Design Materials for Unity Control Loop

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Abstract – This tabloid is about a discovery of control loop. A loop which is used to control a process means that is called as control loop. Control is a process of making a system as stable as possible at preferred reference value or set point of that exact system. Here, this loop gives the output response very nearer to reference value without any controller. That means output response traces the set point instantly. There is a illumination is created in the process. That is, the loop considers the system which is in the loop as one or unity. This origin the loop is named as Unity Control Loop (UCL).

Keywords: UCL, Control Loop, Control System, Process Control Loop.

I. INTRODUCTION

Control loops are mostly used for evaluate the fault value and also to reduce the error. Various control loops invented to perform specific tasks[1,4]. Feedback loop is consuming the wide range of applications in process control industries to compare the output with set point. Those errors are minimized by using various kinds of controllers[6,9]. But UCL is not required any controllers to control the system. It causes, UCL is not have the need of any tuning methodologies and also reduces the cost of controllers. The modelling and simulation are important tools often used nowadays for investigating the system's behavior in the industry and also in other fields of living[7,8,10].

Especially nowadays, when the computation power of today's personal computers is very high and the prize is relatively low the usability of the simulation grows. This contribution combines two modelling techniques[2,5]. At first, the mathematical model of the water tank will be derived, then simulations were done on this model and results are verified by measurements on the real model of the water tank[4,13]. The level process controller is used to perform the control action of level process and study the characteristics of I/P converter. The RF capacitance level transmitter is used to measure the level of the process tank. In level control action, a pump sucks the air from reservoir and gives it to control valve. Every internal transaction is in voltage[3,11].

Here, IBM-PC acts as error detector and controller. According to error signal, corresponding control signal is given to the I/P converter[9,12]. It controls the flow of the liquid in pipeline by varying stem position of the control valve. For maintaining the level of the process tank, flow is manipulated level signal is given to the data acquisition card. By pass line is provided to avoid the pump overloading[12]. From this controller also study the
characteristics of the level transmitter, I/P converter, control valve and justify the various control actions\cite{1,14}. Data Acquisition card has ADC and DAC, so that it acts an effective link between the process and the controller.

II. UNITY CONTROL LOOP

In UCL, set point \( R(s) \) is compared with system response. This compared output \( Y(s) \) is fed back for error calculation. The arrangement of UCL is shown in Fig. 1. Process block covers the proposed quantity of UCL. Residual stuffs are similar to feedback loop only. Feedback gain is considered as 1 (\( H(s) = 1 \)).

![Fig.1 Unity Control Loop](image)

Equations (1), (2), (3) are derived from Fig. 1. Where \( S(s) \) and \( e(s) \) are system response and estimated input respectively.

\[
G(s) = R(s) - S(s) \quad (1)
\]

\[
Y(s) = e(s)G(s) \quad (2)
\]

\[
e(s) = R(s) - Y(s) \quad (3)
\]

Substitute (3) in (2),

\[
Y(s) = [R(s) - Y(s)]G(s) \quad (4)
\]

\[
Y(s) + Y(s)G(s) = R(s)G(s)
\]

\[
Y(s)[1 + G(s)] = R(s)G(s)
\]

\[
T(s) = \frac{Y(s)}{R(s)} = \frac{G(s)}{1 + G(s)} \quad (5)
\]

Substitute (1) in (5),

\[
T(s) = \frac{R(s) - S(s)}{1 + [R(s) - S(s)]} \quad (6)
\]

Since \( R(s) \) is unit step input; substitute \( R(s) = 1 \) in (6),

\[
T(s) = \frac{1 - S(s)}{1 + 1 - S(s)}
\]

\[
T(s) = \frac{1 - S(s)}{2 - S(s)} \quad (7)
\]
Closed loop transfer function of system with UCL is derived in equation (7).

### III. UCL RESPONSE WITH FIRST ORDER SYSTEM

Let consider first order level control process with UCL. Mathematical modelling of VLPA-101-CE is done by Deign Gloria Jose. Transfer function is obtained from modelling and PID controller is used to control the level of process tank. ZN method is implemented to tune the parameters of PID Controller. Output response is explained [1].

![Level control process with UCL](image.png)

Level control process with UCL is illustrated in Fig.2. Transfer function of the first order tank (from [1]) is $S(s)$ and it is controlled using UCL.

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

(8)

### IV. STABILITY ANALYSIS OF UCL

A system is said to be steady, if its output is under control. Else, it is said to be unstable. A stable system produces a confined output for a given bounded input. Types of stabilities,

- Absolutely stable
- Conditionally stable
- Marginally stable

If the system is stable for all the range of system constituent values, then it is known as the absolutely stable system. The closed loop control system is absolutely stable if all the poles of the closed loop transfer function lies in the left half of the ‘s’ plane. If the system is stable for a particular range of system component values, then it is known as conditionally stable system. If any two poles of the closed loop transfer function is lies on the imaginary axis means the system is marginally stable [3].

Substitute (8) in (7),

$$T(s) = \frac{5s}{10s + 1}$$

(9)
Equation (9) is the closed loop transfer function of first order tank system with UCL.

V. RESULTS AND DISCUSSIONS

Open loop response of first order tank system is shown in Fig.3. Where response curve is settled in set point \((R(s)=1)\) and also the settling time is near to 31 sec. Feedback loop of first order tank system is shown in Fig.4. Where response curve is settled in 0.5 \((|=1)\) and settling time is near to 16 sec.

Fig.3 Open Loop Response of System

Fig.4 Feedback Loop Response of System

Fig.5 Unity Control Loop Response of System

Fig.5 is illustrating the response of UCL. It settled in set point \((R(s) =1)\) and also the settling time is 1 sec sharply.
Fig. 6 Root Locus of First order Tank system with UCL

This part of the procedure employs control engineers that have experience with the choice of the input and output variables together with process engineers which know the system from the process point of view. The goal of this contribution was to show the procedure of modelling and simulation before the design of the controller.

In Fig. 6, Pole of the closed loop first order tank system with UCL is placed in left side of the real axis in 's’ plane. That means system is absolutely stable.

The system properties together with the most important quantities and relations between them are sketch out, then the mathematical model was derived with the use of balances inside the system and finally the dynamic analyses were done to obtain the behavior of the system. The next work will be focused on the choice of the optimal control strategy, simulation experiments and again verifications on the real model.

Also, the unity control loop is designed to nullify the disturbance system’s effect on the response of level control system without any controller implementation. By using this UCL, the response of system is settled in the unity value at the time is equal to zero. It concludes this UCL will suitable for all transfer function model of various order of systems.

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