Instructor's Supplement Problems

Chapter 11

1. Given the unity-feedback system of Figure P11.1 in the text problems with

$$G(s) = \frac{K(s+10)(s+15)}{s(s+2)(s+5)(s+20)}$$

do the following: [Section: 11.2]

  a. Use frequency response methods to determine the value of gain, K, to yield a step response with a 20% overshoot. Make any required second-order approximations.

  b. `Use MATLAB or any other computer program to test your second-order approximation by simulating the system for your designed value of K.` MATLAB ML

2. Given the unity-feedback system of Figure P11.1 in the text problems with

$$G(s) = \frac{K(s+10)(s+11)}{s(s+3)(s+6)(s+9)}$$

do the following: [Section: 11.3]

  a. Use frequency response methods to design a lag compensator to yield $K_v = 1000$ and 15%-overshoot for the step response. Make any required second-order approximations.

  b. `Use MATLAB or any other computer program to test your second-order approximation by simulating the system for your designed value of K and lag compensator.` MATLAB ML

3. Design a lag compensator so that the system of Figure P11.1 in the text problems where

$$G(s) = \frac{K(s+4)}{(s+2)(s+6)(s+8)}$$

operates with a 45° phase margin and a static error constant of 100. [Section: 11.3]

4. For the system of Problem 2 above, do the following: [Section: 11.3]

  a. Use frequency response methods to find the gain, K, required to yield about 15%-overshoot. Make any required second-order approximations.

  b. Use frequency response methods to design a PI compensator to yield zero steady-state error for a ramp input without appreciably changing the transient response characteristics designed in Part **a**.

  c. `Use MATLAB or any other computer program to test your second-order approximation by simulating the system for your designed value of K and PI compensator.` MATLAB ML

5. Repeat the design of Example 11.3 in the text using a PD controller. [Section: 11.4]

6. `Repeat Problem 12 in the text problems for a PD controller.` MATLAB ML

7. The model for a specific linearized TCP/IP computer network queue, working under a random early detection (RED) algorithm, has been modeled using the block diagram of Figure P11.1 in the text problems, where $G(s) = M(s)P(s)$, with

$$M(s) = \frac{0.005L}{s+0.005}$$

and

$$P(s) = \frac{140{,}625e^{-0.1s}}{(s+2.67)(s+10)}$$

Also, L is a parameter to be varied (*Hollot, 2001*).

  a. Adjust L to obtain a 15%-overshoot in the transient response for step inputs.

  b. `Verify Part a with a Simulink unit-step response simulation.` Simulink SL

8. Active front steering is used in front-steering four-wheel cars to control the yaw rate of the vehicle as a function of changes in wheel-steering commands. For a certain car, and under certain conditions, it has been shown that the transfer function from steering wheel angle to yaw rate is given by (*Zhang, 2008*):

$$P(s) = \frac{28.4s + 119.7}{s^2 + 7.15s + 14.7}$$

The system is controlled in a unity-feedback configuration.

a. Use the Nichols chart and follow the procedure of Example 11.5 to design a lag-lead compensator such that the system has zero steady-state error for a step input. The bandwidth of the closed-loop system must be $\omega_B = 10$ rad/s. Let the open-loop magnitude response peak be less than 1 dB and the steady-state error constant $K_v = 20$.

b. Relax the bandwidth requirement to $\omega_B \geq 10$ rad/s. Design the system for a steady-state error of zero for a step input. Let the open-loop magnitude response peak be less than 1 dB and $K_v = 20$ using only a lead compensator.

c. `Simulate the step response of both designs using MATLAB.` MATLAB **ML**

9. The amount of leftover moisture in a grain drying conveyor process can be controlled by varying the conveyor's motor speed (*Mansor*, *2011*). Although the process is highly variable, the transfer function at one of the operating points has been found to be

$$G(s) = \frac{0.0169s + 0.03558}{3.368s^3 + 3.762s^2 + 32.19s + 1}e^{-27s}$$

A unity-feedback system will be built around this plant such as the one shown in Figure P11.1 in the text problems to maintain grain moisture at specified levels. The specifications are: $e_{ss} = 0$ for a unit-step input; e_{ss} is half that of the uncompensated system for a ramp input; settling time = 500 seconds, and $\%OS = 13\%$.

Since the system is Type 0, it must be augmented to a Type 1 using an integrator in order to achieve $e_{ss} = 0$ for a step input. In addition, a phase lead-lag compensator will be required to achieve the specifications. Simulate your design using a computer program.

Bibliography

Hollot, C. V., Misra, V., Towsley, D., and Gong, W. A Control Theoretic Analysis of RED. Proceedings of IEEE INFOCOM, 2001, pp. 1510–1519.

Mansor, H., Noor, S. B. M., Ahmad, R. K. R., and Taip, F. S. Online Quantitative feedback theory (QFT)-based self-tuning controller for grain drying process. *Scientific Research and Essays*, vol. 6, no. 31, December 16, 2011, pp. 6520–6534.

Zhang, J.-Y., Kim, J.-W., Lee, K.-B., and Kim, Y.-B. Development of an Active Front Steering (AFS) System With QFT Control. *International Journal of Automotive Technology*, vol. 9, no. 6, 2008, pp. 695–702.