EFFECT OF SAMPLING PERIOD ON PROCESS COMPUTER CONTROL

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ABSTRACT

The study of the transient responses of sampled-data system is extremely important in which the sampling time must be considered as additional tuning parameter. The behavior of a third order liquid level control was chosen to be the basis of the sampling interval selection using the z-plane of the root locus plot. A satisfactory result was obtained.

INTRODUCTION

Every time a digital control algorithm is designed, a suitable choice of the sampling interval could reduces both the computational load and hardware cost [1]. However, as the sampling interval is increased, a number of degrading effects are becoming significant. One of the degrading effect on system performance as the sampling interval T is increased or made excessively short may leads to decrease the stability limit, loss information and reduce algorithm accuracy [2].

The stability test of sampled data system is usually conducted with respect to the pulse sequence rather than with actual output signal. However, the stability analysis based on the z-transform will lead to erroneous results if the system response contain hidden oscillation, thus, a modified z-transform should be used [3]. The system will be stable if the z-transform of the output response must have all its poles located inside the unit circle in the z-plane. In other words, the roots (Zi) of the characteristic equation:

$$1+\overline{HG(z)}G_c(z)=0 \qquad (1)$$

Then, the system is stable if and only if all the Zi satisfy $|Z|<1$.

In this work, a large sampling interval was chosen in the designing of the digital controller for a third order liquid level system. An optimum response was obtained from the use of root locus z-plot on the basis of the damping factor.

Selection of Sampling Intervals

In practice, it is necessary to determine a suitable value of sampling interval with regard to the system time constants and to any constraints imposed by the computer hardware choice. Too long sampling interval will lead to degradation in system stability by reducing the ultimate controller gain. The short sampling (that is usually used to bring digital control closed fit to that of conventional) introduces a problem in that very small changes in controller values cause a considerable change in the response.

Some researchers[4,5] considered that in case where computer speed is not a problem, it is often reasonably to change sampling time of 10 per cent of the fastest system time constant. However, such value may turn out not to be fast enough to obtain the best possible performance especially processes of a high non-linearity, for example, pH process control in which even fast sampling, some information my be lost[6] . This difficulty is most severe and the choice of sampling intervals has to be selected carefully. An addition to above is the effect of the dead time which has a very remarked destabilizing effect on the closed loop system due to the phase shift caused.

An investigation was made by Leigh[2] on the sensitivity of the temperature control loop (represented by first order plus dead time) to variation in sampling, his result showed that the sampling rate may be varied over quite range without significantly affecting the closed loop performance.

Another work by Dalton[7] on the variation of sampling rate showed the decreasing of system stability when sampling interval was increased. The sampling rates were 0.01, 0.1 and 0.5 second and the system to be controlled has transfer function of damping factor of 0.33 and second order time constant of 1.4 second. Such sensitive system, sampling rate should not exceed the 1/10 of the time constant.

In this work, a sampling of 1/3 of the time constant was chosen in order to reveal the system stability under such value if a proper controller design is considered.

The Process

The system chosen for this study is a third order liquid level system, as shown in Figure (1). The objective is to control the liquid level in the bottom vessel by manipulating the water flow rate. The bottom level is measured and interfaced to a microcomputer. The model of the process is derived from the unsteady mass balance[8] and, thus, the process transfer function is

$$G(s)=\frac{5.53}{(1.63s+1)(1.64s+1)(1.73s+1)} \qquad (2)$$

Figure (2) shows the simulated and actual open loop response to a positive step change in the feed. The pneumatic control valve has been approximated by a linear gain of 1.89.

The pulse transfer function for sampling period of 0.5 is:

$$\overline{HG}(z)=\frac{10.45(4.62E-3z^2+9.73E-3z+3.06E-3)}{(z-0.735)(z-0.737)(z-0.749)} \qquad (3)$$

Where the hold circuit is: $H(s)=\dfrac{1-e^{-sT}}{s}$

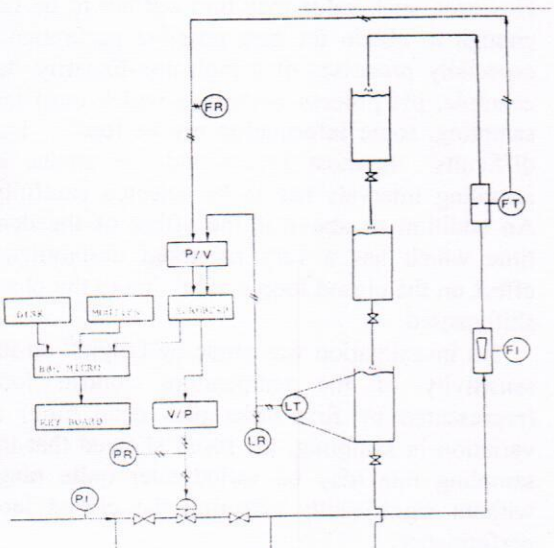

Figure (1) Schematic Diagram of the Third Order Liquid Level Control System

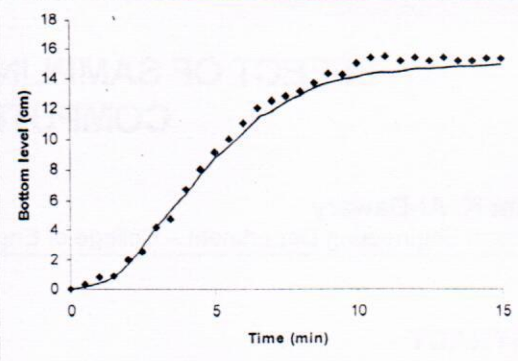

Figure (2) The Actual and Simulated System Open Loop Response

The Digital Control

The block diagram representing the digital control system is shown in Figure (3) from which the pulse closed loop transfer function is derived as:

$$\frac{X(z)}{Xsp(z)}=\frac{Gc(z)\overline{HG}(z)}{1+Gc(z)\overline{HG}(z)} \qquad (4)$$

For the design of the controller Gc(z), the desired closed loop system response must be chosen so that the transfer function must be physically realizable. A controller pulse transfer function an equivalent to the PID controller was adapted to control liquid level system, this controller is:

$$Gc(z)=\frac{Kc(z-\alpha)(z-\beta)}{z(z-1)} \qquad (5)$$

The discrete equation applicable for computer control, thus, will be as follows:

$$P(k)=P(k-1)+Kc[E(k)-(\alpha+\beta)E(k-1)+\alpha\beta E(k-2)] \qquad (6)$$

Where: P(k); the controller output at sample (k), E(k); error signal at sample (k), Kc; controller gain, and α,β are the zeros at the transfer function

The choice of the above controller's zeros was based on the cancellation of two or one of the process poles and values less than the values of the poles (ie closer to the origin), these values are:

Test number	α	β
1	0.735	0.737
2	0.735	0.6
3	0.6	0.6

In order to obtain an optimum responses, the z-plane of root locus was used and the results were based on damping factor (ξ) of 0.22. At this point, the controller gains were determined for each case, the obtained gain values are:

	Test No. 1	Test No. 2	Test No. 3
Kc	0.634	0.29	0.138

Figure (4) shows the locations of the poles and the zeros of the system characteristic equation for the use of different controllers that stated above. This figure shows that the closer the zeros to the origin the less the ultimate controller gain.

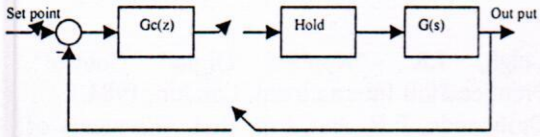

Figure (3) The Typical Digital Control Loop System

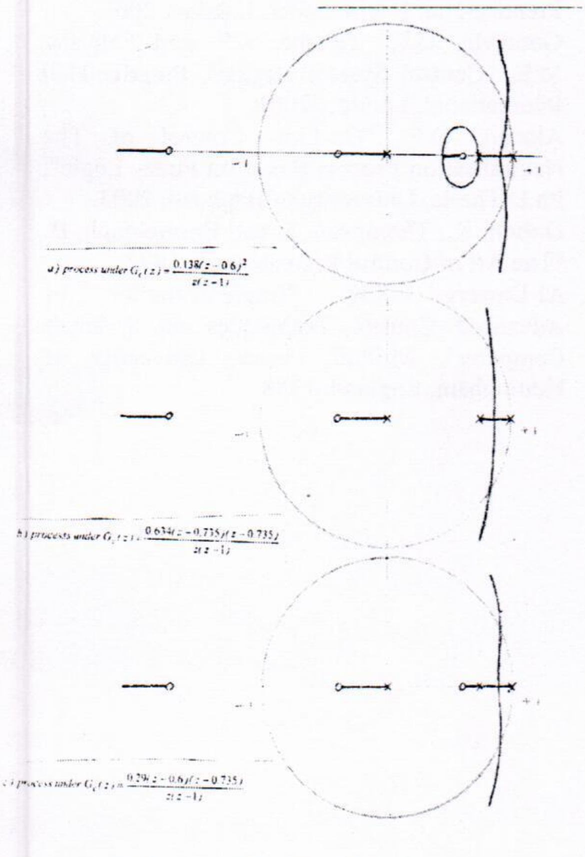

Figure (4) Z-Plane Plot for The Digital Control Loop Under The Use Of Different Gain for The Controller

The application of the above controllers experimentally and theoretically for the control of the bottom level of the considered third order liquid level system are shown in the Figures 5,6 and 7. The obtained system responses prove that the increasing of the sampling interval even up to the third of the value of the dominant time constant does not affect the system stability. Figure (8) shows the acceptable behaviour of the control valve and the controller output signal (ie a very low rate of signal oscillation).

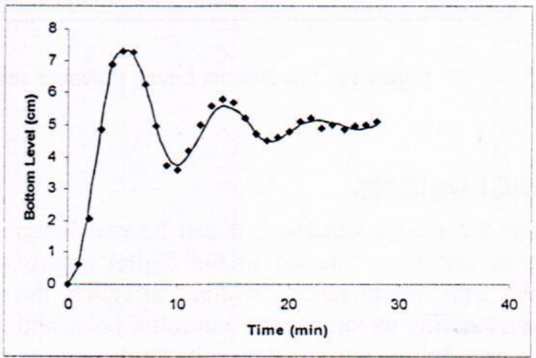

Figure (5) Experimental and Simulated Responses of Bottom Level Using Digital Controller with Kc=0.634

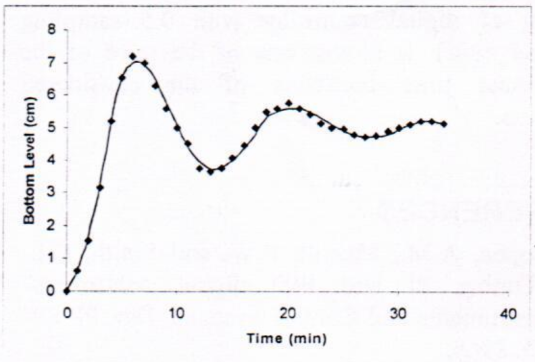

Figure (6) Experimental and Simulated Responses of Bottom Level Using Digital Controller with Kc=0.29

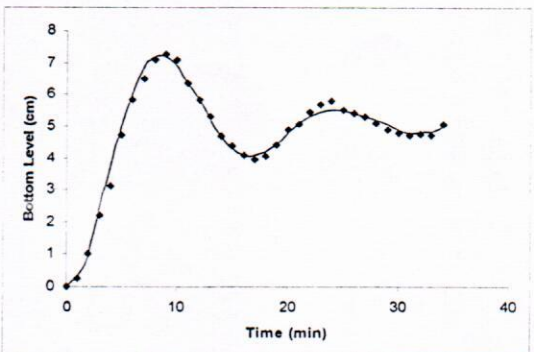

Figure (7) Experimental and Simulated Responses of Bottom Level Using Digital Controller with Kc=0.138

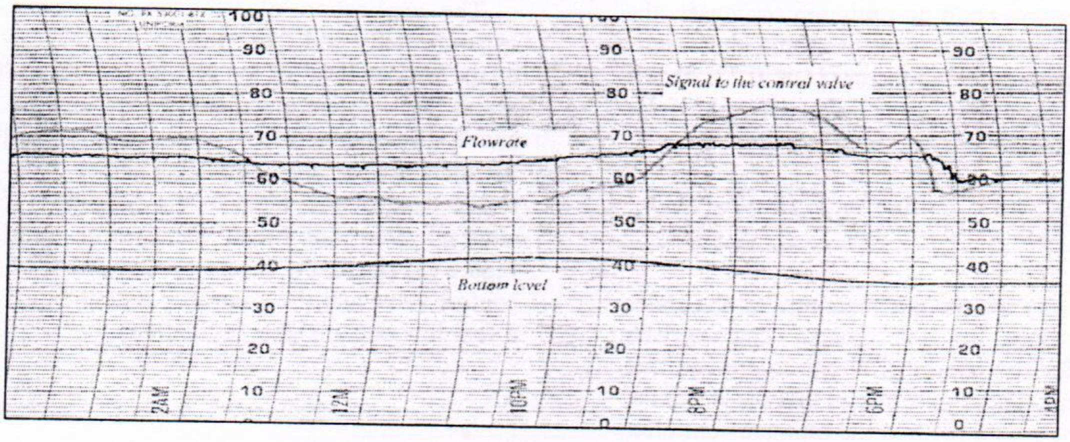

Figure (8) The Bottom Level, Flowrate and Signal to The Control Valve by 3-Pen Recorder

CONCLUSIONS

From the results obtained, it can be concluded that the sampling interval in the digital control system may be increased without affecting the system stability as long as the controller poles and zeros are lying within the unit circle, so as realistic controller gains may be used. Thus, an acceptable responses have been obtained from the using of digital controller with 0.5 sampling period which is almost one of the third of the dominant time constants of the considered process.

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