Chemical Industry & Chemical Engineering Quarterly
Available online at
Association of the Chemical Engineers of Serbia AChE
www.ache.org.rs/CICEQ
Chem. Ind. Chem. Eng. Q. 30 (2) S1–S2 (2024) CI&CEQ

Supplementary material to

INTERNAL MODEL CONTROL OF CUMENE PROCESS USING ANALYTICAL RULES AND EVOLUTIONARY COMPUTATION

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Chem. Ind. Chem. Eng. Q. 30 (2) 89–98 (2024)

The closed-loop setpoint response of the system shown in Figure1 can is represented as,

$$\frac{y}{y_s} = \frac{g(s)c(s)}{g(s)c(s)+1} \tag{A1}$$

Here we have assumed that output measurement y is perfect. In the IMC PID controller, the desired closed-loop response will be specified first, and we will develop a controller that matches the desired closed-loop response.

$$c(s) = \frac{1}{g(s)}\frac{1}{\left(\frac{1}{\left(\frac{y}{y_s}\right)-1}\right)} \tag{A2}$$

We consider the first-order and second-order time delay model g (s) in Eqs. (9) and (11). For the first-order time delay model, the desired response can be equated to Eq. (9)

$$\left(\frac{y}{y_s}\right)_{desired} = \frac{e^{-\theta s}}{\tau_c s+1} \tag{A3}$$

We have kept the delay θ in the "desired" response, which gives a "Smith predictor" controller and can be expressed as

$$c(s) = \frac{(\tau_1 s+1)}{K}\frac{1}{(\tau_c s+1-e^{-\theta s})} \tag{A4}$$

for FOPDT model

$$\tau_c = tuning\ parameter$$

$e^{-\theta s} = 1-\theta s$, First order Taylor series approximation is applied for the delay. The resultant response can be expressed as

$$c(s) = \frac{(\tau_1 s+1)}{K}\frac{1}{(\tau_c+\theta)s} \tag{A5}$$

$$c(s) = K_c\left(1+\frac{1}{\tau_I s}\right) \tag{A6}$$

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From the comparison of Eqs. (17) and (18), the parameters can be obtained as

$$\tau_I=\tau_1,\ K_c=\frac{1}{K}\frac{\tau_I}{(\tau_c+\theta)} \tag{A7}$$

Similarly, the second-order response with a time constant τ_c can be represented as

$$c(s)=\ \frac{(\tau_1 s+1)(\tau_2 s+1)}{K}\frac{1}{\left(\tau_c s+1-e^{-\theta s}\right)} \tag{A8}$$

After the first-order Taylor series approximation of the delay SOPDT model is represented as

$$c(s)=\ \frac{(\tau_1 s+1)(\tau_2 s+1)}{K}\frac{1}{(\tau_c+\theta)s} \tag{A9}$$

$$c(s)=\ K_c(\tau_D s+\frac{1}{\tau_I s}+(\frac{\tau_D}{\tau_I}+1)) \tag{A10}$$