EE324, Control Systems Lab, Problem sheet 6
(Report submission date: 28th Sept 2021)

Q1) Design a Proportional (P) controller with gain K using the root-locus method so that the closed-loop system with unity negative feedback attains the following specifications. The open loop system has the transfer function G(s)=1/((s+3)(s+4)(s+12)).

a) To obtain a steady state error of 0.489 on applying step input.
b) To attain a damping ratio of 0.35.
c) What is the gain value at the break away point?
d) Now for the given open loop system increase the controller gain K in a small range of 0 to 1 in appropriate steps and compare the step responses on a graph. What can you conclude about the locus of these closed loop poles on the root locus of the open loop system? And what can you conclude about the steady state errors?
e) Now do the same for a larger range of proportional gain such as 1 to 1000 in appropriate steps and compare the step responses on a graph. What can you conclude about the locus of these closed loop poles on the root locus of the open loop system? and What can you conclude about the settling times (5%) and steady state errors? What can conclude on the stability of the system?

Q2) For the same open loop system as above, design a Proportional-Integral (PI) controller with transfer function (K(s+z)/s) using the root-locus method to attain the following specifications for the closed-loop.

a) To reach a damping ratio of 0.2 for an initial value of z =0.01.
b) To obtain undamped natural frequencies of 8 and 9 rad/s.
c) Vary the value of 'z' and observe its effect on the root locus of the system.
d) Is it possible to alter the pole locations of a system using a PI controller without changing the damping ratio?

Q3) a) Plot input and output sinusoid of varying frequency (choose 5 different frequencies) and check for a stable transfer function G(s) = 1/(s^2 + 5s + 6) and check that the ratio of the amplitude of output to input is $|G(j\omega)|$ and the phase difference is the angle of $G(j\omega)$, with omega equal to these 5 frequencies.

b) The desired relation (between phase difference and angle of $G(j\omega)$ is for frequency measured in Hz or in rad/s ?

c) Consider G(s) = 60/(s^3+6s^2+11s+6). Find answers to Q4a for this case. Find a frequency when the phase angle difference is 180 degrees. (Find the frequency by trial and error or by any other method.) Did numerator 60 play a role in this argument (of finding the frequency for which we have 180 degrees phase difference between input and output)?