EE324, Control Systems Lab, Problem sheet 7
(Report submission date: 14th March 2021)

Q1) For the same open-loop system as above, design a Proportional-Integral (PI) controller with a 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?

Q2) Consider having a **lag-compensator** that has a ratio of zero-magnitude to pole-magnitude of say 20. This assignment aims to change the absolute pole-zero pair location of this lag-compensator (maintaining the ratio of 20) and see the effect on the transients.
a) Consider G(s)=1/(s^2+3s+2) and first choose a constant gain K to achieve 10% OS in the closed-loop.
b) Find the steady-state error and now add the above lag-compensator and (with the above ratio of 20), find the new steady-state error.
c) Change the location of the pole-zero pair (with say 5 different pole-zero locations) to see the degrading effect on the planned %OS and the trade-off with how late the lag-compensator effect comes into action.

Q3) a) Design a lead compensator for G(s) of Q2 to have 2% settling time made half of the case for Q2-a, and %OS still the same.
b) Design a PD controller to achieve the specification in Q3a.

Q4) 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(jω)| and the phase difference is the angle of G(jω), with omega equal to these 5 frequencies.
b) The desired relation (between phase difference and angle of G(jω) 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)?