Assignment 4

4.1 For a servomechanism system with the following transfer function

$$G(s) = \frac{50000}{s(s+10)(s+50)}, \tag{1}$$

using Matlab, design a lead compensator in a unity-feedback system, through Bode plot specifications, so that PM $\geq 50^\circ$ and $\omega_{BW} \geq 20$ rad/sec, and then verify and refine your design, if need be.

4.2 For a system with open-loop transfer function

$$G(s) = \frac{10}{s[(\frac{s}{1.4})+1][(\frac{s}{3})+1]}, \tag{2}$$

design a lag compensator with unity DC gain, using frequency response method, so that PM $\geq 35^\circ$. Using Matlab Bode plots, what is the approximate bandwidth of this system?

4.3 Consider a unity-feedback system for satellite attitude control with the plant transfer function

$$G(s) = \frac{0.05(s+25)}{s^2(s^2+0.1s+4)}. \tag{3}$$

Using frequency response method, discuss what kind of compensation (with a minimum number of parameters) can stabilize the system response, so that $GM \geq 2$ (6 db) and $PM \geq 45^\circ$, while keeping the bandwidth as high as possible. (Matlab can be used for drawing the Bode plots.)

4.4 Consider a unity-feedback system with the plant transfer function

$$G(s) = \frac{1}{s(\frac{s}{20}+1)(\frac{s^2}{100^2}+\frac{0.5s}{100}+1)}. \tag{4}$$

(a) A lead compensator is introduced with $\alpha = \frac{1}{5}$ and a zero at $\frac{1}{T} = 20$. How must the gain be changed to obtain crossover at $\omega_c = 31.6\ rad/s$, and what is the resulting value of K_v?

(b) With the lead compensator in place, what is the required value of K for a lag compensator that will adjust the gain to a K_v value of 100?

(c) Place the pole of the lag compensator at 3.16 rad/s, and determine the zero location that will maintain the crossover frequency at $\omega_c = 31.6$ rad/s. Using Matlab, plot both the uncompensated and compensated responses on the same graph.

(d) From the plots, determine the PM of the compensated design.

4.5 A cascade controller is to be designed for a unity-feedback system with the plant transfer function

$$G(s) = \frac{10}{s(\frac{s}{10} + 1)}. \tag{5}$$

in order to meet the following specifications:

- $K_v = 100$;
- $PM \geq 45°$;
- the output for the sinusoidal inputs with a frequency up to 1 rad/s is with an error less than or equal to 2%;
- the output for the sinusoidal inputs with a frequency greater than 100 rad/s is attenuated to less than or equal to 5%.

(a) Show the regions in the gain plot where either of the last two conditions cannot be satisfied.

(b) Using Matlab, create the Bode plot of $G(s)$ with the open-loop gain for $K_v = 100$, and show whether or not other design specifications are satisfied.

(c) Explain whether or not and why a lead or lag compensator alone can make the feedback system satisfy all the design specifications.

(d) Design a proper compensation that can make the feedback system satisfy all the design specifications. Explain the design procedure in detail. (Matlab can be used for drawing the Bode plots.)