Effect of Bandwidth Variation of a Low Pass Filter of CDOB for Time-Delay Compensation

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Abstract— This paper presents effectiveness of cut off frequency of a low pass filter of communication disturbance observer (CDOB). This compensation technique requires system model only and not time model. So we can apply this compensation technique to both constant and variable time delay. In this paper, the validity of compensation technique with simulated result has been shown.

Key words: Time delay, stability, communication disturbance observer (CDOB), network disturbance (ND)

I. INTRODUCTION

Due to the rapid development in communication network, network control system (NCS) [1] has gained the attention of the researcher. In NCS we use shared network to transfer data from one element of the control system to another. But time taken by signal to travel is dependent on number of users using the network at that time. This delay destabilizes the entire close loop control system (CLCS). The research area of NCS is inter-disciplinary which combines both communication network and control systems. Many researchers have introduced effective techniques to eliminate effect of time delay.

G Farias, R D Keyser, S Dormido and F Esquembre [2] created interactive networked control labs using two software's Matlab and Easy Java Simulations. The first one is a widely used tool in the control community, whereas the second one is an authoring tool, designed to build interactive applications in Java without special programming skills. The remote labs created by this approach give to students the opportunity to face the effects of network delays on the controlled system. Astrom, Hang, and Lim [3] suggested a Smith predictor for controlling process using integrator and long dead time. Wenshan, Guo-Ping Liu and Rees [4] introduced a model-based networked predictive control scheme based on round-trip time delay measurement rather than separate considerations of the feedback channel delay (between the sensor and controller) and the forward channel delay (between the controller and actuator), which successfully avoids the requirement of synchronization.

In previous paper [5] we have analyzed the concept of CDOB and ND to compensate the effect of time delay. From [5] it is clear that smith predictor is only applicable effectively if time delay is constant but loose effectiveness when delay is random in nature. In this paper we present stability analysis and effect of cut off frequency of LPF of CDOB for delay compensation.

II. STABILITY ANALYSIS

Schematic diagram of time-delay compensation using CDOB and ND is shown in Fig 1. In this time delay compensation technique we need only system modal without the requirement of time delay model. Because of this property we can apply this technique in varying time delay. CDOB estimates the ND using dynamic property of ND. Estimated ND is used to compensate effect of time delay. For simplicity we assume that CDOD is ideal (cut-off frequency is infinity) and estimated ND is same as actual ND. . Here we use first order CDOB represented by following equations [6]......

$$D^*_{net}(s) = \frac{g}{s+g} D_{net}(s) \qquad (1)$$

Where g is the cut off frequency of the LPF of the first order CDOB. Value of g should be as large as possible but there are some limitations on the bandwidth or max value of g which are caused by the specification of the device like the resolution of measurement equipment, processing speed of pc and so.

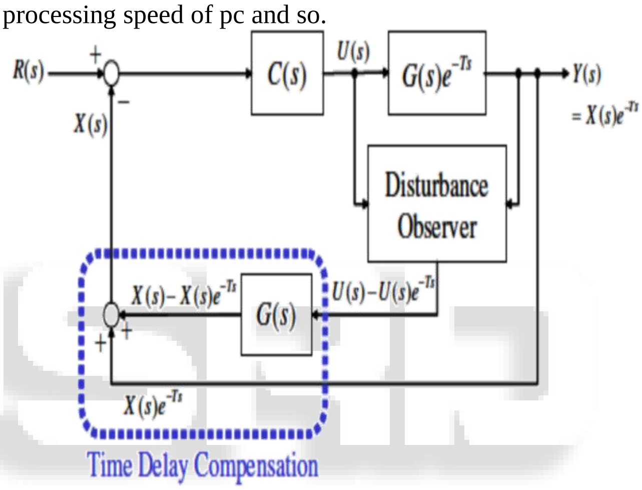

Fig. 1: Schematic Diagram of Time-Delay Compensation

III. SIMULATED RESULTS AND DISCUSSION

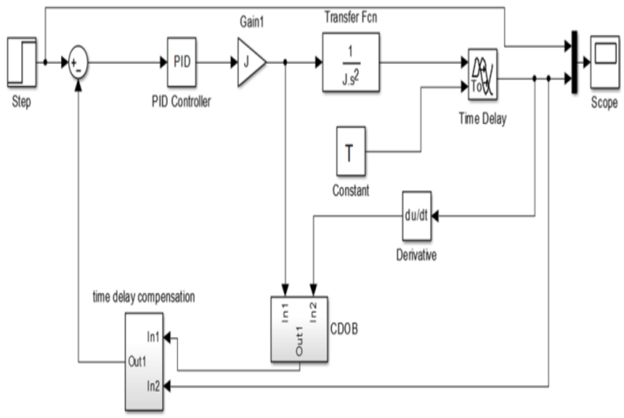

Fig. 2: Block Diagram of Simulation of Delay Compensation by Using First Order CDOB

Above simulated block diagram show CLCS with delay (T) in forward path with compensation. Effect of delay can be considered as called network disturbance (ND). This ND is predicted by CDOB. Prediction of ND depends on bandwidth of LPF of CDOB.

IN the above simulated CLCS we correlate command and corresponding response at different values of T and cut-off frequency (g) of CDOB.

Here we have shown effect of cut off frequency using two different values of time delay (T) 0, 10 ms.

A. Case I T = 0 ms:

When T = 0 ms then above system is same as traditional control systems where we assumed that all the components of system are ideal and there is no processing delay. In this case we draw response diagram for three different value values of g i.e. g = 0, 10 100.

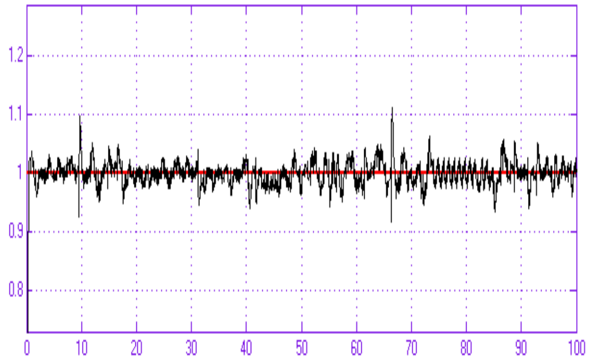

Fig. 3: step response(T = 0ms, g=0)

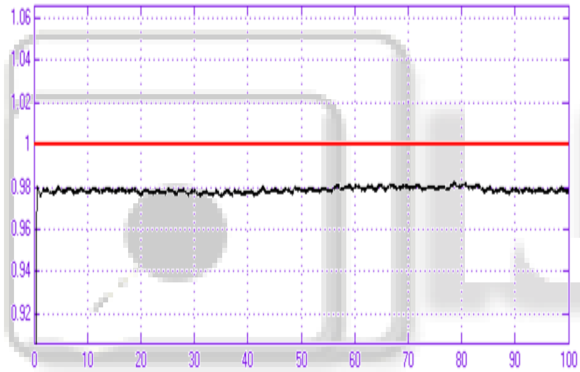

Fig. 4: step response(T = 0ms, g=10)

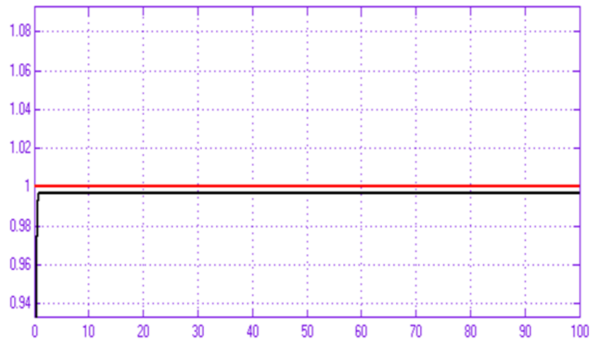

Fig.5: step response(T = 0ms, g=100)

In all three values of g system is stable because of T = 0 ms system has no time delay.

B. Case II T =1 0 ms:

For T = 10 ms we draw response diagram for three different value values of g i.e. g = 0, 25 65.

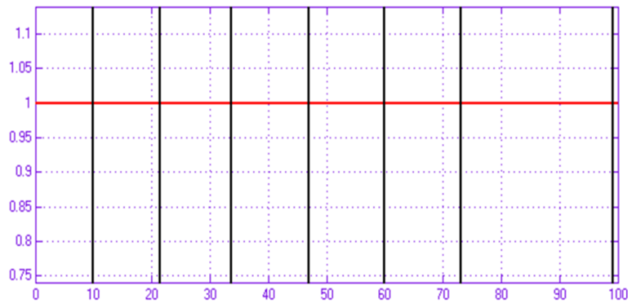

Fig. 6: step response(T =10ms, g=0)

CLCS having some delay (T) in forward path so due to this delay step response is oscillatory in nature and system does not follow the command. Step response is similar to step response of system having some delay without compensation.

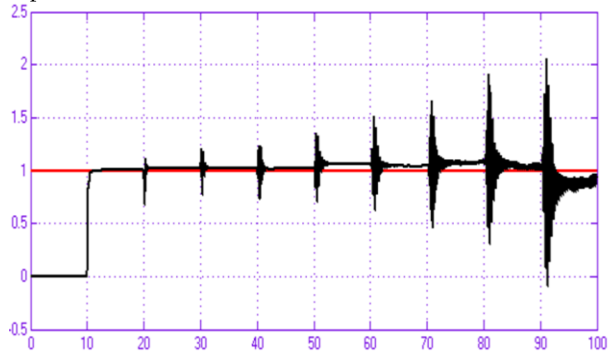

Fig. 7: step response (T =1 0ms, g=25)

Above this step response is batter response as compare to previous one so value of cutt-off frequency(g) improve the stability but at this value of g system is still unstable because of output of system goes to infinity as time increses.

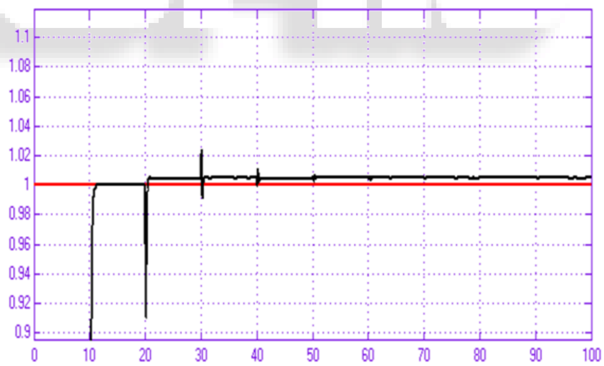

Fig. 8: step response (T =10ms, g=65)

As we can see for delayed system if cut off frequancy g is zero then it becomes unstable but as value of cut off frequancy increses then stability of system start improving and finaly at g = 65 system becomes stable and start following the command.

If bandwidth of LPF of CDOB is infinite then performance of this compensation technique is same as Smith Predictor and without time modaling.

IV. CONCLUSION

In this paper we have shown, how time delay destabilizes the system and also the effectiveness of cut off frequency of a low pass filter of communication disturbance observer. When T = 0ms, for any value of g the system is stable i.e.

for stable system bandwidth of CDOB has no effect on stability.

In the second case (T = 10ms) for low value of cut-off frequency of CDOB, close loop control system is unstable due to time delay in control loop. But as the value of cut-off frequency of CDOB increases the system becoming more stable and stable and for the higher value of cut-off frequency performance of this technique is same as smith predictor.

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