2-DOF Control System Designed By Root Locus Technique.

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Abstract

This paper presents the design technique of the using of PI, PID and PIDA Controllers in order to achieve the desired transient and steady state responses. The merit of the proposed technique is any tuning method is not being required. By using of the forward controller, so that all given specifications to be designed can be obtained via the root locus approach.

1. Introduction

In general, there are many available controllers for controlling the process, *i.e.*, Proportional (P), Proportional-Integral (PI), Proportional-Integral-Derivative (PID), and the latest version is the Proportional-Integral-Derivative Acceleration (PIDA) controller proposed by Dorf and Jung [1]. When the P controller is applied to the first order type 0 plant with consisting of no integrator, the off set or non-steady state error will be occurred. Although, it can be reduced by increasing the proportional gain, however this non steady state error cannot be absolutely reduced to zero. In order to achieve zero steady state error, the PI controller is then properly applied to such plant that consisting of only simple lags time constant. Even the zero steady state error of the time responses of control can easily be achieved by employing the PI controller. However, it is not guaranteed to satisfied almost of the requirements to be designed the control system. Because of the basic requirements of control system design are at least composed of two required transient and steady state specifications.

The basic requirements of control system design [2,3] can be expressed as:

1) Specification for transient state expressed in term of the Percentage of Overshoot $(P.O.)$.
2) Specification for steady state expressed in term of the Settling time (t_s).

This paper is intended to verify that we can employ the conventional PI, PID controllers, and the PIDA controller incorporated by the forward controller, such that all specifications can easily be achieved without any fine-tuning method being required. The merit of this proposed analysis could be shown from [4] that the effect of the remained zero $(s+Z_C)$ in the control loop [2] can efficaciously be reduced by this forward controller, then the overall system become the two-degree of freedom (2-DOF) system. Furthermore, this proposed technique by MATLAB© simulations [5] and experimental results are also being shown.

The structure of the SISO system is shown in Fig.1, where a unity feedback is assumed.

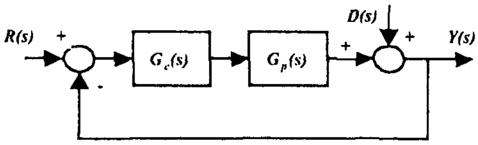

Fig. 1 Structure of the SISO system.

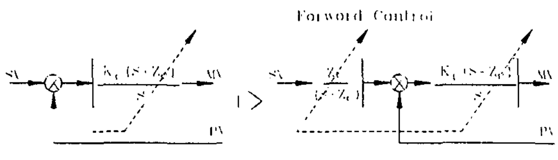

Fig 2 Structure of PI and PI 2-DOF controllers.

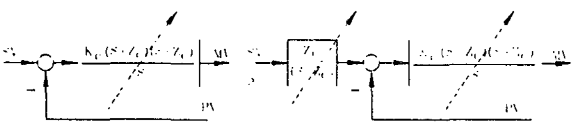

Fig 3 Structure of PID and PID 2-DOF controllers.

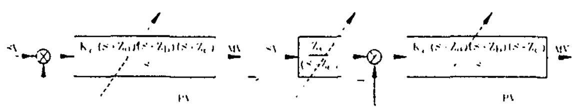

Fig 4 Structure of PIDA and PIDA 2-DOF controllers.

2. Design Procedure of controllers.

The design procedures to meet the transient and steady state response specifications are as follows:

Step 1. The damping ratio (ζ), undamped natural frequency (ω_n) and s_d are determined from the transient response specifications in (1).

$$\left.\begin{aligned} P.O. &= 100e^{-\zeta\pi/\sqrt{1-\zeta^2}}\ \%, \\ t_s &= 4/\zeta\omega_n \quad (\pm 2\%), \\ s_d &= -\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}, \end{aligned}\right\} \qquad (1)$$

where $P.O.$ is percent overshoot and t_s is the settling time.