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AN IMPROVED METHOD OF PID CONTROLLER TUNING FOR UNSTABLE SYSTEM WITH DEAD TIME USING IMPULSE INPUT

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ABSTRACT

Proportional-integral-derivative (PID) controllers tuning methods reported based on the approximate plant models derived from the step response. In this paper, an improved method proposed which based on the direct synthesis method approach (Maclaurin Series) using impulse input instead of step input. For unstable first-order process with dead time (FOUPDT) and second order process with dead time (SOUPDT) system in second order system there two conditions are considered i.e. One unstable and One stable Pole, Two Unstable Poles. Improved method is compare with other available methods for verifying the improved method. Controller tuning methods are compared each other i.e. Ziegler-Nichols method (Z-N) [6], C.T. Huang and Y.S. Lin (H-L) [2], Shamsuzzoha and Lee (S-L) [1], Q. Wang, C. Lu and W. Pan (W-P) [4], Poulin and Pomerleau (P-P) [3], Tayrus and Luyben (T-L) [10], Yongho Lee, Jeongesko Lee, Sunwon Park [7]. Two analysis (Time domain specification and Time integral performance) have observe for these controller tuning methods for finding the response of given methods, on the basis of these analysis methods are compared for FOUPDT and SOUPDT.

Keywords: Dead time, FOUPDT, IAE, ISE, ITAE, PID controller, SOUPDT, Tuning, Time constant

I. INTRODUCTION

Proportional-integral-derivative (PID) controllers have been widely used in process industries for decades. The major reasons for their wide acceptance in industries are their ability to control most of the processes, well-understood control action and ease of implementation. Proportional-integral-derivative (PID) controller has remained as commonly used controllers in industrial process control for 50 yr. even though great progress in control theory design and tuning of PID controllers has been the subject of many researchers working in this field. This because it has a simple structure and is easily understood by the control engineers (Luyben, 1990). As early as 1942, Ziegler and Nichols (1942) proposed the first PID tuning method. It is still widely used in practice at present. While high performance is always, the design target in industrial control applications and the Ziegler-Nichols method is insufficient in such applications. A survey of [8] Desborough and Miller reported that more than 97% of the regulatory controllers utilize the PI/PID algorithm. The PI/PID controllers have only few adjustable parameters, and are difficult to tune properly in real processes. Many researchers have provided PID controller settings for various process models and different performance criteria. All the tuning relations reported in literature based on the approximate plant models derived from the step input of the plant in this paper an improved method is developed for PID controller tuning which is based on the direct synthesis method (in which mathematical approach comes) by maclaurin series with impulse input. The common example of unstable system is the batch chemical reactor, which has a strong nonlinearity due to the heat generation term in the energy balance. In general, transfer function unstable processes are FOUPDT (Huang & Lin, 1995) [2] and SOUPDT having two different case; i) One unstable and One stable pole, ii) Two unstable poles (Yongho & Jeongesko Lee, 1999) [7] are given below,

FOUPDT: $G(s) = \dfrac{Ke^{-\theta s}}{(\tau s-1)}$

SOUPDT: i) One unstable and one stable pole: $G(s) = \dfrac{Ke^{-\theta s}}{(\tau_1 s-1)(\tau_2 s+1)}$

ii) Two unstable poles: $G(s) = \dfrac{Ke^{-\theta s}}{(\tau_1 s-1)(\tau_2 s-1)}$

In this paper, comparison of Ziegler-Nichols (1942) [6], C.T. Huang and Y.S. Lin (1995) [2], Shamsuzzoha and Lee (2007) [1], Q. Wang, C. Lu and W. Pan (2015) [4] methods are used for FOUPDT. Ziegler-Nichols (1942) [6], Tayrus and Luyben (1958) [10], C.T. Huang and Y.S. Lin (1995) [2], Poulin and Pomerleau (1996) [3] are used for SOUPDT (One unstable and One stable pole) and Yongho & Jeongesko Lee (1999) are used for (Two unstable poles). Time domain specification and Time integral performance of all methods are use for finding the best controller tuning method which gives better and higher stability for the process system. MATLAB 7.8 (2009), controller-designing software used in this work. Fig.1 classical feedback process diagram

II. DEVELOPMENT OF PID CONTROLLER SETTINGS

A PID controller designated by,

$$G(s) = K_P\left(1+\frac{1}{\tau_I s}+\tau_D s\right) \quad \text{……….. (A)}$$

Where, K_P = Proportional Gain, τ_I = Integral constant, τ_D = Derivative constant

For the best performance of the system, need to adjust these three parameters called controller tuning.

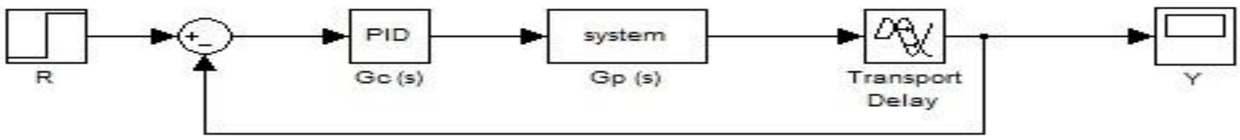

Fig.1 Classical Feedback Diagram

Consider the block diagram of feedback control system shown in Fig.1. The objective is to design a PID controller, $G_C(s)$ of Fig. 1 that will give the desired closed-loop response, Y/R, as specified by $G_D(s)$ which described by either FOUPDT or SOUPDT model. The actual closed-loop response of the control system in Fig.1 is denoted and given by $G_A(s)$ is,

$$G_A(s) = \frac{Y(s)}{R(s)} = \frac{G_C(s)G_P(s)}{1+G_C(s)G_P(s)} \quad \text{………… (1)}$$

Both $G_A(s)$ and $G_d(s)$ can represent by Maclaurin series expansion in

at $s = 0$ $G_A(s) = G_A(0)+sG_A'(0)+\frac{s^2}{2!}G_A''(0)+\frac{s^3}{3!}G_A'''(0)+$........... ………… (2)

$$G_d(s) = G_d(0)+sG_d'(0)+\frac{s^2}{2!}G_d''(0)+\frac{s^3}{3!}G_d'''(0)+.......... \quad .... (3)$$

Where the prime indicates the derivative with respect to s. Note that truncation of the series up to third-order term is sufficient to setup three independent equations to determine the PID controller parameters. For an ideal controller, the closed-loop response of the actual system results in the desired closed-loop response. Then by comparison, of (2) and (3) we have,

$$G_A(0) = G_d(0) \quad .... (4.1)$$

$$G_A'(0) = G_d'(0) \quad .... (4.2)$$

$$G_A''(0) = G_d''(0) \quad .... (4.3)$$

$$G_A'''(0) = G_d'''(0) \quad .... (4.4)$$

The PID controller parameters are to tune to satisfy all the equations in (4). Let us first derive the expressions for $G_A(0)$, $G_A'(0)$, $G_A''(0)$ and $G_A'''(0)$ for the actual system with a general transfer function for the process $G_P(s)$. It noted that no specific transfer function form assumed for the process.

Transfer function of PID controller from eq^n (A) written in the following form,

$$G_C(s) = \frac{K_C}{s}\tilde{G}_C(s) \quad .... (5) \qquad \text{Where } \tilde{G}_C(s) = \tau_D s^2+s+\frac{1}{\tau_I}$$

On substituting (5) in (1) we get,

$$G_A(s) = \frac{K_C\tilde{G}_C(s)G_P(s)}{s+K_C\tilde{G}_C(s)G_P(s)}$$

Defining $G_P(0) = -K_P$, carrying out the indicating differentiation, we get,

$$G_A(0) = 1 \quad .... (6.1)$$

$$G_A'(0) = \frac{-\tau_I}{K_C K_P} \quad .... (6.2)$$

$$G_A''(0) = 2\left(\frac{\tau_I}{K_C K_P}\right)^2\left[1+\frac{K_C G_P'(0)}{\tau_I}-K_C K_P\right] \quad .... (6.3)$$

$$G_A'''(0) = 3\left(\frac{\tau_I}{K_C K_P}\right)^2\left[\frac{K_C G_P''(0)}{\tau_I}+2K_C G_P'(0)-2K_C K_P\tau_D\right]+6\left(\frac{\tau_I}{K_C K_P}\right)^3\left[1+\frac{K_C G_P'(0)}{\tau_I}-K_C K_P\right]^2 \quad .... (6.4)$$

III. FOUPDT MODEL DESIRED RESPONSE

The desired FOUPDT model response given by the transfer function,

$$G_d(s) = \frac{e^{-\theta s}}{\tau s-1} \quad .... (7)$$

For the desired response $G_d(s)$ in (7), we can derive the following as,

$$G_d'(0) = -(\tau-\theta) \quad .... (7.1)$$

$$G_d''(0) = -(2\tau^2-2\theta\tau+\theta^2) \quad .... (7.2)$$

$$G_d'''(0) = (6\tau^3 - 6\theta\tau^2 - 3\theta^2\tau - \theta^3) \quad \text{......... (7.3)}$$

Substituting (6.2), (6.3), (6.4) and (7.1), (7.2), (7.3) in (4), and solving for PID controller parameters, after a tedious and lengthy algebra yields the following design formulae,

$$K_C = \frac{\tau_I}{K_P(\tau-\theta)} \quad \text{......... (8.1)}$$

$$\tau_I = \frac{\theta^2}{2(\tau-\theta)} + 2\tau - \theta - G_P' \quad \text{........ (8.2)}$$

$$\tau_D = \frac{3\tau\theta^2}{2\tau_I(\tau-\theta)} + \frac{\theta^3(2\tau+\theta)}{12\tau_I(\tau-\theta^2)} - \frac{G_P''}{2\tau_I} - G_P' \quad \text{....... (8.3)}$$

IV. SOUPDT MODEL DESIRED RESPONSE

There two processes are consider,

1. One Unstable and One Stable pole
2. Two Unstable pole

1. One unstable and one stable pole

The desired response given by,

$$G_d(s) = \frac{e^{-\theta s}}{(\tau_1 s-1)(\tau_2 s+1)} \quad \text{.......... (9)}$$

For the desired response $G_d(s)$ in (9) we have,

$$G_d'(0) = -(\tau_1 - \tau_2 - \theta) \quad \text{.......... (9.1)}$$

$$G_d''(0) = \theta^2 + 2(\tau_2 - \tau_1)\theta + 2\tau_2^2 - 2\tau_1\tau_2 + 2\tau_1^2 \quad \text{....... (9.2)}$$

$$G_d'''(0) = \theta^3 - 3(\tau_1 - \tau_2)\theta^2 + 6(\tau_2^2 - \tau_1\tau_2 + \tau_1^2)\theta + 6\tau_2^2(\tau_2 - \tau_1) + 6\tau_1^2(\tau_2 + \tau_1) \quad \text{.......... (9.3)}$$

Substituting (6.2), (6.3), (6.4) and (9.1), (9.2), (9.3) in (4), and solving for PID controller parameters, after a tedious and lengthy algebra yields the following design formulae,

$$K_C = \frac{\tau_I}{K_P(\tau_1 - \tau_2 - \theta)} \quad \text{.......... (10.1)}$$

$$\tau_I = \tau_1\left[2 - \frac{\tau_2}{(\tau_1 - \tau_2 - \theta)}\right] - \left[\frac{\theta^2}{2(\tau_1 - \tau_2 - \theta)} - \theta - G_p'\right] \quad \text{.......... (10.2)}$$

$$\tau_D = \left[\begin{array}{l} \frac{\theta^2}{2\tau_I}[3(\tau_1 - \tau_2) + 2 - \theta] - \frac{(\tau_1^2 + \tau_2^2)}{\tau_I}(3\tau_1 + 3\tau_2 + 2) - \frac{(2(\tau_2 + \tau_1) - \tau_1\tau_2)}{\tau_I} - (\tau_1 - \tau_2 - \theta) \\ + \frac{(4\tau_1 + \tau_2 + \theta - 2)}{2} G_P' + (G_P'^2 + 2G_P' + 1)\tau_I + G_P'' \end{array}\right] \quad \text{............. (10.3)}$$

2. Two unstable poles

The desired response given by,

$$G_d(s) = \frac{e^{-\theta s}}{(\tau_1 s-1)(\tau_2 s-1)} \quad \text{.......... (11)}$$

For the desired response $G_d(s)$ in (11), we have

$$G_d'(0) = -(\tau_1 - \tau_2 - \theta) \quad \text{.......... (11.1)}$$

$$G_d^{''}(0) = \theta^2 - 2(\tau_2+\tau_1)\theta + 2\tau_2^2 + 2\tau_1\tau_2 + 2\tau_1^2 \quad \text{..........} (11.2)$$

$$G_d^{'''}(0) = \theta^3 - 3(\tau_2-\tau_1)\theta^2 + 6(\tau_2^2+\tau_1\tau_2+\tau_1^2)\theta - 6(\tau_2+\tau_1)(\tau_2^2+\tau_1^2) \quad \text{..........} (11.3)$$

Substituting (6.2), (6.3), (6.4) and (11.1), (11.2), (11.3) in (4), and solving for PID controller parameters, after a tedious and lengthy algebra yields the following design formulae,

$$K_C = \frac{\tau_I}{K_P(\tau_1-\tau_2-\theta)} \quad \text{..........} (12.1)$$

$$\tau_I = \frac{\theta^2}{2(\tau_1-\tau_2-\theta)} + \frac{(\tau_1+\tau_2)\theta+3\tau_1\tau_2}{(\tau_1-\tau_2-\theta)} - G_P^{'} \quad \text{..........} (12.2)$$

$$\tau_D = \left[\left(\frac{\theta^2}{2\tau_I}\right)\left(\theta+3(\tau_1-\tau_2)+2\right) + \frac{1}{\tau_I}\left(\tau_2(3\tau_1-2)\theta - 2\tau_1(\theta-\tau_2)\right) - 2\left(\tau_1+\tau_2-\theta\right) + \tau_I + \left(1+\frac{2(\tau_1-\tau_2)G_P^{'}}{\tau_I}+\frac{2\left(G_P^{'}\right)^2}{\tau_I}\right) - \frac{G_P^{''}}{2\tau_I}\right] \quad \text{.....} (12.3)$$

Where,

$$G_P^{'} = \frac{G_P^{'}(0)}{G_P(0)} \quad G_P^{''} = \frac{G_P^{''}(0)}{G_P(0)} \quad \text{................} (B)$$

The controller parameters given by (8), (10) and (12) can compute if $G_P(0)$, $G_P^{'}$ and $G_P^{''}$ known since all other parameters specified for the desired response.

In this work, $G_P(0)$, $G_P^{'}$ and $G_P^{''}$ are computed from the impulse response of the process rather than assuming any specific transfer function form. Treating the impulse response of the plant as a statistical distribution, the mean and the variance of the distribution are calculated and used in the determination of $G_P^{'}$ and $G_P^{''}$. Consider the general input–output model of a single-variable system in the form,

$$Y(s) = G_P(s)X(s) \quad \text{..........} (13)$$

For a unit impulse input, for which $X(s) = 1$, we have

$$Y(s) = G_P(s) \quad \text{..........} (14)$$

The left hand side of eq^n (14) using the definition of Laplace transforms can written as,

$$Y(s) = \int_0^\infty Y(t)e^{-st}dt \quad \text{..........} (15)$$

$Y(t)$, unit impulse response of process, expanding the exponential term inside the integral of eq^n (15) in terms of a series,

$$Y(s) = \int_0^\infty Y(t)\left[1 - s + \frac{s^2}{2!}t^2 - \frac{s^3}{3!}t^3 + \text{..........}\right]dt$$

$$Y(s) = \int_0^\infty Y(t)dt - s\int_0^\infty tY(t)dt + \frac{s^2}{2!}\int_0^\infty t^2Y(t)dt - \frac{s^3}{3!}\int_0^\infty t^3Y(t)dt + \text{........} \quad \text{..........} (16)$$

$G_P(s)$ An also be expanded in a Maclaurin series in as,

$$G_P(s) = G_P(0) + sG_P^{'}(0) + \frac{s^2}{2!}G_P^{''}(0) + \frac{s^3}{3!}G_P^{'''}(0) + \text{........} \quad \text{..........} (17)$$

On comparing eq^n (16) and (17),

$$G_P(0) = \int_0^\infty Y(t)dt \text{ And } G_P^{"}(0) = \int_0^\infty t^n Y(t)dt$$

The first moment of *Y*(*t*) i.e. the characteristic time,

$$\bar{t} = \frac{\int_0^\infty t^n Y(t)dt}{\int_0^\infty Y(t)dt} = \frac{G_P^{'}(0)}{G(0)} \qquad \text{.......... (18)}$$

The second moment of the variable *Y* (*t*) about its mean $\bar{t}$, variance σ^2 given by,

$$\sigma^2 = \frac{\int_0^\infty (t-\bar{t})^n Y(t)dt}{\int_0^\infty Y(t)dt} = \frac{\int_0^\infty t^n Y(t)dt}{\int_0^\infty Y(t)dt} - \bar{t}^n \qquad \text{.......... (19)}$$

For FOUPDT,

First moment,

We Know,

$$\int_0^\infty t^n Y(t)dt = (-1)^n \left(\frac{d^n}{ds^n} G_P(s) \right)_{s=0}$$

For First moment n=1

$$\int_0^\infty tY(t)dt = (\tau-\theta)K_P \qquad \text{.......... (20)}$$

$$\int_0^\infty Y(t)dt = \left[G_P(s)\right]_{s=0} = -K_P \qquad \text{.......... (21)}$$

On putting (20) and (21) in (18) we get,

$$\bar{t} = -(\tau-\theta) \qquad \text{.......... (22)}$$

Second moment,

$$\int_0^\infty t^2 Y(t)dt = -\left(2\tau^2-2\tau\theta+\theta^2\right)K_P \qquad \text{.......... (23)}$$

On putting (23) and (21) in (19) we get,

$$\sigma^2+\bar{t}^2 = \left(2\tau^2-2\tau\theta+\theta^2\right) \qquad \text{.......... (24)}$$

Similarly, first and second moments calculated for both case of SOUPDT.

Hence, controller tuning Formulae become;

4.3 FOUPDT

$$K_C = \frac{\tau_I}{K_P(\tau-\theta)}$$

$$\tau_I = \frac{\theta^2}{2(\tau-\theta)} + 2\tau - \theta + \bar{t}$$

$$\tau_D = \frac{3\tau\theta^2}{(\tau-\theta)^2\tau_I} + \frac{\theta^3(2\tau+\theta)}{12\tau_I(\tau-\theta)^2} - \frac{(\sigma^2+\bar{t}^2)}{2\tau_I} + \bar{t}$$

4.4 SOUPDT

- **One Unstable and One Stable Pole:**

$$K_C = \frac{\tau_I}{K_P(\tau_1-\tau_2-\theta)}$$

$$\tau_I = \tau_1\left[2 - \frac{\tau_2}{(\tau_1-\tau_2-\theta)}\right] - \frac{\theta^2}{2(\tau_1-\tau_2-\theta)} - \theta - \bar{t}$$

$$\tau_D = \frac{\theta^2}{2\tau_I}\left[3(\tau_1-\tau_2)+2-\theta\right] - \frac{(2(\tau_2+\tau_1)-\tau_1\tau_2)}{\tau_I} - (\tau_1-\tau_2-\theta) + \frac{(4\tau_1+\tau_2+\theta-2)}{2}\bar{t} + (\overline{t^2}+2\bar{t}+1)\tau_I + (\sigma^2+\overline{t^2})$$

- **Two Unstable Poles:**

$$K_C = \frac{\tau_I}{K_P(\tau_1-\tau_2-\theta)}$$

$$\tau_I = \frac{\theta^2}{2(\tau_1-\tau_2-\theta)} + \frac{(\tau_1+\tau_2)\theta+3\tau_1\tau_2}{(\tau_1-\tau_2-\theta)} - \bar{t}$$

$$\tau_D = \left[\left(\frac{\theta^2}{2\tau_I}\right)\left(\theta+3(\tau_1-\tau_2)+2\right) + \frac{1}{\tau_I}\left(\tau_2(3\tau_1-2)\theta - 2\tau_1(\theta-\tau_2)\right) - 2\left(\tau_1+\tau_2-\theta\right) + \tau_I + \left(1 + \frac{2(\tau_1-\tau_2)\bar{t}}{\tau_I} + \frac{2\bar{t}^2}{\tau_I}\right) - \frac{(\sigma^2+\bar{t}^2)}{2\tau_I}\right]$$

V.SIMULATION

All simulations in this paper were performing using MATLAB 7.8, (2009) (control system design and simulation software) (Shahian & Hassul, 1993) [11]. There example consider for both FOUPDT and SOUPDT for studying the controller tuning methods and result of each method is shown below separately. Comparison of methods in graph shows by output of the process. Unit step changes are consider for regulatory problems.

Examples,

For FOUPDT, The Following process considered [1] (Shamsuzzoha and Lee, 2007)

$$G_P(s) = \frac{1.e^{-0.4s}}{1.s-1} \qquad \text{(Step input of magnitude 1 at t = 20sec given for the process)}$$

Table 1 given below show the controller parameters value calculated by proposed and other considered methods,

Sr. No.	**Method**	K_C	τ_I	τ_D

1	Ziegler – Nichols	1.9647	0.95	0.2375
2	C.T. Huang and Y.S. Lin	2.520	1.65	0.191
3	Shamsuzzoha and Lee	2.62	1.08	0.214
4	Q.Wang, C. Lu and W. Pan	2.21	1.01	0.17
5	Proposed (Improved)	1.888	1.133	0.384

Table 1

For SOUPDT,

1. One Unstable and One Stable Pole, The Following process considered [2] (Huang & Chen, 1997)

$$G_P(s) = \frac{1e^{-0.939s}}{(5s-1)(2.07s+1)}$$ (Step input of magnitude 1 at t = 200 sec given for the process)

Table 2 given below show the controller parameters value calculated by proposed and other considered method,

Sr. No.	Method	K_C	τ_I	τ_D
1	Ziegler – Nichols	1.8882	0.14285	1.75
2	Tayrus-Luyben	1.45	0.032	2.22
3	C.T. Huang and Y.S. Lin	3.954	0.2016	2.074
4	Poulin and Pomerleau	3.050	0.1323	2.070
5	Proposed (Improved)	2.889	0.1738	4.6058

Table 2

2. Two Unstable Poles, The Following process considered [7] (Yongho Lee et al., 1999)

$$G_P(s)=\frac{2.e^{-0.3s}}{(3s-1)(s-1)}$$ (Step input of magnitude 1 at t=200 sec given for the process)

Table 3 given below show the controller parameters value calculated by proposed and other considered method,

Sr. No.	Method	K_C	τ_I	τ_D
1	Yongho Lee et al.	2.0	1.7	4.1
2	Proposed (Improved)	0.29	1	4.32

Table 3

IV. TIME DOMAIN SPECIFICATION

For FOUPDT,

Table 4

Sr. No.	Method	Time domain specification (Sec)	
		Rise Time (T_R)	Settling Time (T_S)
1	Ziegler-Nichols	0.833	45.67
2	C.T. Huang and Y.S. Lin	0.833	30
3	Shamsuzzoha and Lee	0.834	30
4	Q.Wang, C. Lu and W. Pan	0.836	20
5	Proposed (Improved)	0.73	16

For SOUPDT,

1. One Unstable and One Stable Pole

Sr. No.	Method	Time domain specification (Sec)	
		Rise Time (T_R)	Settling Time (T_S)
1	Ziegler-Nichols	4.5	260
2	C.T. Huang and Y.S. Lin	5.667	180
3	Shamsuzzoha and Lee	3.33	400
4	Q.Wang, C. Lu and W. Pan	3.66	193.33
5	Proposed (Improved)	4.1	60

Table 5

2. Two Unstable Poles

Sr. No.	Method	Time domain specification (Sec)	
		Rise Time (T_R)	Settling Time (T_S)
1	Yongho Lee et al.	1.25	195
2	Proposed (Improved)	2.5	105

Table 6

V. TIME INTEGRAL PERFORMANCE

For FOUPDT,

Sr. No.	Method	IAE	ISE	ITAE
1	Ziegler – Nichols	3.702	3.287	9.054
2	C.T. Huang and Y.S. Lin	4.446	4.098	13.01
3	Shamsuzzoha and Lee	2.462	2.408	3.813
4	Q.Wang, C. Lu and W. Pan	3.07	3.064	5.664
5	Proposed (Improved)	4.32	3.246	14.37

Table 7

For SOUPDT,

1. One Unstable and One Stable Pole

Sr.No.	Method	IAE	ISE	ITAE
1	Ziegler – Nichols	43.47	38.15	1324
2	Tayrus-Luyben	49.79	62.91	1201
3	C.T. Huang and Y.S. Lin	37.03	22.38	1400
4	Poulin and Pomerleau	16.96	12.79	245.2
5	Proposed (Improved)	10.92	6.237	110.3

Table 8

2. Two Unstable Poles

Sr.No.	Method	IAE	ISE	ITAE
1	Yongho Lee et al.	7.729	2.489	131
2	Proposed (Improved)	6.369	2.87	56.31

Table 9

V. SIMULATION RESULTS

Fig. 2 and 3 shows PID controller performance by proposed and each considered method and comparison of these methods for FOUPDT system.

Fig. 4 and 5 shows PID controller performance by proposed and each considered method and comparison of these methods for SOUPDT (One Unstable and One Stable Pole) system.

Fig. 6 and 7 shows PID controller performance by proposed and each considered method and comparison of these methods for SOUPDT (Two Unstable Poles) system.

For FOUPDT,

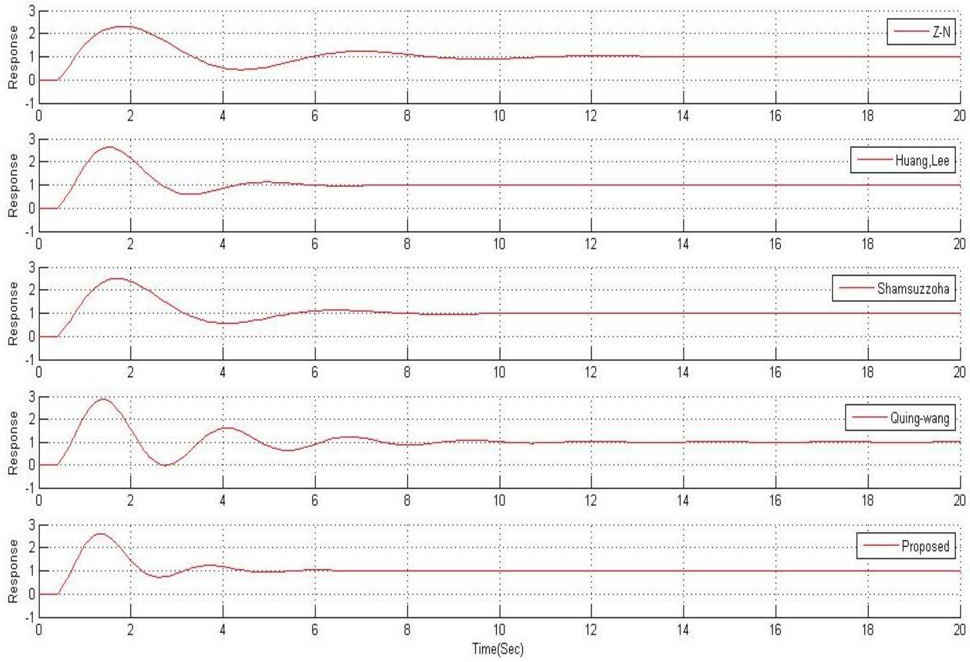

Fig. 2

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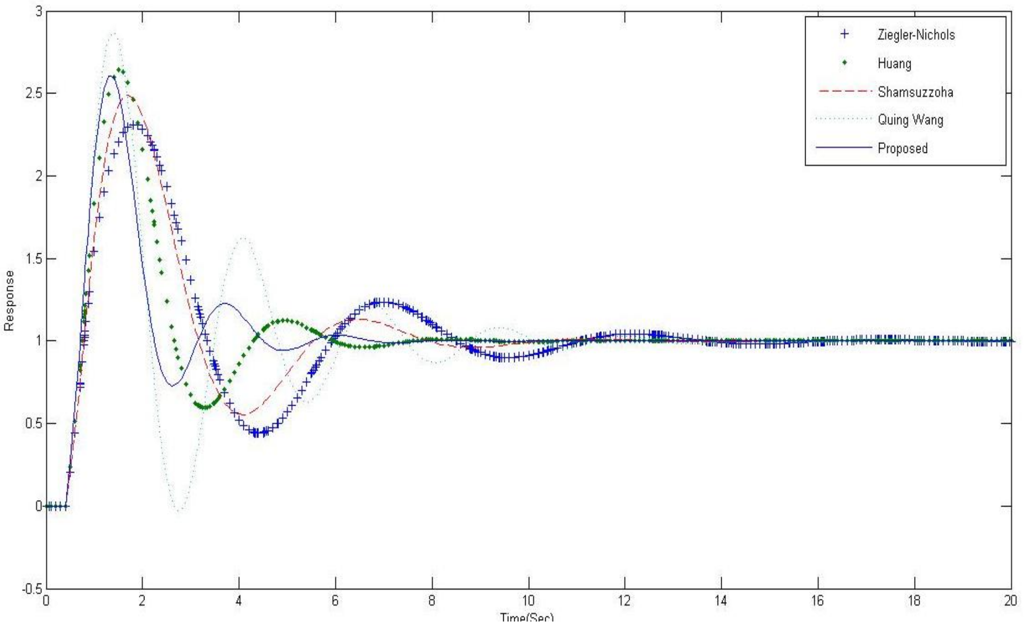

Fig. 3

For SOUPDT,

- One Unstable and One Stable Pole

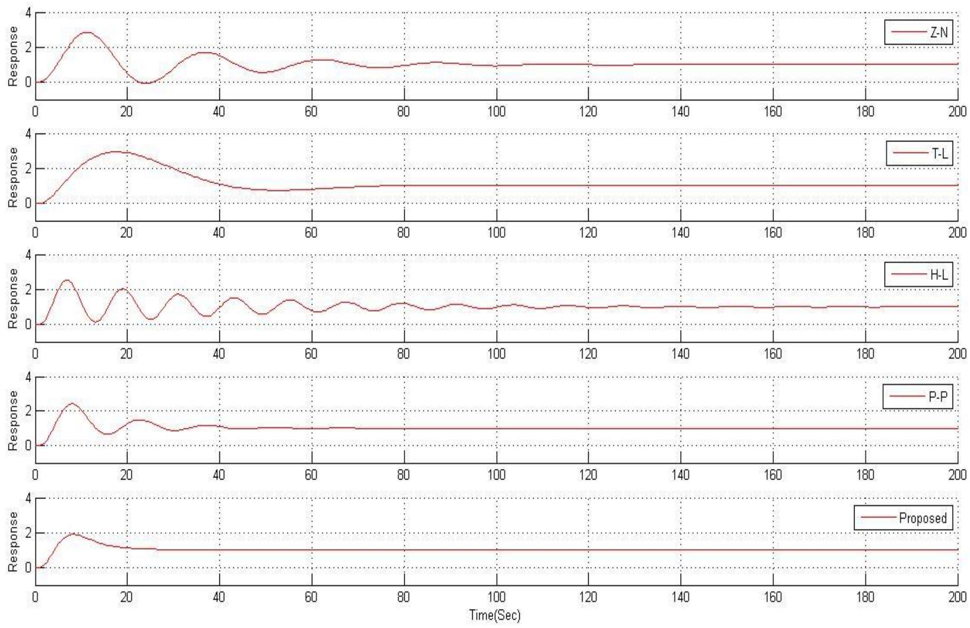

Fig. 4

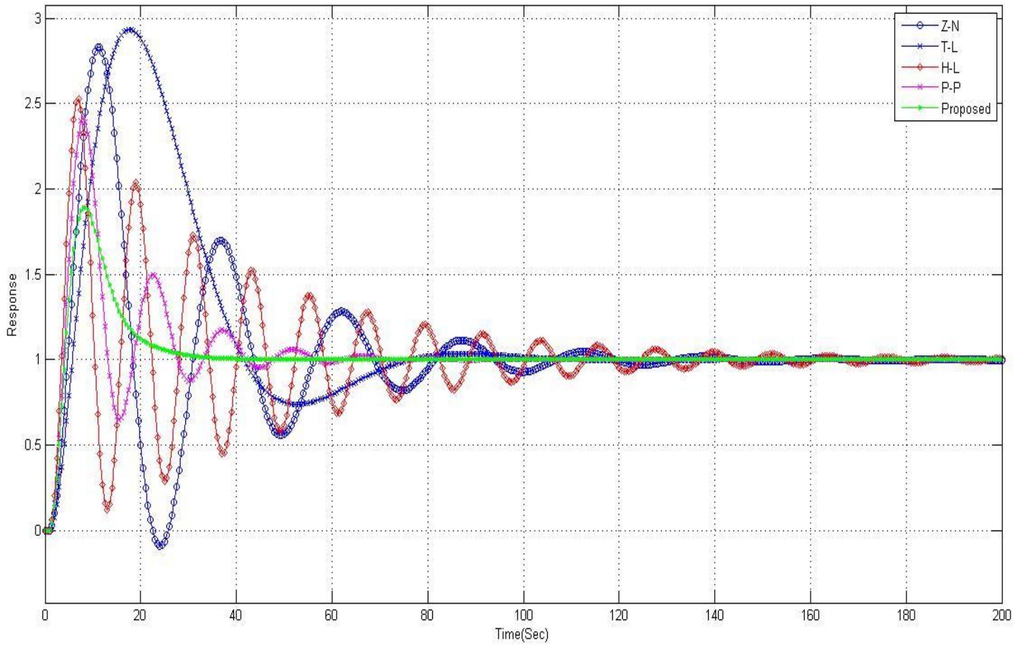

Fig. 5

- Two Unstable Poles

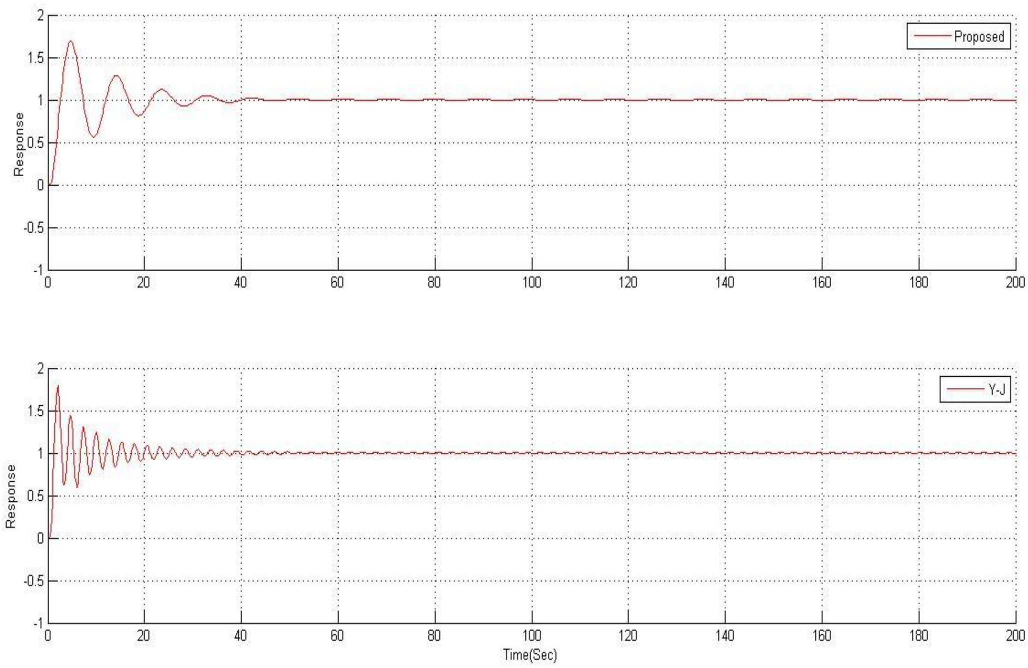

Fig. 6

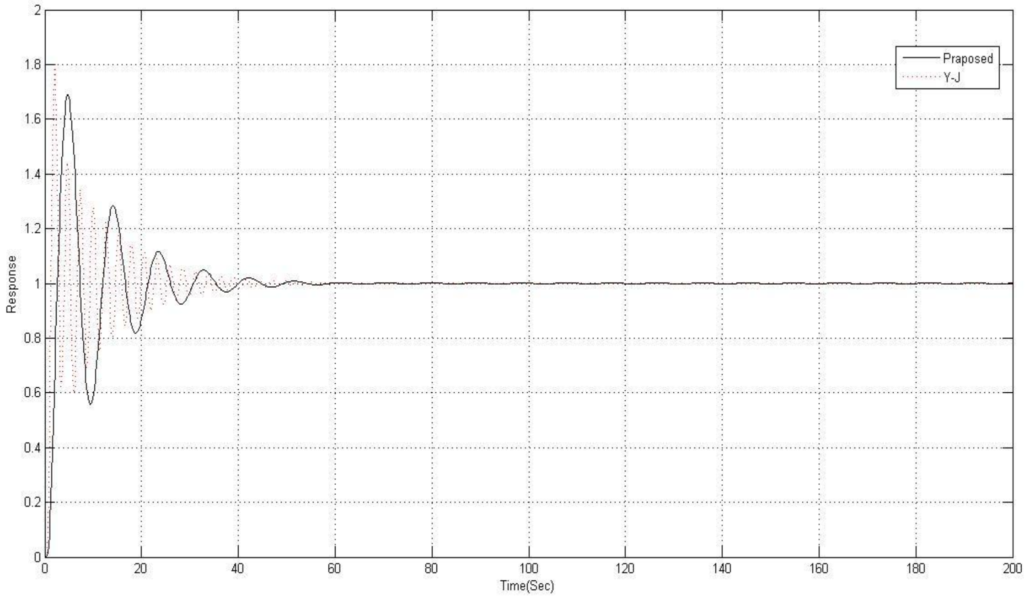

Fig. 7

VI. RESULTS AND DISCUSSION

Controller parameters calculated by tuning, these parameters make inverse effect to each other for optimum value of controller. Proposed and other considered methods used for controller design for seeing which design method gives good stability of the controller response. Time domain specification shows rise and settling time of controller, minimum rise and settling time needed for good response of controller. Time integral performance shows different error like IAE, ISE, and ITAE, which shows controller robustness.

VII. CONCLUSION

PID controller designed for FOUPDT and SOUPDT by Proposed and other considered controller tuning methods. All methods are work in direction of settling the process variable to a desired set value. In FOUPDT, time domain specification shows proposed method have less rise and settling time compared to other method and time integral performance shows proposed method have IAE, ISE and ITAE are minimum compared to C.T. Huang and Y.S. Lin method and maximum compared to other controller tuning methods for FOUPDT system. However, on time basis proposed method is better response and shows good stability this shows that proposed method for first order unstable process without taking too much time and oscillation for attain stability of the system. In SOUPDT, for one unstable and one stable pole, Time domain specification shows proposed method have more rise time compared to other method but less settling time. Controller stability and time integral performance shows proposed method have IAE, ISE and ITAE are minimum compared to other controller tuning method this shows this method gives very good stability and robust response of controller for second order unstable process without taking too much time and oscillation for attain stability of the system. In case of two unstable poles, Time domain specification shows proposed method have more rise time compared to other method but less settling time. Controller stability and time integral performance shows proposed method have IAE, ISE and ITAE are minimum compared to other controller tuning method this shows this method gives very good stability and robust response of controller for second order unstable process without taking too much time and oscillation for attain stability of the system.

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