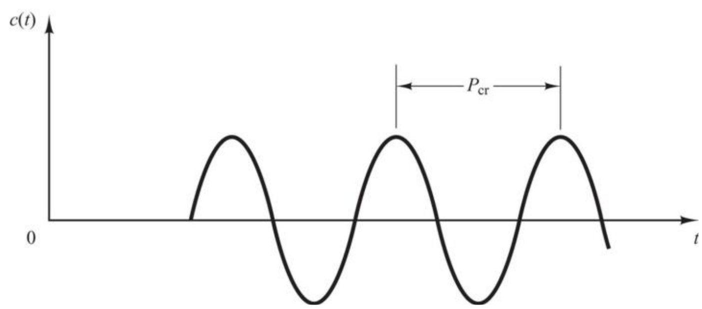
Ziegler–Nichols Tuning, Second Method

•Start with Closed-loop system with a proportional controller.

•Begin with a low value of gain, KP

•Potential of this method to go unstable or cause damage.





The most often technique for closed loop technique was developed by the Ziegler and Nichols technique in 1942. The following steps illustrate the procedure to find the ultimate gain and ultimate period.

1. Set the integral and derivative constants to its maximum value i.e Ti is large and Td is „0" by leaving the proportional value. Maintain the controller in auto mode with closed loop.
2. Set the proportional constant to some arbitrary value and observe the response of the process by giving some upset to the process. The best way to provide upset to the process is to increase the set-point for small time and return back to the original value.
3. If the response curve is does not damp out and gives a increasing decay ratio (as in curve A) , illustrates that the gain (Kp) is too high (Proportional Band (PB) is too low). The gain should be reduced (PB should be increased) and repeat the same step-2.
4. If the response curve dams out (as shown in curve C) at steady state then the gain is too low (PB is too high), the gain should be increased (PB should be reduced) and repeat the step-2.
5. The step-2 should be repeated by changing the proportional gain until the response of the closed loop is oscillatory (similar to curve B). i.e without damping and without increasing decay ratio. The values of the ultimate gain and ultimate period are noted if the response is similar as shown in curve B. The ultimate gain which results the closed loop response with sustained oscillation is the ultimate sensitivity Su and

   ultimate period is Pu.

The ultimate gain and ultimate period are used to calculate the controller settings as per the tuning method.

Ziegler and Nichols correlated in the case of proportional control that the value of proportional setting should be half of the ultimate sensitivity Su. This setting often provides a closed response with one quarter decay ratio in case of proportional controller. Same way by following equations are found out as good rules of thumb for better combination of controller parameters.

Proportional controller

$$Kc = 0.5\ Su$$

Proportional- Integral (PI)controller

$$Kc = 0.45\ Su$$

$$Ti = Pu / 1.2$$

Proportional – Derivative (PD) controller

$$Kc = 0.6\ Su$$

$$Td = Pu / 8$$

Proportional – Integral – Derivative (PID) controller

Kc = 0.6 Su

Ti = o.5 Pu

Td = Pu / 8

Again it should be that the above equations are empirical and inherent and chosen to achieve a decay ratio of one quarter.

2.What is cycling in the process output in which control mode it occurs.(may10)

Any PID controller will have Kp (Proportional) , Ki(Integral) abd Di (for Differential) you can Add one more constant for Feed forward Kf. Controller should give a constant output for a fixed input for a simple single input and single output system and multiple input single output system or whatever may the case. Now imagine if control input is changing constants Kp , Ki etc must be retuned again and it is more needed for Multiple input single output system and this tuning time is what i understand as cycling time.

In literatures critical cycling method , continuous cycle methods are mentioned as a technique to optimise control loop parameters.

3.A second order process with the transfer function of g(s)=5/(10s+1)(3s+1) is controlled by a proportional controller. Find the value of kp required offset due to unit step change in set point is 5% of steady state value of controlled variable.(may10)

4.Explain Various steps involved in process reaction curve method of tuning of controllers.(may09)
Explain the various time integral performance criteria with closed loop response.(may09)

Reaction Curve Technique

This is basically an open loop technique of tuning. Here the process is assumed to be a stable first order system with time delay. The closed loop system is broken as shown in Fig.2; a step input is applies at , output is measured at b. In fact, a bias input may be necessary so that the plant output initially becomes close to the nominal value. The step input is superimposed on this bias value. The input and the output response are plotted by suitable means as shown in Fig

Tuning Of Controller By Process Reaction Curve Method:

Developed by Cohen-Coon which has been opened by disconnecting the controller from the final control element.

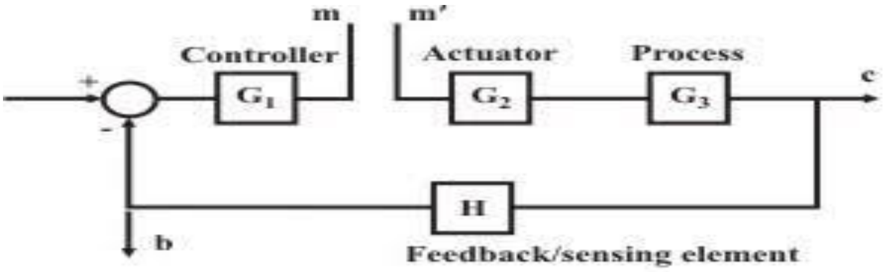
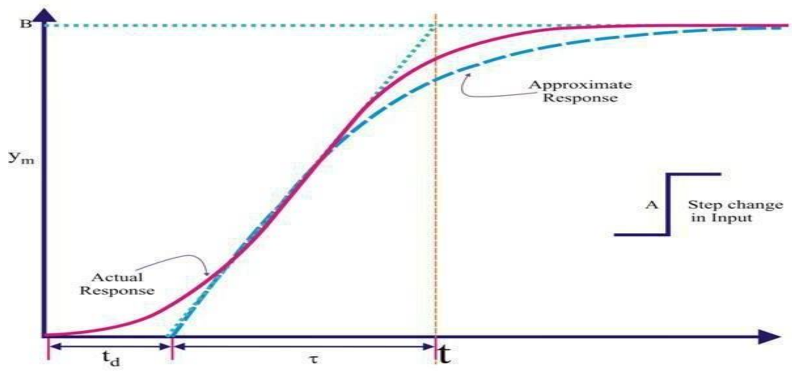


Fig. 2 Reaction curve technique for controller tuning.

It is observed that the response of most of the processes under step change in input yields a sigmoidal shape.



Process Reaction Curve for Cohen Coon Method

Such sigmoidal shape can be adequately approximated by the response of a first order process with dead time.

$$G_{PRC} = \frac{y_m(s)}{u(s)} \cong \frac{Ke^{-t_d s}}{\tau s + 1}\ ; \qquad K = \frac{B}{A}$$

=

S = slope of the sigmoidal response at the point of inflection

-time elapse until the system responded

K- static gain

-time constant

From the approximate response it is easy to estimate the parameters. The controllers are designed as given in Table

Controller settings using Cohen-Coon design method

	K_c	τ_I	τ_D
P	$\frac{1}{K}\frac{\tau}{t_d}\left(1+\frac{t_d}{3\tau}\right)$	–	–
PI	$\frac{1}{K}\frac{\tau}{t_d}\left(0.9+\frac{t_d}{12\tau}\right)$	$t_d\frac{30+3\,t_d/\tau}{9+20\,t_d/\tau}$	–
PID	$\frac{1}{K}\frac{\tau}{t_d}\left(\frac{4}{3}+\frac{t_d}{4\tau}\right)$	$t_d\frac{32+6\,t_d/\tau}{13+8\,t_d/\tau}$	$t_d\frac{4}{11+2\,t_d/\tau}$

Processes with very short time delay

- When is very small the process reaction curve reminds us of the response of a simple first order system

  The cohen coon setting dictate an extremely large value for the proportional gain.

(b) Time Integral performance criteria

The *error* in a control loop is usually defined as the deviation from setpoint. There are a variety of ways of quantifying the cumulative error:

- *Integral Squared Error*. Penalizes large errors more than small.

$$ISE = \int_0^{time} (e(t))^2\, dt$$

- *Integral Absolute Error*. The sum of areas above and below the setpoint, this penalizes all errors equally regardless of direction.

$$IAE = \int_0^{time} |e(t)| dt$$

- *Integral Time Weighted Absolute Error*. Penalizes persistent errors.

$$ITAE = \int_0^{time} t|e(t)| dt$$

IAE - allows larger deviation than ISE (smaller overshoots)

ISE - longer settling time

ITAE - weights errors occurring later more heavily

UNIT 4

PART A

1. Draw the block diagram of inferential control scheme?

Pg-439(stephanopoulous)

2. List the precautions to be taken while tuning the cascade control scheme?

i.determine the settings for the secondary controller using one of the methods(cohen-coon,Ziegler-Nichols or others employing time integral criteria or phase and gain margin considerations)

3. What is ratio control? Where is it needed?

Ratio control is special type of feed forward control where two disturbances are measured and held in a constant ratio to each other. It is used to control the flow rates of the two streams

4. What are the advantages and disadvantages of feedback and feed forward controllers?

Advantages : 1. Acts before the effect of a disturbance has been felt by a system.
2. Good for slow systems.
3. Does not introduce instability in closed loop response.

Disadvantages:1. Requires identification of all possible disturbances and their direct measurement
2. Cannot cope with unmeasured disturbance.
3. Sensitive to process parameter variations.
4. Requires good knowledge of the process model**.**

5. What are the advantages and disadvantages of cascade control?

The Cascade control is useful in reducing the effect of a load disturbance that moves through the control system slowly. This type of control gives very high performances than conventional control. the draw back of this type of control is the two loop should be tuned properly with fine tuning methods.

6. Define and explain the concept of feed forward control.

Feed forward control configuration measures the disturbance directly and takes control action to eliminate its impact on the process output. Therefore; feed forward controllers have the theoretical potential for perfect control.

7. Briefly explain about multivariable control.

When many inputs (manipulated variables) and many controlled variable (measured outputs) are present in a loop the multi variable control is suitable. The variables may be interacting, interconnecting and decoupling. This may be controlled by this method.

8. State the conditions for the cascade control to be effective.

Cascade control is useful in reducing the effect of a load disturbance that moves through the control system slowly since the inner loop has the effect of reducing the lag in the outer loop with the result that the cascade system results more quickly with a higher frequency of response. For cascade control process of the inner loop should be faster than the outer loop. For cascade control to be effective the control action of the inner loop is often proportional with the gain set to a high value. The action of the primary controller is generally PI or PID**.**

9. Give the applications of cascade control.

The cascade control are used in CSTR’s (Continuous Stirrer Tank Reactors), distillation column, value position control, boilers and etc.

10. What is meant by auctioneering control?

Such control configurations select among several measurements the onewith the highest value and feed it to the controller. Thus it is a selective controllerwhich possesses several measured outputs and only one manipulated input.

11..What is the advantage of cascade control over conventional control?

The cascade control has two loops. When any load changes the inner loop corrected before they affected the primary loop. This control gives high performance when the load is frequency changes. The tuning of the control is easy compared to conventional feedback control.

12. What are decouplers?

The special element introduced in a system with two strongly interactingloops to cancel the interaction effect between the two loops and thus render two non-interacting control loops is called decoupler.

13.What are the differences between Feed Forward and Feedback controllers?

Feed forward control	Feed forward control
1) It is useful for slow process.	It is unsatisfactory for slow processes
2) It does not introduce instability in the closed loop response.	It may create instability in the closed loop response
3) It requires identification of all possible disturbances and their direct measurement.	It does not require identification and measurement of any disturbance.
	It is insensitive to parameter changes
4) It is sensitive to process parameters	

14.State any two conditions under which the cascade control is much effective?

The cascade control is recommended whenever high performance is mandatory in the face of frequent load changes, where the secondary part of the process contains an undue amount of phase lag or non-linearity.

14. Differentiate between feedback and feedforward control.

Feed Back control: It is useful for slow process.
It does not introduce instability in the closed loop response.
It requires identification of all possible disturbances and their direct measurement.
It is sensitive to process parameters.

Feed forward control: It does not require identification and measurement of any disturbance. It may create instability in the closed loop response.
It is unsatisfactory for slow processes It is insensitive to parameter changes.

15.When the split range control is needed in a process?

In a split –range control we can control a single Process output by coordinating the actions of several Manipulated variables, all of which have the same effect on the controlled output. The split range control are used, when the additional safety and operational optimality whenever necessary.

16..What is inferential control? Give an example:

Inferential control uses secondary measurements to adjust the PV, as CV cannot be measured. An estimator in the inferential control computes the estimate of values of unmeasured cv from material and energy balance and the measured outputs.
Eg. Distillation column fig 2.2c pg. 17 Stephanopoulos

17. Describe split-range controller with an example.

In a split –range control we can control a single Process output by coordinating the actions of several Manipulated variables, all of which have the same effect on the controlled output. Eg: in a split range control of the pressure in a steam Header, several boilers discharge steam in a common Steam header and from there to the process needs .Here instead of controlling the steam flow from each boiler, the firing rate and steam production rate at each boiler is controlled .The control objective is to maintain constant pressure in steam header when steam demand at various processing units increase.

18. What is distillation?

Distillation separates a mixture on the basis of a difference in composition between a liquid and the vapor formed from the liquid. In the process industry, distillation is widely used to isolate and purify volatile materials.

19.List some of the variables which can be manipulated when controlling a distillation column.

a. Column pressure
b. Feed flow rate
c. Feed composition(or feed quality)
d. Heat added(boil-up)
e. Bottom product flow rate
f. Heat removed(reflux)
g. Distillate product flow rate

20. Why are fuel and air sent at a specified ratio into a combustion chamber?

Fuel & air are sent at a specified ratio into a combustion chamber in order to obtain complete combustion. (i.e., if the inflow increases the air ratio also increases & hence the input is min. & o/p is max).

PART B

1. What are the main advantages and disadvantage of cascade control for what kind of process can you employ cascade control.(nov 04)

2. What is split range control? Describe a situation when you could use split range control.(nov 04)

3. Explain feed forward control with an example from distillation column.(apr 06)

4. Justify the cascade control can give better performance then feedback controller(may 06).

5.. Describe an application which needs cascade control.(may 06).

6. Explain the difficulties involved in controlling multivariable system with example from distillation column.(may 06)

7. Explain the feed forward control with an example .compare feed forward controller with fed back controller. Also bring out its merits and demerits.(may 12)

8. A cascade control system is shown in fig. Calculate the maximum gain and critical frequency of the primary controller? Eliminating the inner loop compare these valves the single loop system. Use bode plot technique.(may 12).

9. Explain the concept of ratio control with an example.(nov 12)

10. Explain the application of feed forward control and cascade control in distillation column.(nov 12)

1. What is cascade control? Explain need for cascade control with an example. When do you prefer cascade control mode (may09)

2. What is the need for inferential control? Explain the method finding the estimate for a process needs interferential control.(may09)

3. Explain the design of cascade scheme for a system of our choice from the fundamental. What are the precaution taken to tuning of cascade control loop.(may10)

4. Explain the block diagram of cascade control and adaptive control. List the advantages and disadvantages of feed forward control scheme.(dec10)

5. With the block diagram explain the operation of split range control scheme.(dec10)

6. Explain the feed forward control with an example. Compare this with feedback control. Also bring out this merits and demerits.(may12)

7. Discuss the procedure for setting controller parameters using frequency response method.(nov12)

8. Explain the method of process reaction curve and damped oscillations for tuning the controllers.(nov12)

9. Explain how to find the controller settings using process reaction curve.(nov13)

UNIT 5

PART A

1. Why are the installed characteristics of control valve differ from its inherent characteristics?
Inherent Characteristics (ideal):

The control valve acts like an orifice and the position of the plug decides the area of opening of the orifice. The flow rate through an orifice can be expressed in terms of the upstream & downstream static pressure heads as:

$$Q=k1a\ (2g(h1-h2))^{1/2}$$

Q=flow rate in m3/sec
K1=flow coefficient
A=area of the control valve opening in m2
H1=upstream static head of the fluid in m
H2= downstream static head of the fluid in m

Installed Characteristics (Effective):
When valve are installed with pumps,piping and fitting,and other process equipment,the Pressure drop across valve will vary as the plug moves through its travel.

2. What is the function of valve positioner?

The valve positioner are use to minimize the effect of lag in large-capacity actuators, stem friction due to tight stuffing boxes, friction due to viscous or gummy fluids, process line in pressure changes.

3. What is the function of an actuator? What are the different types of actuators?

An Actuator is used to translate the output signal of the automatic controller into a position of a member exerting large power and often it is employed as a power amplifying mechanism. Different types of actuators used in control valve are pneumatic actuators, hydraulic actuators, electro-pneumatic actuators, and electric motor actuators.

4. What are the advantages and disadvantages of pneumatic actuator over other actuators?
The pneumatic actuator is used in wide range of pressure. The pneumatic signal is easily available which can transmit quite long distance without and transmission losses. No wear and tear problem is needed as in hydraulic actuators. The main drawback in pneumatic actuators is it requires signal conversion when the process is automated. This type of actuators is dependable and difficult in construction.

5. Define range-ability of a control valve.

The range ability of a control valve is the ratio of maximum controllable flow to minimum controllable flow.

6. What are the advantages and disadvantages of rotary type motion valves over linear stem motion type valves?

The rotary type stem motion valve is providing high capacity flow with minimum pressure drop. They are used to handle slurries or fibrous materials. They require minimum space for installation and they are used in low pressure services. The rotating type valves have low leakage tendency and the range ability is limited.

7. What are the different types of process parameters to be considered in selection of control valves?

Different types of process parameters to be considered in selection of control valves are the pressure drop across the value, range ability, flow rate coefficient, control valve size and etc.

8. What are the different types of factors to be considered in control valve sizing?

The proper sizing of the control valve is important because of the effect on the operation of automatic controllers. if the control valve is oversize, for eg, the valve must operate at low lift and the minimum controllable flow is too large. In addition, the lower part of the flow-lift characteristics is most likely to be non-uniform in shape. On the other hand if the control valve is undersize, the maximum flow desired for a process may not be provided.

9. Differentiate flashing and cavitations in a control valve.

In a control valve when the pressure at venacontracta goes below the vapour pressure and also at the pressure is below the liquid vapour pressure. So the fluid enters the port as a liquid & comes out as a vapour. This phenomenon is called Flashing. It occurs in a valve when the pressure drop across the orifice first results in the pressure is being lowered to below the liquid's vapour pressure and then recovering to above vapour pressure. This pressure recovery causes on implosion or collapse of the vapour bubbles formed at the venacontracta. This Phenomenon is called Cavitation.

10. What are the different types of flow-characteristics of a control valve?

The flow lift characteristics of a control valve fall into three approximate categories

a. Decreasing sensitivity type
b. Linear type
c. Increasing sensitivity type.

11. What do you mean by Flashing?

In a control valve when the pressure at venacontracta goes below the vapour pressure and also at the pressure is below the liquid vapour pressure. So the fluid enters the port as a liquid and Comes out as a vapour. This phenomenon is called Flashing

12. When a Butterfly valve is used?

The butterfly valve is most often used in sizes from 4 to 60 inch for the control of air and gas. It is also used for liquid flow if the pressure differential is not large.

13. Relate valve flow coefficient and liquid flow rate.

For control valve the flow rate is given by $\mathbf{m = K_a \sqrt{2g(h1 - h2)}}$

where m – flw rate ft^3 / sec
K_1 – a flow coefficient
a – area of control valve port, ft^2.
g = acceleration sue to gravity, ft/ sec^2.

h_1 – upstream static head of flowing fluid, ft
h2 – downstream static head of flowing fluid, ft

14. Mention the two distinct characteristics of an equal percentage valve.

The equal %valve has increasing sensitivity and linear Characteristics. When the valve pressure drop is small or when the process gain decreases with increasing flow this valve can be used.

15. What is the function of the spring in a control valve?

The spring is used to bring back the actuator in static position. The spring develop Inertia and static force which may use to get the force balance in control valve.

16. What are I/P and P/I converter? State the stand and valves for P and I in instrumentation practice.

I/P and P/I converter are signal converters which are use to convert current to pneumatic and vise versa in process system. The standard Pneumatic value is 3 – 15 psi and the current is 4 – 20 mA DC.

17. What is meant by cavitation in a control valve?

It occurs in a valve when the pressure drop across the orifice first results in the pressure being lowered to below the liquid's vapour pressure and then recovering to above vapour pressure. This pressure recovery causes on implosion or collapse of the vapour bubbles formed at the venacontracta. This Phenomena is called Cavitation

18. Why is equal % valve mostly used in process industries?

The equal %valve has increasing sensitivity and linear Characteristics. When the valve pressure drop is small or when the process gain decreases with increasing flow this valve can be used.

19. What is meant by cavitation and flashing in a control valve?

Flashing: In a control valve when the pressure at venacontracta goes below the liquid vapour pressure the fluid enters the port as a liquid & comes out as a vapour. **Cavitation**: It occurs in a valve when the pressure drop across the orifice first results in the pressure is being lowered to below the liquid's vapour pressure and then recovering to above vapour pressure. This pressure recovery causes on implosion or collapse of the vapour bubbles formed at the venacontracta.

20. List the merits and demerits of using a positioner in a control valve?

Merits: Hysteresis is reduced and linearity is improved, Actuator can handle higher static forces and speed of response is improved.

Demerits: Does not improve the ability of actuator to handle inertia or thrust forces. Requires maintenance.

PART B

1. Write the flow equation of a equal percentage valve and sketch its inherent valve characteristics (may 12)
2. With necessary diagram, explain the characteristics of control valves.(nov 13)
3. Explain the procedure for control valve sizing for a flow control system.(nov 13)
4. Explain the principles of working and construction of I/P converter.(nov 12)

5. Explain in detail the various control schemes used for binary distillation column(may 10)
6.. With the help of the neat diagram describe the operation of
A. Heat exchanger
B.drying process
7. Draw a neat sketch of pneumatic actuated control valve with positioned and explain its working.(dec 10)
8. Explain cavitations and flashing effect. (apr 06)
9. Explain the principle of direct and reverse acting pneumatic actuators with a neat sketch.(may 09)
10. Write short notes on the following. (may 10 &dec 10)
a.) valve sizing
b.) cavitations and flashing
c.)I/P converter.