Robust PID Controllers for Time Delay Systems in Wireless Network Environment

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Abstract - *The synthesis method that we describe deals with creating robust PID controllers while in practical systems like engineering, biological and other* ***control system's delays are kept in consideration. The plant controller's process has various uncertainties*** *that can be described as a feedback method for controlling a plant. Delay in time can appear in process by internals working or by sensors and actuators used. The time delay can also occurs due to communication delay of various parts of system. System oscillation or instability may arise in applied system because of these time delays in the controllers and due to these uncertainties the system analysis and control gets complicated so a lot of literatures presented on time delayed processes for system stabilizing, analysis of stability and controlling time delay system and the researches and literatures are still counting. The first order controller are very simple and can easily be implemented practically that means these lower order controllers greatly reduces the controller complexities so we can stabilize a high order process or complex plant by using various lower order controllers. In any controller designing problem stabilization is the base requirement that stabilize all PID parameters then other performance measures must be satisfied like unit step response, overshoot, settling time etc. By applying some alteration in plant parameters we can apply our proposed method to any first order controller and can obtain a stabilized PID controller of that class. The result of the research are displayed that can be applicable for industrial application.*

Key Words: PID controllers control system, linear time invariant (LTI), Delay Time, Stability Region, Robustness.etc…

1. INTRODUCTION

Tuning methods are very easy for the controller by proportional-integral-derivative (PID) method it also provides a flexible structure. For controlling various industrial processes PID controller is the most applicable controller. PID controller should consider robust stability in the real industry process. Classic PID controller is better suited to precise mathematical model has poor self-adaptive and is hard to obtain robust stability region which is caused by the external interruption and uncertainty. Inspite of easy implementation technique controller work on heuristic method i.e. it omits various uncertainties in proposed system and uses dead time approximation. The method we use in this paper is parameter space approch which gives satisfactory result for synthesizing the PID controller in time delayed systems. This method of tuning gives similar output as literature examples because the method follows a transparent and systematic step for superior output. While implementing the PID controller in practical environment the effect of uncertainties in plant must be considered. If any PID based controller stabilizes a nominal plant the uncertainties creates the closed loop unstable. This type of stability problem with uncertainties is called robust stability problem [2]. And we know that almost all practical working methods include uncertainties. So designing robust modified PID controller with uncertainties is more important. However no one can guarantee that a PID controller gives robust stability for time delayed processes with uncertain data. Here in this research we proposed a method for robust PID controller that stabilizes the time delayed plants with some defined uncertainties.

2. REVIEW OF OTHER PROPOSED TECHNIQUES

There is a growing demand of PID in diverse application areas, such as Plant Control, Flow Control, Speed Control, Navigation etc.

N. Hohenbichler et al. [1] Presented a "Synthesis of Robust PID Controllers For Time Delay System". This research uses the "Parameter Space Approach". This method divides the process into two parts one is Controller Synthesis step and the other is Control Loop Analysis step. It is bounded to certain classes such as ignoring uncertainties in parameters of controller.

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Yifei YANG et al. [3] Presented a Robust Stability Regions of PID Parameters for Uncertainty Systems with Time Delay Using D-partition Technique. This paper works on the frequency response of controller that fulfils the desired performance of applied transfer function with any order. Firstly the small gain theorem finds the stability condition by H-infinity index and then delay ratio index is calculated i.e. parameter boundaries by boundary crossing theorem.

Vipul B. Patel et al. [10] Field Programmable Gate array (FPGA) is the method that can be used for implementing digital PID controllers and this method is explained in this paper. Applications like embedded control system uses less power and fast response PID controllers in closed loop which reduces the cost and increases the performance with less resources. Error signals are generated in digital PID controllers by analog components in comparator.

Takaaki Hagiwara et al. [2] In this paper he provide a method for uncertain time delayed plants that stabilize the modified PID controller at a great extend. It creates the time delay plant stable and find reliable values of P, I, and D parameters that do not depends each other. It also gives heat flow experimental result for illustrating this method.

Xavier Litrico et al. [4] Dam Driver control system is described in this paper where the action variable and controlled variable are upstream flow rate and downstream flow rate respectively. The method can design the robust control system for continuous-time and discrete-time flow.

P. V. Gopi Krishna Rao et al. [5] Here the tuning method given is Model based. For robust operation of controller a method named IMC-PID (Internal Model Control tuning method) is used. First Order plus Delay Time (FOPDT) model can easily characterize the process dynamics for implementing the IMC in large industrial applications.

Karim Saadaoui et al. [6] Another class of stabilized time delay system is presented in this paper. Many physical applications can use this method that may be locating any ship or other under water vehicle. Linear time invariant delay free systems can be modelled with this proposed method.

3. OBJECTIVE

1. Performance of Proportional – Integral controller are not satisfactory in terms of settling time, peak overshoot and steady state error.

2. Performance of Proportional – Derivative controller are not satisfactory in terms of steady state error.

3. Performance of Proportional – Integral - Derivative controller is performing better when system is ideal means without any uncertainty and time delay.

4. Now we have to design a robust Proportional – Derivative - Integral controller which can perform satisfactory with noisy and uncertain system. Hermite-Biehler.

4. METHODOLOGY

Block diagram below shows a control system with closed loop consisting of a controller and a process or plant in the absence of any uncertainty and time delay, or we can say in ideal condition. Here $G_p(s)$ shows the nominal plant and K(s) is the PID controller. R(s) and Z(s) are input signal and output signal respectively. The input to the system is the "set point" i.e. the desired output. The input given to the controller is the error value that we earlier calculated.

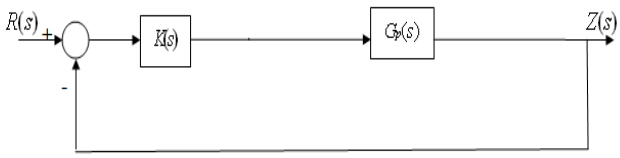

Fig. 1 Block diagram of system without delay and uncertainty

Error = present output – set point

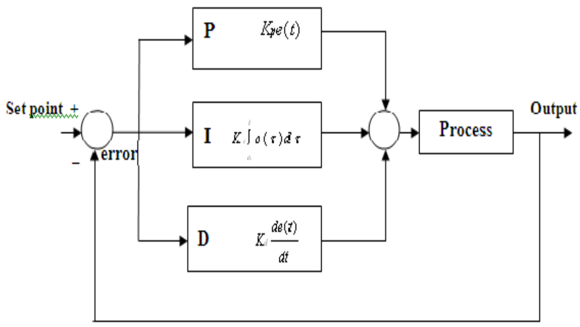

Figure 2 Block diagram of PID controller

A PID controller as name suggests consists three elements namely a proportional element, an integral element and a derivative element, all three connected in parallel. All of them take error as input Kp, Ki and Kd are the gains of P, I, D elements respectively.
For understating PID controller we design a PID controller. Let a plant equation will be,

$$T.F = \frac{1}{s^2 + 20s + 30}$$

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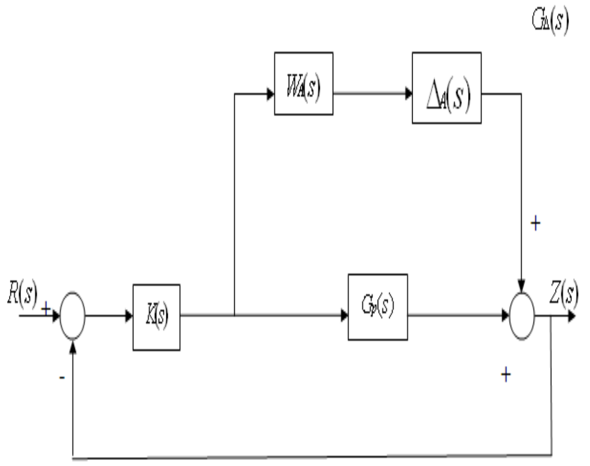


Fig.3 Block diagram of system with additive uncertainty weight

Now, we will discuss the mathematical formulations that are most vital in order to obtain the set of PID controller gains that will enable us to obtain the nominal stability boundary and robust stability region for an arbitrary order perturbed plant with additive uncertainty, while ensuring closed loop stability.

$$K(s) = K_p + \frac{K_i}{s} + K_d s$$

A SISO and linear time invariant (LTI) system with additive uncertainty is shown. Here $G_p(s)$ is the nominal plant, $K(s)$ is the PID controller, and $W_A(s)$ is the additive weight. The input signal and the weighted output signal are R(s) and Z(s) respectively.

In Figure, $G_\Delta(s)$ represents the perturbed plant which includes $\Delta_A(s)$, which is any stable transfer function such that $|\Delta_A(j\omega) \le 1, \forall\omega|$.

In the frequency domain we can represent these transfer functions as ,

$$G_p(j\omega) = \mathrm{Re}(\omega) + j\mathrm{Im}(\omega)$$

$$K(j\omega) = K_p + \frac{K_i}{j\omega} + K_d j\omega$$

$$W_A(j\omega) = A_A(\omega) + jB_A(\omega)$$

In order to achieve robust stability for the perturbed system, we want to find all PID controller gains that stabilize the closed loop system for the entire range of uncertainties. This goal can be achieved if the nominal system is stable and the robust stability constraint,

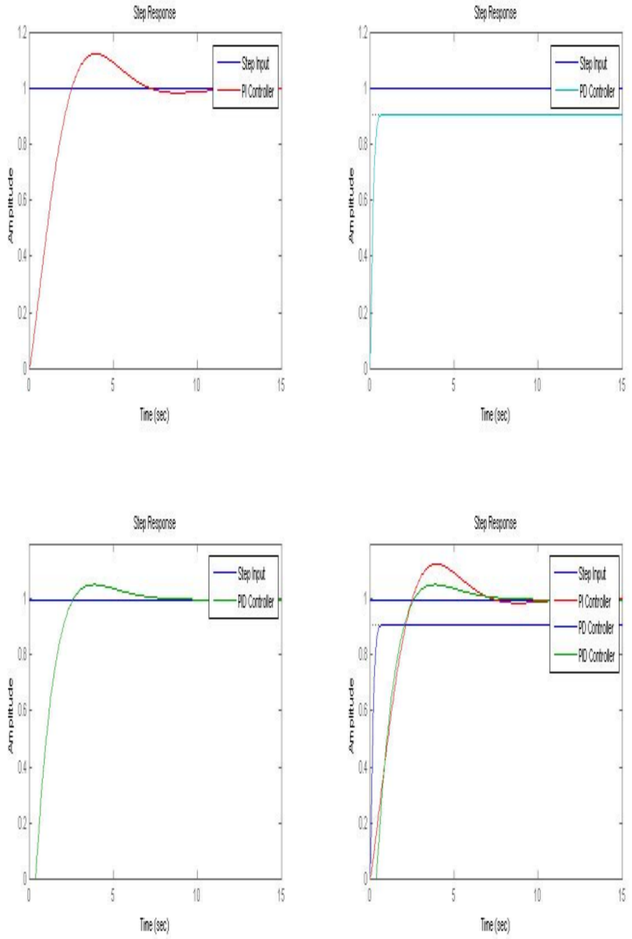
$$\left\| W_A(j\omega) K(j\omega) S(j\omega) \right\|_\infty \le \gamma$$

is satisfied, where $S(j\omega)$ is the sensitivity function and $\gamma = 1$.

Here shows the region of convergence or boundary condition for controller beyond that the controller cannot operate correctly or controller fails

5. RESULT AND ANALYSIS

The simulation is carried out in MATLAB and SIMULINK .With the help of robust PID controller system stability is achieved and the system with delay gets stable and gives high degree of Performance. The intermediate and final results are shown in figures below. The simulink result can be observed with PI parameters, PD parameters and then PID parameters and their related terminologies can be views as values like peak overshoot and undershoot, rise time, settling time etc. The simulink result can be seen as:-



The above results are graphical representation. The quantitative values of different parameters and related terms like peak time, settling time, rise time etc can also be viewed on simulation results

6. CONCLUSIONS

By applying some variation in algorithm the robust PID controller has made the system stabilized through various types of delay present in the system. The robustness of the controller is the major advantage and it guarantees the

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robustness of system with respect to plant communication variation and disturbance caused by the external factors. It promises the control system with good tracking and distribution rejected behaviour. The simulation result shows the controller gives good time response as well as reduces the delay time. PID controller receives the sensor information or transmits its output through the communication network. This PID controller method can improve the relative stability and improves the steady state. The simulation result can be viewed as graphically as well as the related values. They are listed in table for reference

7. FUTURE WORK

(1) Using H infinity optimal criterion other methods can be developed for PID controllers that can be applicable in chemical or industrial second-order plants that may or may not have time delays.

(2) By using the analytical design method of PID controller we can extend it for second-order integrating processes with time delay processes.

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