Advanced Process Control

CBEg 6142

School of Chemical and Bio-Engineering
Addis Ababa Institute of Technology
Addis Ababa University

Chapter 8

Smith Predictor

Smith Predictor

- In order to improve the performance of system containing time delays, special control strategies have been developed that provide effective time-delay compensation. The *Smith predictor* technique is the best-known strategy (Smith, 1957).

- Various investigators have found that the performance of a controller incorporating the Smith predictor for set-point changes is better than a conventional PI controller based on an integral-squared-error criterion. However, the Smith predictor performance may not be superior for all types of disturbances.

Smith Predictor: Derivation

Consider the conventional feedback control system with dominant time delay.

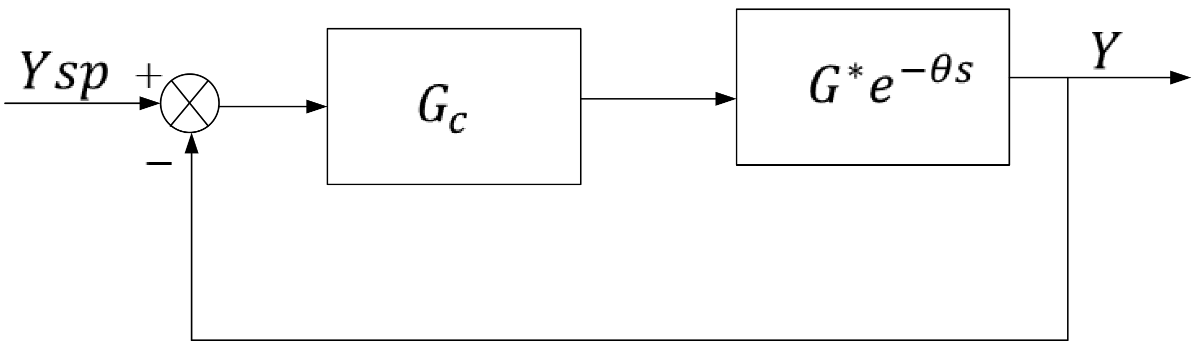

Figure 8.1 Conventional feedback control system

The closed-loop response becomes

$$\frac{Y}{Y_{sp}} = \frac{G_c G^* e^{-\theta s}}{1 + G_c G^* e^{-\theta s}} \qquad (8.1)$$

Smith Predictor: Derivation

- The problem in the closed-loop response of the conventional feedback control system stems from the time delay in the denominator.

- To address this problem consider a desired closed response where there is no time delay in the denominator

$$Q_d = \frac{Y}{Y_{sp}} = \frac{G_c G^* e^{-\theta s}}{1 + G_c G^*} \qquad (8.2)$$

Smith Predictor: Derivation

Taking (8.2) as the desired response and using the direct synthesis method, design a feedback controller $\bar{G}_c$

$$\bar{G}_c = \frac{1}{G^* e^{-\theta s}} \frac{\dfrac{G_c G^* e^{-\theta s}}{1 + G_c G^*}}{1 - \dfrac{G^* e^{-\theta s}}{1 + G_c G^*}} \tag{8.3}$$

$$\bar{G}_c = \frac{G_c}{1 + G_c G^* - G^* e^{-\theta s}} \tag{8.4}$$

$$\bar{G}_c = \frac{G_c}{1 + G_c (1 - e^{-\theta s}) G^*} \tag{8.5}$$

Smith Predictor

- Equation (8.5) can be realized by the configuration shown in Figure 8.2 with G_c conventional feedback controllers (PI, or PID).

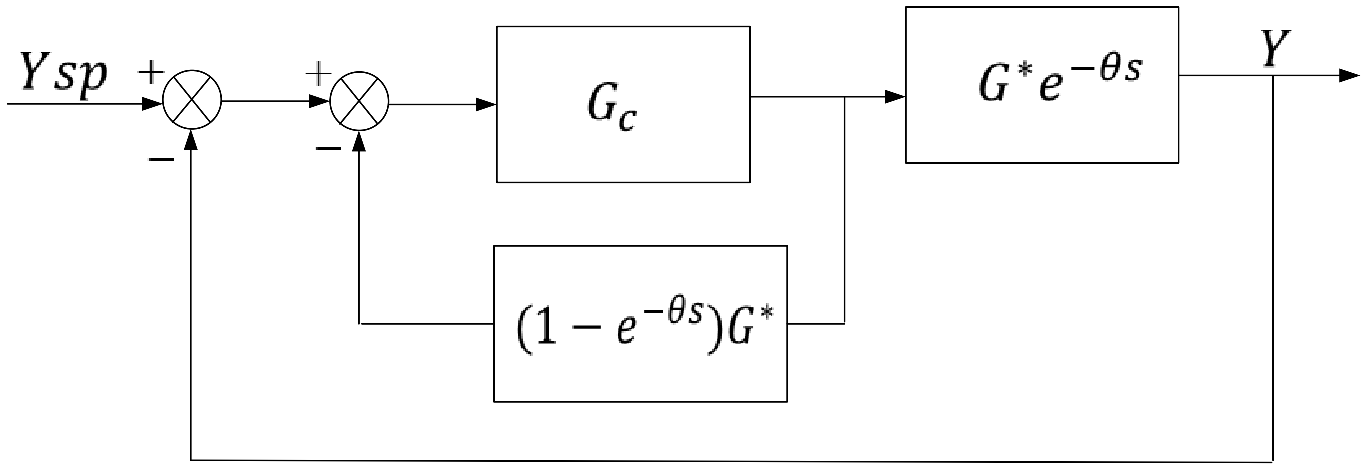

Figure 8.2 Smith Predictor

Smith Predictor: Example

<u>Example 8.1</u>

Determine the controller setting for a first order plus time delay (FOPTD) and second order time delay (SOPTD) process that use smith predictor. Construct the control structure.

$$G = \frac{Ke^{-\theta s}}{\tau s + 1}$$

$$G = \frac{Ke^{-\theta s}}{(\tau_1 s + 1)(\tau_2 s + 1)}$$

Solution

Since the closed-loop response does not contain time delay in the denominator, the setting can be determined just a process without time delay.

$$G_c = \frac{\tau s + 1}{K} \frac{\frac{1}{\tau_c s + 1}}{1 - \frac{1}{\tau_c s + 1}} = \frac{\tau s + 1}{K} \frac{1}{\tau_c s + 1 - 1}$$

$$= \frac{\tau s + 1}{K \tau_c s} = \frac{\tau}{K \tau_c} + \frac{1}{K \tau_c s}$$

$$G_c = \frac{\tau}{K \tau_c} \left(1 + \frac{1}{\tau s}\right)$$

This is a PI controller with $K_c = \frac{\tau}{K \tau_c}$,