Master study
Systems and Control Engineering
Department of Technology
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SCE1106 Control Theory

Exercise: re-tune a PI controller for oscillating feedback system

Task 1

Consider a level system which is modeled by an integrator plus time delay as

$$y = h_p(s)(u - v). \tag{1}$$

u is the flow control input, v the outflow disturbance, and where the process transfer function is given by

$$h_p(s) = k\frac{e^{-\tau s}}{s}, \tag{2}$$

with process gain $k = 1$ and time delay $\tau = 1$.
The level is initially controlled by a PI controller,

$$e = r - y, \tag{3}$$

$$u = h_c(s)e, \tag{4}$$

$$h_c(s) = K_p\frac{1 + T_i s}{T_i s}, \tag{5}$$

with an initial tuning with proportional gain, K_p, and integral time, T_i, given by

$$K_p = 0.005,\ T_i = 6. \tag{6}$$

The feedback control system have inherent oscillations in the step responses and the feedback system have to be re-tuned. Step responses of the control system is shown in Figure 1.

a) Simulate step responses of the system controlled by the initial tuning given above. Simulate both set-point step responses and disturbance step responses. Use Control system toolbox functions and analytical Laplace plane definitions, as (s=tf('s'), $h_p(s) = k * exp(-tau * s)/s$, etc.), or similar time domain simulations.

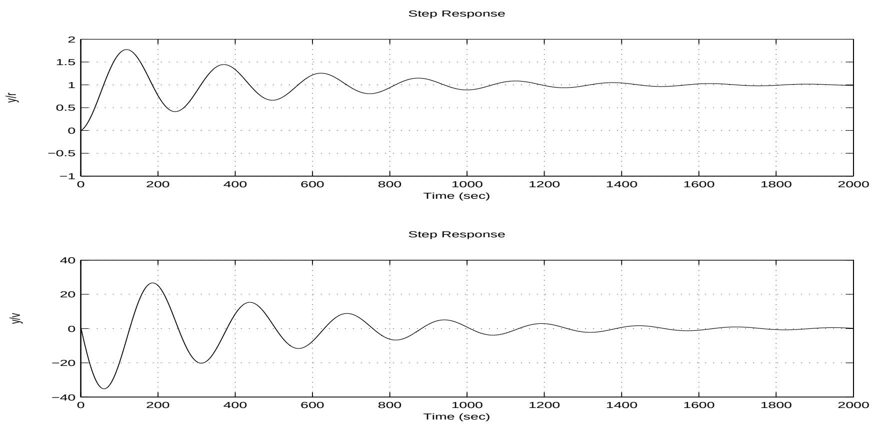

Figure 1: Example of an oscillating feedback system with initial wrong tuning. Feedback control of integrating plus time delay process, $h_p(s) = \frac{e^{-s}}{s}$, and PI-controller $h_c(s) = K_p \frac{1+T_i s}{T_i s}$ with initial settings as in (6).

b) Often, process operators are intuitively decreasing the controller proportional gain, K_p. This is the opposite of what which have to be done in order to remove the loop oscillations, if we still want to use a PI controller with this T_i setting.

Note however, that oscillations may be avoided by also using a P-controller but the controller will not reject load disturbances in this case.

Show that the proportional gain in the PI controller have to be increased in order to remove the oscillations. Deduce the rule that the product of the proportional gain, K_p, and the integral time, T_i, should be

$$K_p T_i = \frac{4}{k}, \tag{7}$$

in order to avoid oscillations in the feedback control loop. Tips: Find this condition from the pole polynomial obtained from the denominator $1 + h_p h_c$ in the set-point and disturbance transfer functions and with the transfer function as a pure integrator $h_p(s) = \frac{k}{s}$.

c) Find new controller parameters and simulate step responses similar to the one in task a) above, but with re-tuned PI controller parameters.