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PID Controller Design and Closed-Loop Identification with Linear Time-Invariant

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***Abstract:** In this research, analysis and developed identification of closed loop system with mathematical modeling. Implemented the mathematical analysis & the process parameters by the data obtain in the closed-loop test. Tuned the closed-loop system by control system methodology and using controller. To analyzed the behavior and all parameters of closed loop system i.e. the parameters include stability, frequency, load disturbance and the system output etc. experiment the proposed work for model identification and performance of set point and load-disturbance ,controller output ,robustness, stability margins, noise measurement etc.*

***Keywords:** PID controllers, Closed- loop, plat, Bode plot, Model reduction technique.*

I. INTRODUCTION

Most of the process industries use PID controllers because of there are several advantage and cost to benefit ratio for many applications. Various design methodologies are prevalent in the literature like model based design methods, optimization of integral error performance criteria, design methods utilizing frequency response data, loop shaping method, robust controller design, etc. There are also numerous designs of controllers (PID) methods, which is connected to the open loop system with an aim to achieving different control objectives like gain-margin and phase margin, specification response for set point. Form responses with load response (overshoot, settling time, rise time) closed-loop frequency response specification (peak resonance, bandwidth) minimization of various error criteria etc. This proportional-integral-derivative controller broadly uses in process factories industries.

However proportional-integral controller has two adjustable variables, this is not simple for the good setting and controller turned poorly results. So, simply PI and PID Controllers are initially planned utilizing Frequency response techniques, and then changed over into digital controllers. In this research it's also going with identifications with the converter which are enhance a different level of the system input. The proportional-integral-controller given great results of related to used process but somewhere responses with disturbance is too slow and process control became slower with constant ratio and small time delay. In process control application disturbance rejection is so important. If using a closed loop control design with DC-DC converter its focus two control structure which are named current mode control and voltage mode control. Signal conditioning circuit always prefers high speed current sensor and its need current control mode and its made system costly. This all happed just because of PID controller parameters and the converters used control loop design. The PID controller easily tunes and design according to need and then implement.

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II. CLOSED-LOOP SYSTEM PROCESS IDENTIFICATION

Many industrial processes are non-linear and/or of high order. Simple and easy-to-use controller design equations for such processes are not available. In this process, basically reduce higher model system v/s low model system, it's kind of representation of model with PI and PID controller. This method based on the assumption for suitable model with for require parameters.

Open loop responses based on the initial model selection. Introducing the open loop system with manipulated variable, which has given change step values in fig.1.

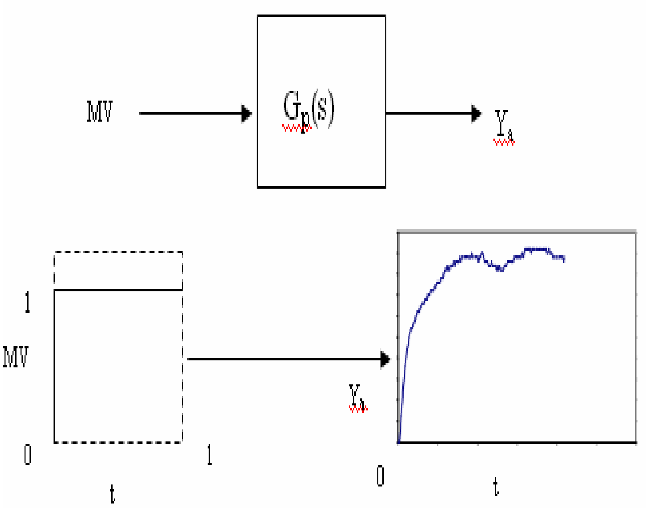

Figure.1. Operation of open-loop system

The variation of the open loop and closed system with a straight forward point in operation below given fig.2. So, the Process of closed loop system involved with feedback loop in this controller design. The only the difference of the process is feedback. Feedback makes system stable with simple process.

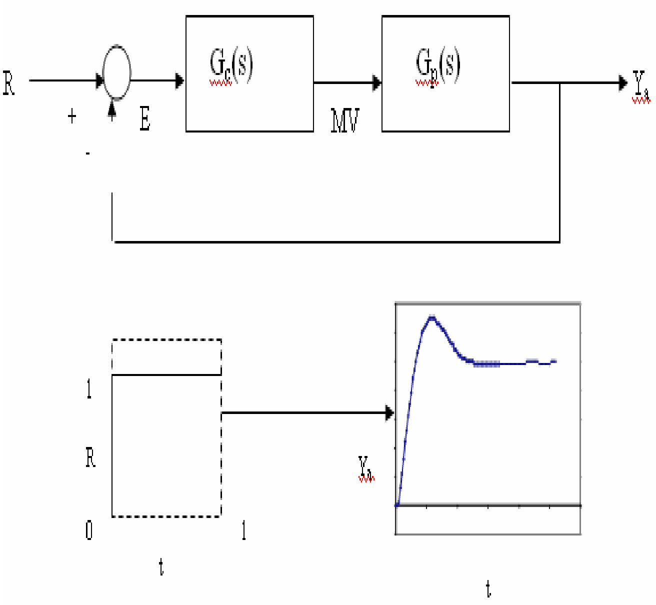

Figure.2. Operation of closed loop system

A. Identification using simulated data

2001 selected only four examples by Huang et al. for study of simulation. Example 1 and 2 introduced positive and negative zeros with positive denominators. This used for curve fitting of the simulated model.

Example-1 $G_p = \frac{(2s+1)e^{-2s}}{(4s^2+2s+1)(s^2+s+1)}$

Example-2 $G_p = = \frac{(-2s+1)e^{-3s}}{(4s^2+2s+1)(s^2+s+1)}$

Example 3 and 4 used for higher model with no time delay which including model response for curve fitting with non-zero process.

Example-3 $G_p = = \frac{1}{(s+1)^5}$

Example-4 $G_p = = \frac{e^{-0.2s}}{(s+1)^3}$

B. Controller analysis

Let the transfer function process-

$$G(s) = \frac{N(s)}{D(s)} e^{-sL} \qquad (1)$$

The set-point and disturbance rejection of both closed-loop transfer function given as-

$$\frac{y(s)}{r(s)} = \frac{C(s)G(s)}{1+C(s)G(s)} \qquad (2)$$

$$\frac{y(s)}{r(s)} = \frac{G(s)}{1+C(s)G(s)} \qquad (3)$$

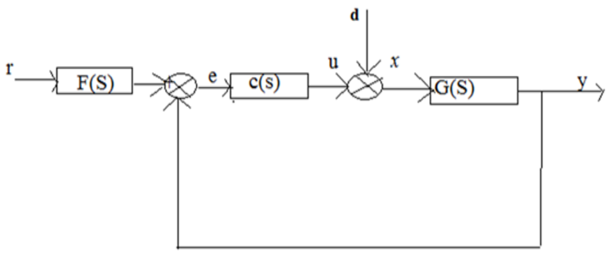

Fig.3.Closed loop system to be observed

Eq. (2) as-

$$C(s) = \frac{Gr,y(s)}{G(s)[1-Gr,y(s)]} \qquad (4)$$

The closed-loop transfer function $G_{d,y}(s)$ and the controller *C(s)* can be get from Eq. (3)as-

$$C(s) = \frac{1}{Gd,y(S)} - \frac{1}{G(S)} \qquad (5)$$

The structure and the order of the controller *C(s)* depend on the desired closed-loop transfer function and the process model as can be seen from Eqs.(4) and (5).

$$C^{PID}(s) = KP\pi r^2 \frac{KI}{s} \qquad (6)$$

III. PROPOSED WORK

Tuning PID Controllers with Ziegler-Nichols methods

In these tuning rules through broadly used to tune PID controllers in whole process control system, where the plant dynamic is not precisely.

Let, assume the unknown plant for control system-

$$\text{Plant} = \frac{1}{s(s+1)(s+5)} \qquad (4)$$

In this control system used also a PID, The transfer function of this PID-

$$G_c(S) = K_p\left(1 + \frac{1}{T_i s} + T_d s\right) \qquad (5)$$

According to the Z-N rules, apply the value of the K_P, T_i & T_d. After that get a unit response which gives at least 25% maximum overshoot. From plant integrator, Z-N tuning rules by setting $T_i = \infty$ & T_d =0.

Now proportional control and plant as following closed loop transfer –

$$\frac{C(S)}{R(S)} = \frac{K_P}{s(s+1)(s+5)} \qquad (6)$$

$$\frac{C(S)}{R(S)} = \frac{K_P}{s(s+1)(s+5)} \qquad (7)$$

$$H(S) = 1$$

The characteristics equation- $1 + G(S)H(S) = 0$

$$1 + \frac{K_p}{s(s+1)(s+5)} = 0$$

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$$s^3 + 6s^2 + 5s + K_p = 0 \quad (8)$$

According to the Routh's Hurwitz –

$$s^3 + 6s^2 + 5s + 30 = 0 \quad (9)$$

$$(jw)^2 + 6(jw)^2 + 5(jw)^2 + 30 = 0 \quad (10)$$

Or

$$6(5 - w)^2 + jw(5 - w)^2 = 0 \quad (11)$$

$w^2 = 5$ or $w\sqrt{5}$

Hence, the period of sustained oscillation is,

$$P_{cr} = \frac{2\pi}{w} = 2.8099 \quad (12)$$

So, determine the K_p, T_i, & T_d -

K_p =18

T_i =1.405

T_d = 0.35124

Put the value of K_p , T_i and T_d in equation (5)

$$G_c(S) = 18\left(1 + \frac{1}{1.405s} + 0.35124s\right)$$

$$G_c(s) = \frac{6.3223(s+1.4235)^2 A=\pi r^2}{s} \quad (13)$$

So, the control system with PID controller and plant from equation (4) and (13)

$$\frac{C(s)}{R(s)} = \frac{6.322s^2+18s+12.811}{s^4+6s^3+11.3223s^2+18s+12.811} \quad (14)$$

After getting the plant transfer function mentioned the continuous time domain. Pole of function gives the information about the system transfer function where it will be undefined. Poles are obtained from the dominator of the transfer function polynomial. Poles are defined the states of the system whether they are stable, unstable.

IV. RESULTS AND DISCUSSIONS

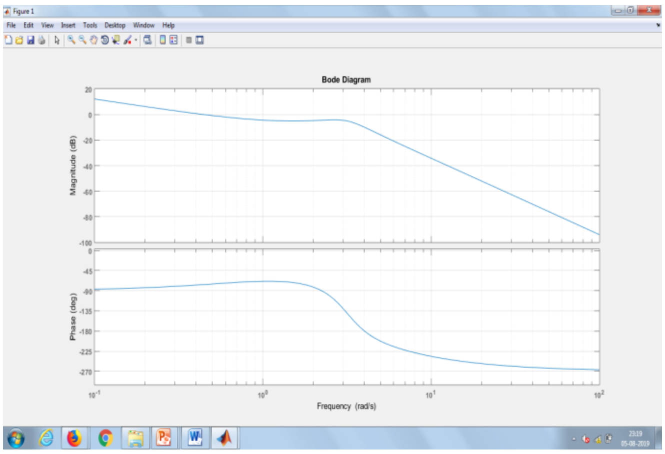

Fig.4. Process of minimum-phase system vs non-minimum phase system

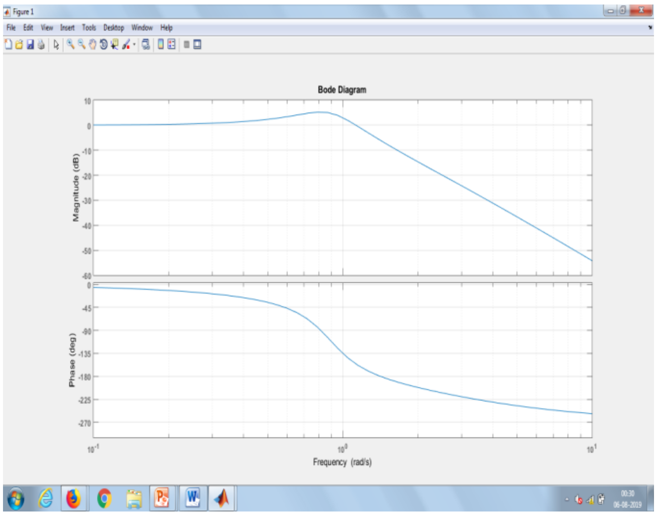

Fig.5. Process of resonant peak, resonant frequency, and bandwidth

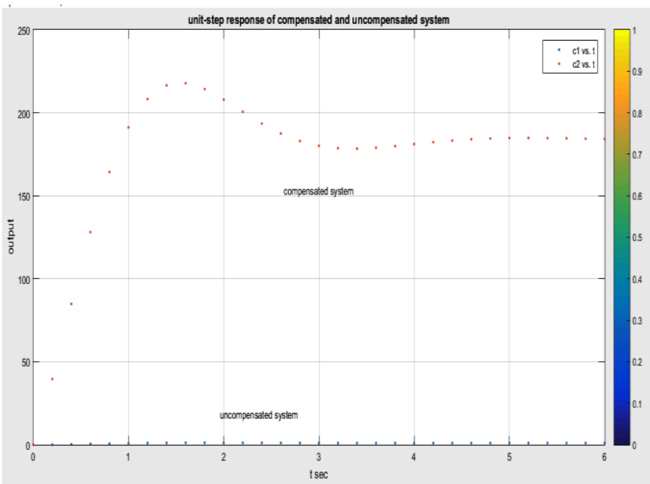

Fig.6. Compensation and un-compensation response of lead with step response

In phase lead compensation, the gain cross-over frequency shift to a higher value and therefore the bandwidth increase ,speed of response become fast but the steady state error does not show as much improvement. In fig.6, its compensate unit response and taking a long time period.

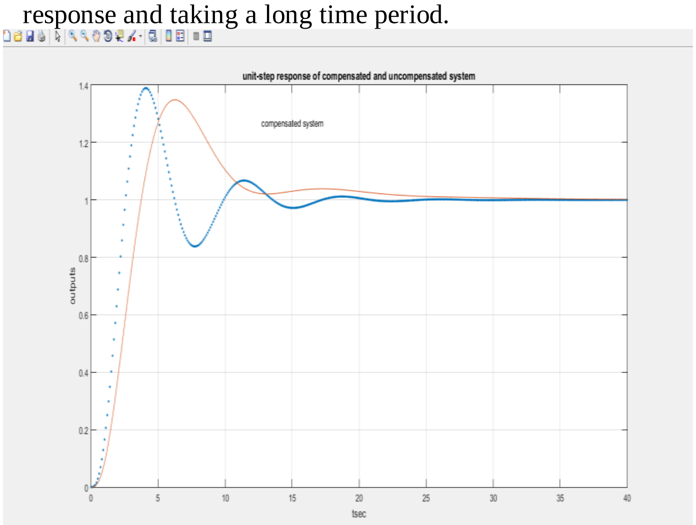

Fig.7. Compensation and un-compensation response of lead with step response

In phase lag compensation, the gain cross-over frequency shift to a lower value & therefore the bandwidth decrease, speed of response reduced but the steady state error improves. In fig.7, its compensate unit response and it's also taking a long time period.

Again examine the response of the frequency and gain adjusted with stability.

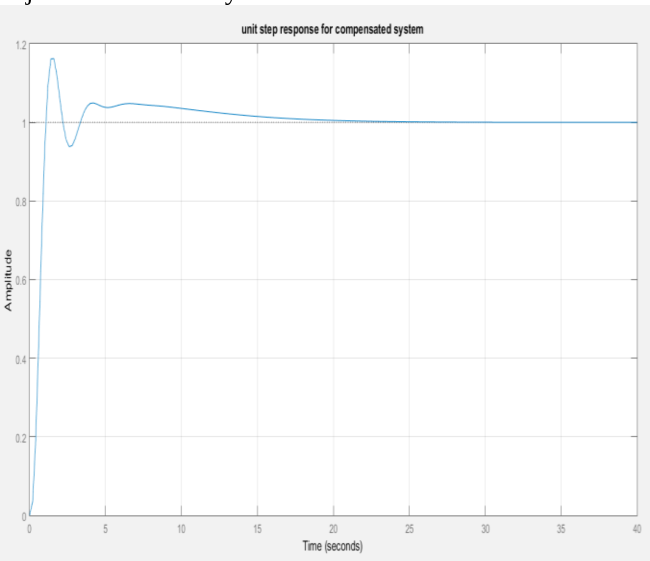

Fig.8. Lag-lead compensation unit response

Again examine the response of the frequency and gain adjusted with stability.

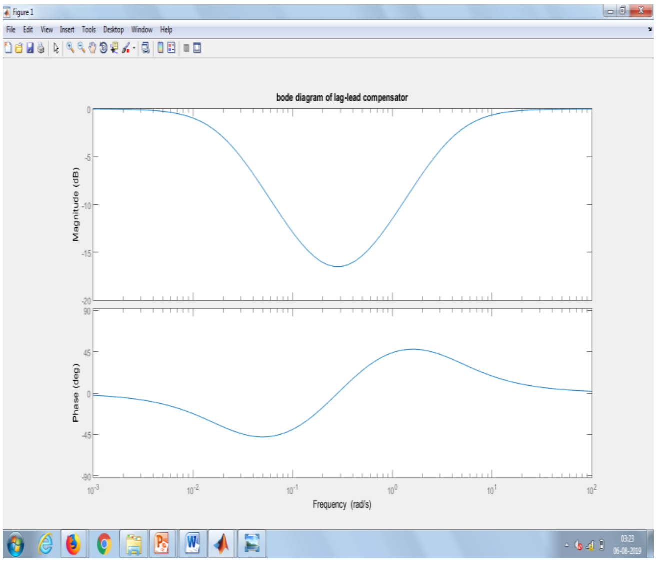

Fig.9 Lag-lead compensation bode diagram

Again examine the response of the frequency and gain adjusted with stability.

The speed of response & steady state error can be simultaneously improved if both phase lead & phase lag compensation networks are used. In fig.8, this is taking very few second for compensation the unit response

V. SIMULINK MODEL OF PID CONTROLLER

Simulation of closed-loop has been different variety for proposed process of all cases which are suitable for both performances. It can be assume for PI setting which based on step response experiments with three different overshoot.

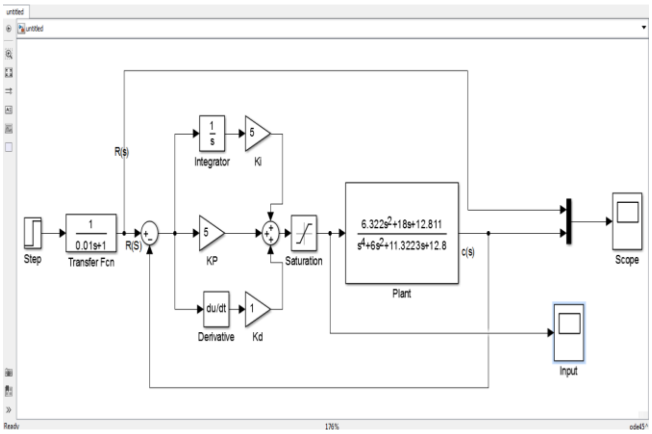

Fig.10.Simulink model of PID controller

Simulation of closed-loop has been different variety for proposed process of all cases which are suitable for both performances. Assume for PID setting which based on step response experiments with three different overshoot.

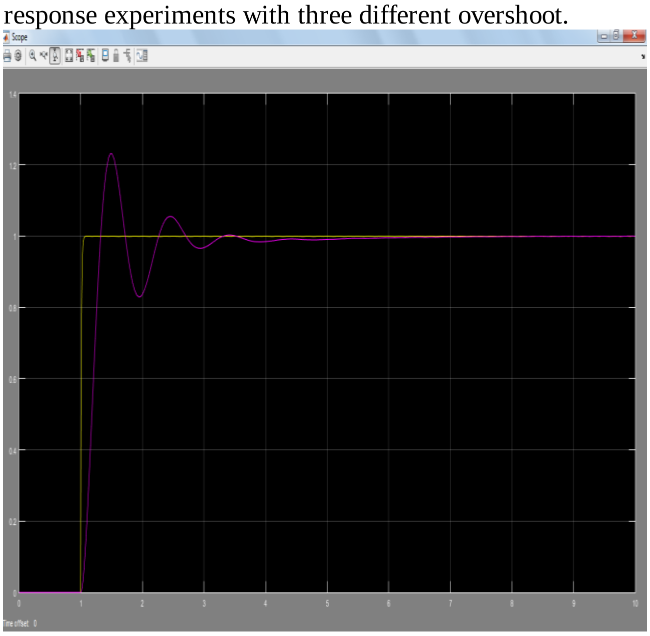

Fig.11.Output of the model

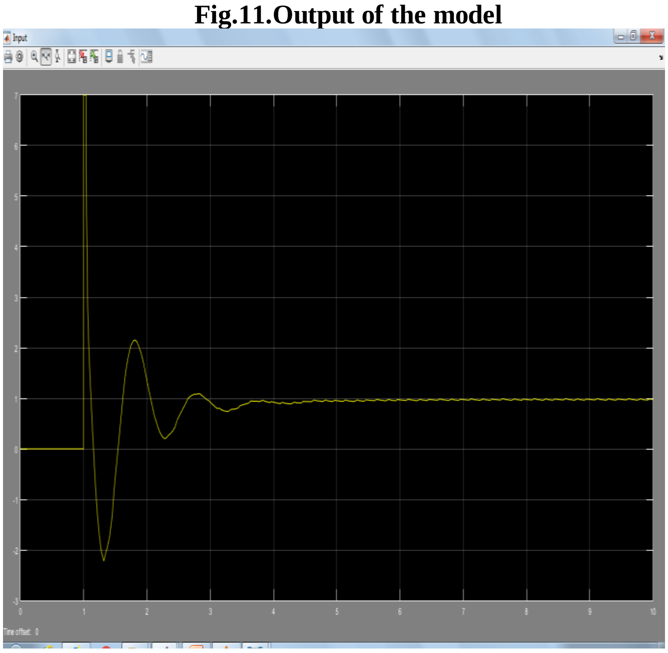

Fig.12. Input of the model

VI. CONCLUSION

This method also can be accept by computation burden and proposed PID controller settings. This gives very good response for industry application. Overshoot method is faster and simpler to use and also gives better setting in most cases, which reduce overshoot approx. 25% overshoot. Basically, get a new process of control and further change into a PID controller, which use frequency matching method.

PID controller day by day very needed for the industries, and its proposed very simple controller with the help of plants. It's based on the closed loop set point experiment. In this method proposed a free model reduction process for higher order to low order process and remove complication of the plant. This is process done by the MATLAB/SIMULINK.

Future Scope:-

All future work is summarized schematically in following ideas:-

Develop a new PID controller with the help automatic controller system, which can be achieving better performance. This new controller may be able to follow or extended with Artificial Intelligence like fuzzy controllers.

- Develop a completely auto adaptive controller with the help of PID controller. This controller must be adaptive to any motor.
- Try to overcome the noise of electrical, low cost, better speed.

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