EEE 342 Feedback Control Systems
Spring 2022-2023
Lab 3 - Margin Analysis of a System

The purpose of this lab is to understand how gain, phase and delay margins can be estimated by using mathematical model, and how these calculations can be verified.

Part-1: Margin Estimation

A controller is designed for your plant, which contains a first order LPF and PI, such that

$$G_c(s) = \left(\frac{1}{s + \tau_{LPF}}\right)\left(\frac{K_c(s+80)}{s}\right)$$

where K_c, τ_{LPF} is found by

$$K_c = \frac{2}{K_g}, \quad \tau_{LPF} = \frac{3}{\tau_p}$$

where K_g is the DC gain of the plant, and τ_p is the reciprocal of distance of pole of the plant to the imaginary axis (K and τ found in Lab 1).

1. For this controller ($G_c(s)$) and the first order approximation of DC motor found in the first lab ($G_p(s)$), draw the Bode plot of open loop transfer function, $G = G_c G_p$.

2. Calculate gain margin and phase margin by using this plot. Also, calculate the delay margin by using phase margin and crossover frequency, ω_c, where $DM = PM(\text{in radians})/\omega_c$. You can check your results using 'allmargin' command.

Check-1 Show your calculations, estimated margins and Bode plot in your report.

Part-2: Margin Verification

1. Download all the files uploaded on Moodle for Lab 3 and put them on a folder. Then open Matlab and change the path with your folder.

2. Open `lab3_DCmotor.mlapp` and enter the inputs (K and τ found in Lab 1) to obtain complex model of your DC motor. Run this app first. A new window will open and click on 'Build My Motor' in the opened window. This gives you the step responses of output of your model and DC motor. Also, the variables k, p, τ, z can be seen on Matlab workspace.

3. Open `lab3_step_GM.slx`.

4. Set $r(t) = 40u(t)\ rpm$ and your controller ($G_c(s)$), and increase gain (K) until the system is unstable. To observe this, plot the output of the response after Run the simulink file (you need to find the gain margin experimentally, therefore you can start with the GM you estimated in Part 1, and decrease if it is already unstable or increase if it is not. At the end, you need to find the exact value of final gain (K_f) that makes the system unstable, so that the system is stable for all gains such that $K < K_f$).
Here, to obtain the correct value of K_f, change the gain until the oscillatory response starts to increase. The point where you observe any increase in the oscillations indicates that the system is unstable. Therefore, the K_f value should be just below this gain.

Check-2 Show your calculated GM, observed GM and response of the system for two cases: K_1 is slightly less than K_f, so that the system is stable, and K_2 is slightly larger than K_f such that the system is unstable. Show corresponding plots in time domain in your report (you should have 3 plots using K_f, K_1 and K_2).

5. Open `lab3_step_DM.slx`.

6. Set $r(t) = 40u(t)\ rpm$ and your controller ($G_c(s)$). The block with the title 'Delay' causes time delay in system. Increase the time delay until the system is unstable to find the delay margin (h_f). You can use the same procedure as explained in Step 2.

Check-3 Show your calculated DM, observed DM and response of the system for two cases: h_1 is slightly less than h_f, so that the system is stable, and h_2 is slightly larger than h_f such that the system is unstable in your report (you should have 3 plots using h_f, h_1 and h_2).

Report Compare estimated and calculated margins. Draw the plots you used to get checks. If they are different, explain the reasons.

In your report, you are expected to explain the work done in order. It needs to include all plots you draw, all mathematical equations you did (handwritten results will not be accepted), and all the results you obtained in the lab. You also need to comment on each result you obtained between checks (they are given while reading your reports). All Matlab codes should be included in your reports. Do not forget to use report template and write introduction and conclusion parts.