INDIAN INSTITUTE OF TECHNOLOGY MADRAS
Department of Chemical Engineering

CH3050 Process Dynamics & Control
Assignment #5

Due: Saturday, May 08, 2021

Exercise

1. A process $G_p(s)$ is in feedback control with a P-controller using a measuring element $G_{\mathsf{sens}}(s)$.

$$G_p(s) = \frac{s^2 - 4s + 8}{s(s+1)(s+3)}; \quad G_{\mathsf{sens}}(s) = \frac{1}{s+10}$$

   (a) Sketch the root locus of a feedback compensated closed-loop system consisting of as the proportional controller gain K_c varies from 0 to $+\infty$. Compute the asymptotes angles, centroid, angles of arrival, break-in and entry points.

   (b) Generate the root locus on the computer and verify your sketch (do not reverse the order of parts (b) and (a) for your own benefit!)

   (c) Determine the ultimate gain by hand (show your calculations) and verify your answer with the computer generated plot.

   (d) Find the value of K_c such that the closed-loop response to a set-point change has the minimum settling time.

   (e) If a PI-controller $G_c(s) = \left(K_c + \frac{K_I}{s}\right)$ was used instead, find the ultimate value of K_I with the value of K_c fixed to what you obtained in (1d).

2. A process with the transfer function $G(s) = \frac{2(s+4)}{10s^2 + 7s + 1}e^{-2s}$ is placed in feedback with a controller $G_c(s)$

   (a) Suppose G_c is a P-controller. Design K_c s.t. the gain margin is 8.2 dB. Report the corresponding PM.

   (b) DelayNaJaane, who is in charge of the controller design, is uncertain about the delay but would like to know the extent of delay for which the control system can robustly remain stable. What is the maximum delay uncertainty with the value of K_c chosen in (2a)?

   (c) Using the K_c value in part (2a), now design a PI controller of the form $G_c(s) = K_c\left(1 + \frac{1}{\tau_I s}\right)$ s.t. the phase margin is $60°$. Report the corresponding GM.

   (d) Evaluate the sensitivity function of the feedback system with the above settings. Verify numerically that indeed Bode's sensitivity integral holds (up to the numerical approximation).

3. A process has the transfer function $G(s) = \frac{2(s+2)}{s^2 + 2s - 3}e^{-s}$

   (a) Using Pade's first-order approximation, design a P controller (call it G_{c1}) such that the closed-loop system is stable and has the dominant pole located at $p = -2$.

(b) Design another P controller (call it G_{c2}) using the Nyquist diagram such that the gain margin is 10.5 dB. Calculate the offset in output to a step-type set-point change for this value of K_c.

(c) Using SIMULINK, compare the performances of above two controllers for step-type set-point change and disturbance. Would the performance of first controller improve if we had taken into account the delay using a Padé's second-order approximation?