INDIAN INSTITUTE OF TECHNOLOGY MADRAS
Department of Chemical Engineering

CH3050 Process Dynamics & Control
Assignment #5

Due: April 30, 2020

Exercise

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

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

   (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) Find the value of K_c such that the dominant poles of the closed-loop system have a damping ratio of 0.4.

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

2. A process with the transfer function $G(s) = \dfrac{2(s+1)}{10s^2+7s+1}e^{-2s}$ 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) Using the K_c value in part (2a), now design a PI controller of the form $G_c(s) = K_c\left(1 + \dfrac{1}{\tau_I s}\right)$ s.t. the phase margin is $60°$. Report the corresponding GM.

   (c) Plot the step response (set-point change) of the resulting closed-loop system.

   (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 $G(s) = \dfrac{2}{s^2+3s-10}e^{-s}$

   (a) Ignoring the delay, design a P controller (call it G_{c1}) such that the closed-loop system is stable and has the dominant pole located at $p = -1$.

   (b) Design another P controller (call it G_{c2}) using the Nyquist diagram such that the gain margin is 1.5 dB.

   (c) 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?