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Tuning of PID Controller for FOPDT and SOPDT Systems

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***Abstract*—Due *to* the ease implementation, the simple mechanism and robustness of PID controllers has made it the most used controllers in the process industries. There are numerous tuning techniques are available for tuning of PID controllers. In this research work, in the first part basically a first-order plus dead time (FOPDT) model is designed and consequentlytuning of PID controller is done by using the Ziegler -Nichols method and in second part, a second-order plus dead time (SOPDT) model is developed and tunning of PID controller is done by using the root locus method.**
In Root-Locus method poles are allocated in such a way that model poles are cancelled out by controller zeros, but exact cancellation is not possible. Since the controller cancels out the model poles which are nearest to its exact value, hence an approximation is done to cancel the model poles and to determine damping ratio and the time constant. In this technique, the higher order system (oscillatory and non-oscillatory) with delayed input is reduced into a second order system and then tuning is done. Here in this work, the damping ratio and the time constant is also calculated to improve the speed of the response. TheRouth-Hurwitz criterion is also usedto find the value and range of the dc gain k to design a stable system. In this paper a quantitative and comparative analysis of the original higher order systems and the reduced FOPDT and SOPDT systems (modelled by Ziggler-Nicholas and Root-Locus technique respectively), is also donefor the various parameters like, settling time, rise time, transient time, peak overshoot, peak time etc. and then the unit step response for both the systems has been plotted and analyzed.

***Index Terms*-FOPDT, SOPDT, PID Controller, Ziegler Nichols, Root Locus, settling time, tuning, rise time, Peak overshoot.**

I.INTRODUCTION

PID controller, as name suggests is a combination of 3 gain parameters, namely P-Proportional, I-Integral and D- Derivative gain parameters. These three elements control all the processes in the process industries [1].The PID controller as a whole change the dc gain, increases the order of the system, reduces the steady state error, increase the stability and improve the transient response of the system.

II.OBJECTIVE AND MOTIVATION FOR TUNING OF PID CONTROLLERS

Since the last few decades, a lot of research work has been done because of the growing popularity into process control industries. In very early nineties century Ziegler-Nichol [2] gave tuning procedure for PID controller, after that a large number of methods have been used and developed to tune PID controller for getting good results. Because of high requirement of best tuning procedures which tune the plant in such a way that could provide optimized solution, many tuning methods have been developed so far in which some methods give better response to improve the speed of the system and some show good response for stability. Thus, maximum methods are application oriented. Some important methods of tunning of PID controller are: Tuning method of PID controllers for desired damping coefficient [3], Tuning of PID controller by D-partition rule [4],and Tuning of PID controller using immune algorithm [5], etc.

III.TUNNING OF PID CONTROLLER FOR FOPDT PROCESS

Herethe tuning of PID controller is done by using Ziegler-Nichols's method. In this method the higher order system with delayed input is reduced into a FOPDT process and consequently the tuning is done.

3.1 ZIEGLER-NICHOLS'SMETHOD

This is the oldest and simplest method used for tuning of FOPDT process. In this method first, the higher order system is modeled into a FOPDT process and then the three parameters of PID controller are calculated by using some empirical formulas [2].

Let us consider the first-order plus delay time process with transfer function,

$$G(s) = \frac{ke^{-st_0}}{1+Ts} \qquad (1)$$

There are three unknown parameters k, T and t_0 in Eq.1.These unknowns have been calculated using the stated method. The MATLAB tool is being used here to model a higher order system into FOPDT system. To model this, the following steps are followed-

(i) First the step response of the given higher order system is plotted using MATLAB tool.

(ii) A tangent to the curve (step response) is drawn and its cuts x-axis. The distance from origin to the point where the tangent cuts the x-axis ismeasured; it is the time delay parameter t_0 of FOPDT process.

(iii)A perpendicular line to x-axis and touching the tangent (at starting point of tangent) is drawn and measure the distance from origin to the point where this perpendicular line cuts x-axis, let this distance beT_1. The time constant T of the FOPDT process is given by Eq. 2,

$$T = T_1 - t_0 \qquad (2)$$

(iv) The dc gain k is calculated using Eq. 3, G (0) =k (3)

(v) The controller parameters are calculated using the following empirical formulae [2];

Experimentally the tuned gain parameter 'a' [2], related to proportional gain parameter K_p and is given by,

$$\frac{kt_0}{T} = a \quad (4)$$

And the value of K_p is given by Eq. 5,

$$K_p = \frac{1.2}{a} \quad (5)$$

Now let τ_i is the tuned time constant parameter related to integral gain parameter K_I and it is given by [2] Eq. 6,

$$\tau_i = 2t_0 \quad (6)$$

And the integral gain parameter K_I is given by [2] the Eq.7,

$$K_I = \frac{K_p}{\tau_i} \quad (7)$$

Now let τ_d is the tuned time constant parameter related to derivative gain parameter K_D and it is given by [2] Eq. 8,

$$\tau_d = \frac{t_0}{2} \quad (8)$$

And the derivative gain parameter K_D is given by [2] the Eq. 9,

$$K_D = K_p \tau_d \quad (9)$$

IV MODEL REDUCTION TECHNIQUE FOR SOPDT PROCESS

In this Section Model reduction technique is discussed for modelling of higher order system into a SOPDT system and subsequently tuning of PID controller is done by using Root-Locus technique is discussed in next section.Tuning of PID controller by using the root locus method is simple and result oriented for any systems; whether it is the high order or low order, high delay time or low dead time, the oscillatory or non-oscillatory.

Several methods have been developed and used to find out PID controller parameters for SISO (single input single output) and multiple input multiple output (MIMO) systems [6-7], but maximum of these tunning methods are developed for any specific applications [8-11] hence can be used only for the particular application, but the Root Locus technique is a general tunning method and can be used for several applications in process control industries.

Let us take a SOPDT (second order plus dead time) system for getting the best results after tuning. In this method, first of all, the higher order system is reduced into a second order system by using the model reduction technique. For this, if we put s=jw, then the complex variable is divided into two parts and then angle condition is applied. In the FOPDT model for the monotonic (non oscillatory) system, we cannot generate peaks, but it is possible in case of the SOPDT system, also FOPDT have only real poles not imaginary poles. Hence, they are not able to generate peaks for oscillatory systems, so we are using here second order plus dead time system for PID tuning to get better results.

In SOPDT systems, closed loop poles are selected according to the delay to time constant ratio, damping ratio and delay time model hence in this system we have more satisfactory results compare to other methods.

4.1 Higher Order Reduction Method

Consider the closed single loop controller feedback system as shown in Fig.1.

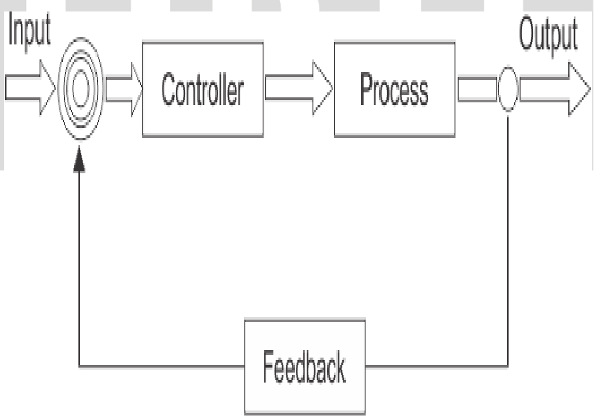

Fig.1: Single loop controller feedback system

Let us consider the SOPDT model process with the transfer function G(s) given by Eq. 10,

$$G(s)=\frac{1}{as^2+bs+c}e^{-st_0} \quad (10)$$

Depending upon the values of a, b, and c, this model can be characterized into real or complex poles. Hence it is easy to represent both the systems non-oscillatory as well as oscillatory.

A PID controller is given by Eq. 11,

$$K(s) = K_P + \frac{K_I}{s} + K_D s \quad (11)$$

Our aim is to calculate K_P , K_I and K_D in such a way that it improves the response of the system and will give a satisfactory results.

In Eq. 10, put s=jw, then divide it into two parts that is real and imaginary part. We need four equations to find out four unknowns a, b, c andt_0. For this we are calculating phase of the gain G(s) at two nonzero different frequency points w_b and w_c such that ∠G (jw_b) =$-\frac{\pi}{2}$ and ∠G (jw_c) = $-\pi$. Here we are taking two non-zero frequency points on negative real axis as we are considering the poles are located in negative half of s-plane for the stable system.

By putting s=jw in Eq. 10, we have,

$$G(jw) = \frac{1}{-aw^2+jwb+c} e^{-jwt_0} \quad (12)$$

Calculating the phase angle of G(s),

$$\angle G(jw) = -\tan^{-1}\left[\frac{wb}{(c-aw^2)}\right] - wt_0 \quad (13)$$

In Eq.13, putting the condition, ∠G(jw_b) =$-\frac{\pi}{2}$ and ∠G(jw_c)= $-\pi$ and solving the trans-dental Eq.13, we can calculate w_b and w_c.

With condition, ∠G(jw_c)= $-\pi$, we get the equation,

$$(c-aw_c^2)\sin(w_c t_0) + b\, w_c \cos(w_c t_0) = 0 \quad (14)$$

And with condition ∠G(jw_b) =$-\frac{\pi}{2}$, we get the equation,

$$(c-aw_b^2)\cos(w_b t_0) + bw_b \sin(w_b t_0) = 0 \quad (15)$$

Eq. 13, Eq.14 and Eq. 15 are useful to calculate w_b and w_c .

Now magnitude of G(jw), $|G(jw)| = \frac{1}{\sqrt{[(c-aw^2)^2+b^2w^2]}}$ (16)

We have to calculate the 4 variables a, b, c and t_0 so we need 4 equations.

Now calculating the magnitude of G(jw) at w_c and w_b, we get,

$$|G(jw_c)| = \frac{1}{\sqrt{[(c-aw_c^2)^2+b^2w_c^2]}} \quad (17)$$

$$|G(jw_b)| = \frac{1}{\sqrt{[(c-aw_b^2)^2+b^2w_b^2]}} \quad (18)$$

Using above equations and after some simple calculations we get,

$$(c-aw_c^2) = -\frac{1}{|G(jw_c)|}\cos(w_c t_0) \quad (19)$$

$$(c-aw_b^2) = \frac{1}{|G(jw_b)|}\sin(w_b t_0) \quad (20)$$

$$bw_c = \frac{1}{|G(jw_c)|}\sin(w_c t_0) \quad (21)$$

$$bw_b = \frac{1}{|G(jw_b)|}\cos(w_b t_0) \quad (22)$$

From Eq. 21 and Eq.22, we can calculate unknown b as,

$$b = \frac{1}{|G(jw_c)|\, w_c}\sin(w_c t_0) = \frac{1}{|G(jw_b)| w_b}\cos(w_b t_0) \quad (23)$$

And we calculate a and c as,

$$a = \frac{1}{|w_c^2-w_b^2|}\left[\frac{\cos(w_c t_0)}{|G(jw_c)|} + \frac{\sin(w_b t_0)}{|G(jw_b)|}\right] \quad (24)$$

$$c = \frac{1}{|w_c^2-w_b^2|}\left[\frac{\cos(w_c t_0) w_b^2}{|G(jw_c)|} + \frac{\sin(w_b t_0) w_c^2}{|G(jw_b)|}\right] \quad (25)$$

To calculate, t_0 we use Eq. 21 and Eq. 22,

$$b = \frac{1}{|G(jw_c)|\, w_c}\sin(w_c t_0) = \frac{1}{|G(jw_b)| w_b}\cos(w_b t_0) \quad (26)$$

From Eq. 26, let us assume; $A = \frac{\sin(w_c t_0)}{\cos(w_b t_0)} - \frac{w_c}{w_b}\frac{|G(jw_c)|}{|G(jw_b)|}$ (27)

Now expanding, sin ($w_c t_0$) and cos($w_b t_0$)upto second order polynomial and after solving with approximation we get a quadratic equation in t_0 as given below,

$$-0.34[w_c^2 - Aw_b^2]t_0^2 + [1.7w_c + A\,(0.11)w_b]t_0 - A = 0 \quad (28)$$

From Eq. 28, we can calculate delayt_0, here all the unknown a, b, c and $t_0$should be positive as we require a stable reduced 2nd order system. Also delay can't be negative hence $t_0$is always be positive.

V TUNNING OF PID CONTROLLER FOR SOPDT PROCESS

For tuning of the PID controller, we will first calculate the range k (dc gain) for which system is stable; it can be done by using Routh-Hurwitz criterion.

5.1 CALCULATION OF RANGE OF DC GAIN (k)

There is a range of dc gain k for which the system is stable and we want a stable system hence we only tune PID controller for the given system in the calculated range of dc gain k. Assume PID controller transfer function in terms of dc gain is given below,

$$K(s) = \frac{k}{s}(\alpha s^2 + \beta s + \mu) \quad (29)$$

Where K(s) is the controller transfer function.

We choose the controller zeros which cancel out model poles that implies, α= a, β= b and μ = c. Here a, b and care the values which are calculated by using Eq. 23, Eq. 24 and Eq. 25.

Comparing Eq. 11 & Eq.29, we can write the proportional, integral and derivative constants of PID controller as,

K_P =kβ, K_I=kμ and K_D =kα (30)

Refer to Fig .1, the system is unity feedback hence H(s) =1, and assume process gain,

$G(s)=\frac{e^{-st_0}}{s}$ (31) Now the characteristics Equation (refer to Fig. 1) is,

$$1+G(s)H(s)K(s)=0 \quad (32)$$

From Eq.29, Eq.31 &Eq. 32, we can write the characteristics equation as,

$$1+\frac{e^{-st_0}}{s}\frac{k}{s}(\alpha s^2+\beta s+\mu)=0 \quad (33)$$

Here to calculate characteristics equation we approximated the delay term,

$$e^{-st_0}=\left[\frac{(1-\frac{st_0}{2})}{(1+\frac{st_0}{2})}\right] \quad (34)$$

Now from Eq. 33 & Eq. 34 we can write the characteristics equation given by Eq.35,

$$(t_0-at_0k)s^3+(2ak+2-bt_0k)s^2+(2bk-t_0ck)s+2ck=0 \quad (35)$$

Now applying Routh Hurwitz criteria and taking all the elements of first column in Routh table of the same sign we can show that the range of value of k for a stable system is given by Eq. 36,

$$k\leq\frac{b}{t_0} \quad (36)$$

5.2 CALCULATION OF TIME CONSTANT (τ)

From Eq. 10, the pole location can be calculated by solving the equation,

$$as^2+bs+c=0 \quad (37)$$

Calculating the poles' location,

$$s_{1,2}=-b\pm\sqrt{(b^2-4ac)}/2a \quad (38)$$

The speed of response of any process is inversely proportional to its equivalent time constant and it is given by the inverse of real part of the pole location i.e.,

$$\tau=\frac{1}{Re(pole\ location)} \quad (39)$$

Hence, the value of the time constant depends on real part of the pole and will always be a positive value, and it depends on the value of (b^2-4ac), so from Eq. 39, it can be shown that,

If, $b^2-4ac=0$ then time constant,

$$\tau=\frac{2a}{b}$$

And the equivalent time constant [12] can be calculated as,

$$\frac{1}{\tau}=\begin{cases}\frac{b}{2a}, if\ (b^2-4ac)\geq 0\\ \frac{c}{\sqrt{b^2-2ac}}, if\ (b^2-4ac)<0\end{cases} \quad (40)$$

5.3 CALCULATION OF DAMPING RATIO (ξ)

Compare Eq. 37 with 2nd order system's general equation $s^2+2\xi w_n s+w_n^2=0$

It can be shown that,

$$w_n=\sqrt{\frac{c}{a}}$$

$\xi=\frac{b}{2\sqrt{ac}}$ for complex poles (i.e., $(b^2-4ac<0)$)

And for real poles ($(b^2-4ac)\geq 0$), we are assuming a critically damped system (ξ=1).

Hence Equivalent damping ratio [13] is given by,

$$\xi=\begin{cases}1, if\ (b^2-4ac)\geq 0\\ \frac{b}{2\sqrt{ac}}, if\ (b^2-4ac)<0\end{cases} \quad (41)$$

Here the model poles have to be cancelled out by controller zeros, but exact cancellation may not possible so we approximate the zero to the nearest of model poles. For a process with a damping ratio less than one, un-cancelled dynamics may provide the heavy oscillations so it is not desirable to create one more oscillatory term in the system, but we can choose the real part of the close loop pole. For monotonic (non-oscillatory) processes, un-cancelled dynamics do not create the process over oscillation so selection of close loop pole will give a better result. Based on this, Four cases are considered to calculate the value of k in terms of ξ. Taking ξ=0.7071 as reference here.

Case (1) ξ>0.7071

In this case, both real and imaginary poles on the root locus can be chosen.

Considering 2nd order plus delay time systemwith open loop transfer function,

$$G(s)H(s)=\frac{kw_n^2}{s(s+2\xi w_n)}e^{-st_0} \quad (42)$$

Having pair of complex poles, $s_{1,2}=-\xi w_n\pm jw_n\sqrt{1-\xi^2}$

To find the dc gain using root locus method here the magnitude condition [13] is used i.e.,,

$$|G(s)H(s)|=1 \quad (43)$$

Here we can calculate the approximate value of k as,

$$k=w_n e^{-\xi w_n t_0} \quad (44)$$

Here, the pair of complex poles and real pole should be on root locus, we can calculate the value of w_n by using phase condition of root locus [13] that is,

$$\angle G(s)H(s)=\pm(2n+1)\,\pi$$

Or, $$-\tan^{-1}\frac{w}{2\xi w_n}-\frac{\pi}{2}-wt_0=\pm(2n+1)\pi$$

At w=w_n with the given value conditions of ξ, we have,

$$w_n=\frac{\cos^{-1}(\xi)}{t_0\sqrt{1-\xi^2}} \quad (45)$$

Putting $\xi = 0.707$, we have,

$$w_n = \frac{1.10}{t_0} \quad (46)$$

From Eq. 44 & Eq. 45, it can be shown that,

$$k=\frac{0.5}{t_0} \quad (47)$$

Case (2) $\xi \le 0.7071$ & $0.15 < \frac{t_0}{\tau} < 1$

In this case there may be 2 real closed loop poles and a pair of complex poles.

$\because 0 < \xi < 1 \Rightarrow (b^2 - 4ac) < 0$

$\Rightarrow \frac{1}{\tau} = \frac{c}{\sqrt{b^2-2ac}}$,

Now from Eq. 44, we can calculate,

$$k=\frac{1}{\tau}e^{-\frac{t_0}{\tau}} \quad (48)$$

Case (3) $\frac{t_0}{\tau} > 1$

In this case since ratio of delay to time constant is greater than 1, so the value of k is slightly greater than that in case 1.

From Eq. 48, we can calculate the approximate value of k as,

$$k=\frac{0.6}{t_0} \quad (49)$$

That is slightly greater than the value of k calculated in case 1.

Case (4) $0.05 < \frac{t_0}{\tau} < 0.15$

In this case the poles are complex $\Rightarrow 0 < \xi < 1$

For example, take ξ=0.5 & $\frac{t_0}{\tau}$ =0.10

From Eq. 48, we can calculate the approximate value of k as,

$$k=\frac{0.4}{t_0} \quad (50)$$

VI RESULTS AND DISCUSSION

In this section some examples have been taken and will demonstrate how to use these both methods Ziegler-Nichols's and Root - Locus techniques. Also, a comparative and quantitative analysis is done for original higher order system (for which PID tunning is done) and the reduced 2nd order system in terms of different parameters like, settling time, peak time, stability, overshoot and undershoot etc. These quantitative parameters are shown in table for a comparison. The simulation results of step response for both the system are also plotted for a comparative study and a better understanding.

6.1 ZIEGLER-NICHOLAS METHOD OF FOPDT PROCESS

In this section some examples are taken and the demonstration of Ziegler-Nichols's method for tunning of FOPDT model is done. Firstly, the original higher order system is modeled into a FOPDT process and then tunning is done by Ziegler-Nichols's technique.

EXAMPLE1: Let us consider a non-oscillatory system,

$$G(s) = \frac{1}{(s+1)^2(s+2)}e^{-0.3s}$$

DC gain k for modeled FOPDT process, k =G(0) =0.5

Figure 2, shows the step response and the demonstration of the Ziegler-Nichols's method for the given higher order system,

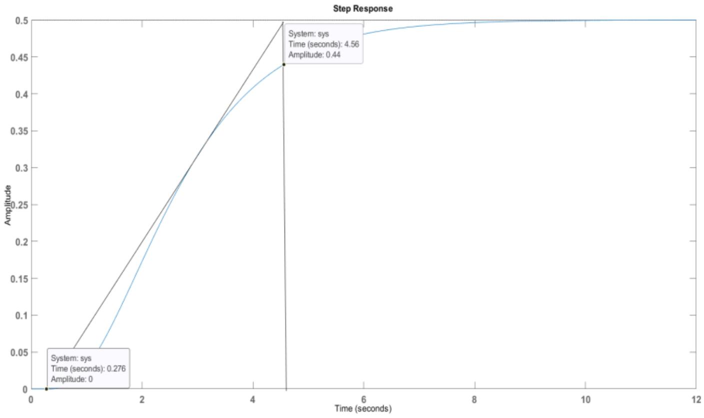

Fig. 2: Unit step response of the system $G(s) = \frac{1}{(s+1)^2(s+2)}e^{-0.3s}$

From **Fig. 2**, it is clear that, the time delay, t_0=0.276, the residential time, T_1=4.56, hence the time constant, T=T_1-t_0=4.284.
The modeled or reduced FOPDT system is given by Eq. 51,

$G_1(s) = k\frac{e^{-st_0}}{(1+Ts)}$=0.5 $\frac{e^{-0.276s}}{(1+4.284s)}$ (51)

Now value of a can be calculated by Eq. 4, a=0.032
Value of K_p is calculated by Eq. 5, K_p =37.25
Value of $\tau_i$is calculated by Eq. 6,τ_i=0.552
Value of K_I is calculated by Eq. 7, K_I =67.02
Value of $\tau_d$is calculated by Eq. 8, τ_d=0.138
Value of K_D is calculated by Eq. 9, K_D =5.140
Now the Required PID controller is given by Eq. 52,

K(s) =37.25+$\frac{67.02}{s}$ + 5.140s (52)

Cascading this controller with FOPDT process in forward path, the combined system is let denoted by C(s). Now the step response for this combined system C(s) with unity feedback is plotted in **Fig. 3**,

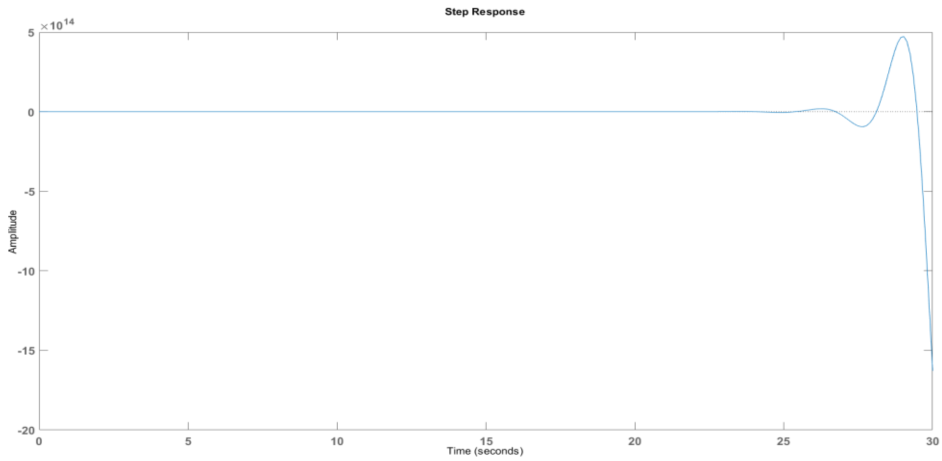

Fig. 3: Unit step response of the combined system $C(s)$

Clearly **Fig. 3** shows the undesirable and impractical result; hence we shifted towards root locus technique for tunning of PID controllers.
Figure 4, shows the step response of reduced or modeled FOPDT process,

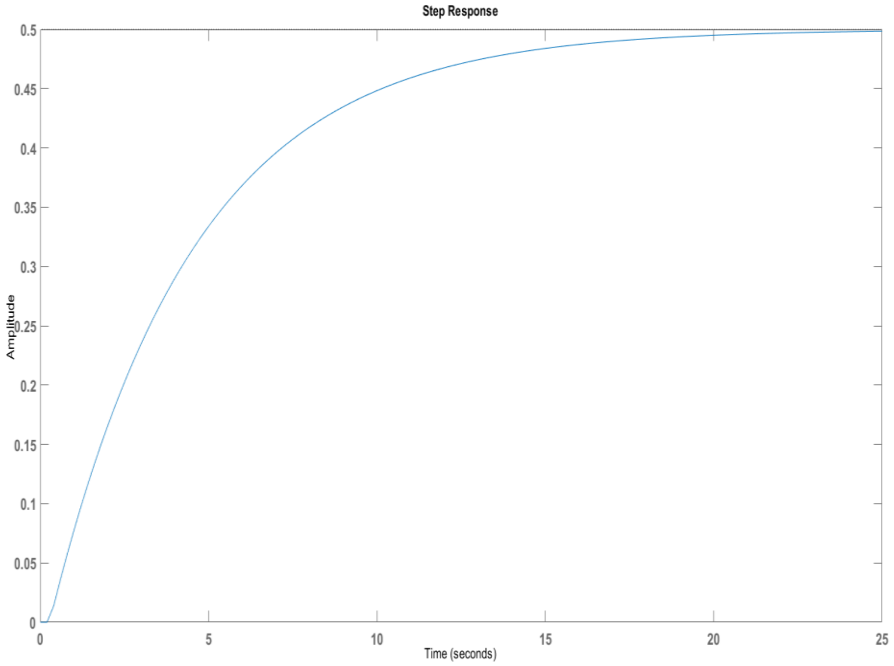

Fig. 4: Unit step response of the reduced FOPDT system $G_1(s)$=0.5 $\frac{e^{-0.276s}}{(1+4.284s)}$

QUANTITATIVE AND COMPARATIVE ANALYSIS

The comparative analysis of both systems is shown below in table 1,

Table 1:Response values for unit step input

Parameters	Response values for Higher order system G(s)	Response values for reduced FOPDT system G_1 (s)
Rise time	3.6132	9.413
Transient Time	6.7730	17.03
Settling Time	6.7730	17.03
Overshoot (%)	11	0
Undershoot (%)	0	0
Peak	0.500	0.499
Peak time	12.8484	33.34

From the above table it is clear that the stability of the reduced 1st order system is decreases but the percentage overshoot is decreases (advantage). Also for reduced system the rise time increases hence the transient response is not improved by use of this method.

6.2 ROOT-LOCUS METHOD FOR SOPDT PROCESS

In this section the higher order system is first modeled to reduced 2nd order PDT system then tunning is done using Root-Locus technique. The same example is taken to demonstrate the method and compare with Ziegler-Ncholas method.

EXAMPLE 1: Let us consider a non-oscillatory system,

$$G(s) = \frac{1}{(s+1)^2(s+2)} e^{-0.3s}$$

Here two points are calculated by the method is w_b=3.5 and w_c=1.56, and |G(jw_b)|=0.0187 and |G(jw_c)|=0.1148.

The model of the process or the reduced 2nd order system is given by,

$G_1(s)$=$\frac{1}{5.276\,s^2+4.469\,s+18.040}e^{-0.595s}$

And the PID parameter is calculated as,

$$K(s) = 1.425 + \frac{5.754}{s} + 1.683s$$

QUANTITATIVE AND COMPARATIVE ANALYSIS

The comparative analysis of both systems is shown below in Table 2,

Table 2: Response values for unit step input

Parameters	Response values for Higher order system G(s)	Response values for reduced 2nd order system G_1 (s)

Rise time	3.6132	0.6720
Transient Time	6.7730	5.8622
Settling Time	6.7730	5.8622
Overshoot (%)	11	7.533
Undershoot (%)	0	0
Peak	0.500	0.0818
Peak time	12.8484	2.392

From the above table it is clear that the stability of the reduced 2nd order system is more because settling time of the model is smaller and rise time is very much less than higher order system hence the transient response is improved in reduced 2^{nd} order system. Also, the reduced 2^{nd} order system is a better system because of having smaller peak time and peak overshoot than higher order system.
The unit step response for both the systems G(s) and G_1(s) is shown below in **Fig. 5** and **Fig. 6** respectively,

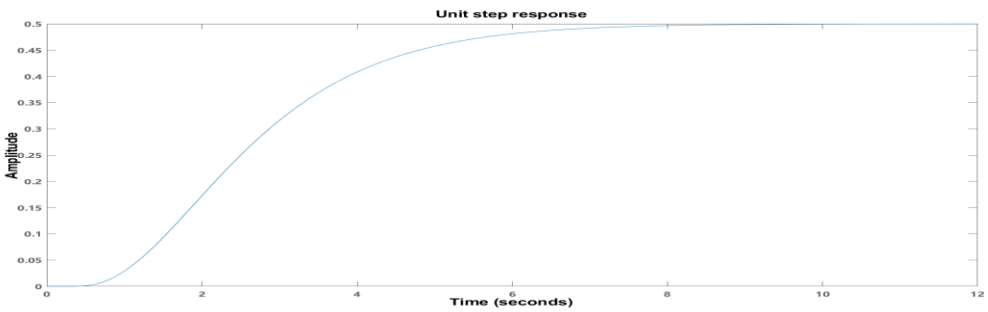

Fig. 5: Unit step response of the system $G(s) = \frac{1}{(s+1)^2(s+2)} e^{-0.3s}$

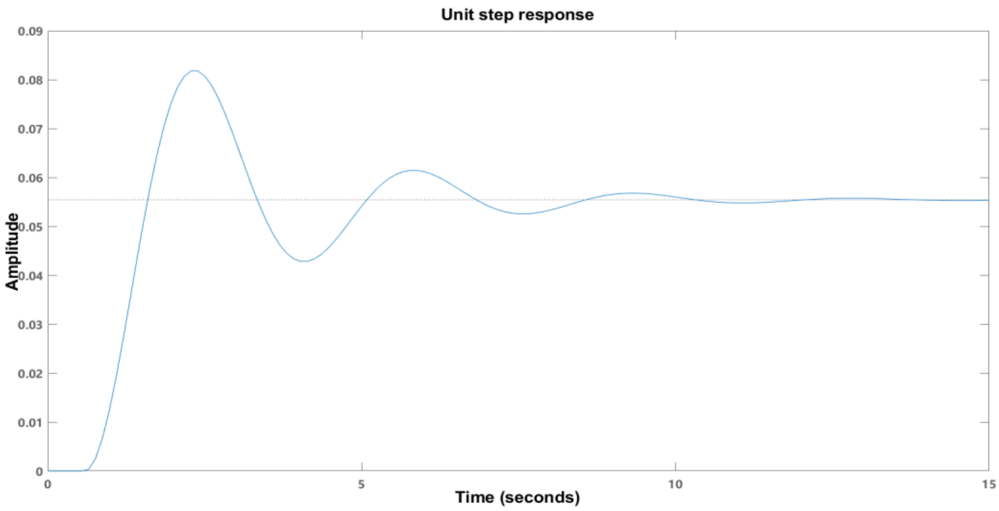

Fig. 6: Unit step response of the system, G_1(s)=$\frac{1}{5.276\,s^2+4.469\,s+18.040} e^{-0.595s}$

VII ACKNOWLEDGEMENT

In this research work, the main focus has been given towards the applications of tuning of PID controllers for the higher order system to reduce the system order. In today's process control industries, the major attention is given to the development of those controllers which are most suitable and the best for application-based processes. There are several methods of tuning of PID controllers for FOPDT (First order plus dead time) systems, but the biggest problem of FOPDT tunning is that it is unable to generate peaks for monotonic systems. So, here tunning of PID controllers for SOPDT systems is done to find out the controller parameters. In this work the first part is carried out for a FOPDT process using Ziegler-Nichols Technique. In this method the higher order system is reduced into a FOPDT system and then tunning of PID controller is done. This method produced some undesirable results hence in the second part of this research work Root -Locus technique is used for modelling of SOPDT systems and PID tunning is done. In this method, angle conditionsareused in which two angle conditions are divided into four parts so that four variables (a, b, c and delay t_0) are calculated. Here in this method for the tuning, if model poles are monotonic (all poles lie in the negative half of s-plane and hence the system is stable) then un-cancelled dynamics do not produce any oscillations. The performance comparison for both the methods has been done and it is found that, The Root-Locus Technique for tuning of PID Controllers provides a satisfactory result over Ziegler-Nichols method. The results show that the Root-Locus method improves the speed and transient response and also increase the stability of the system.

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