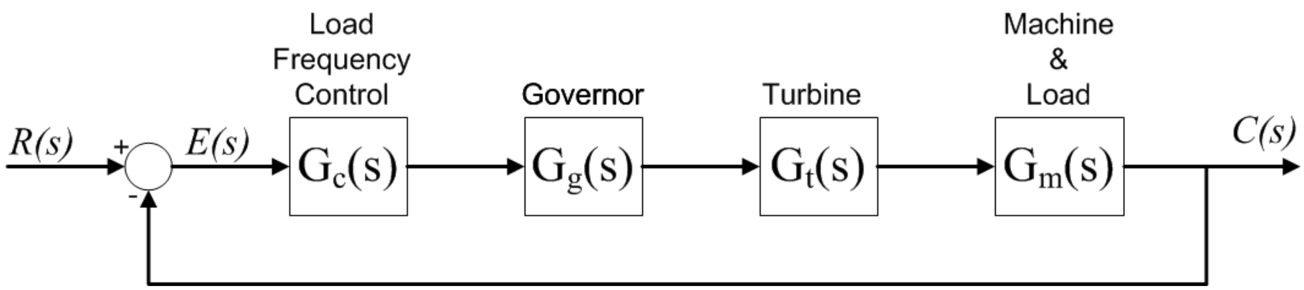
THE CITADEL
THE MILITARY COLLEGE OF SOUTH CAROLINA

Department of Electrical & Computer Engineering

ELEC 312 – Systems I

Spring 2015 Software Project 3:
Proportional and PID Control for a Steam-Driven Power Generator

Objective: To use MATLAB® to design a proportional controller and a PID controller to meet transient response and steady-state error specifications for a steam-driven power generator system.



Governor Transfer Function:

$$G_g(s) = \frac{1}{0.2s + 1}$$

Turbine Transfer Function:

$$G_t(s) = \frac{1}{0.5s + 1}$$

Machine/Load Transfer Function:

$$G_m(s) = \frac{1}{10s + 0.8}$$

Assignment: Steam-driven power generators rotate at a constant speed via a governor that maintains constant steam pressure in the turbine. In addition, load frequency control (LFC) is added to ensure reliability and consistency despite load variations or other disturbances that can affect the distribution line frequency output. A specific turbine-governor system can be described using the block diagram and transfer function described above. The controller transfer function $G_c(s)$ is the LFC compensation to be designed. Write a single MATLAB script to implement solutions to the following problems:

1. **Proportional-Control Design** – Assume that the LFC compensation is a proportional controller with transfer function $G_c(s) = K$.

   (a) Using the `rlocus` command, plot the root locus (as the proportional gain K is varied) in Figure 1 (using the `figure` command). Figure 1 should include the lines of constant damping ratio corresponding to $\zeta = 0.7$ by using the `sgrid` command.

   (b) Using Figure 1, determine the value of proportional gain K that will result in dominant closed-loop poles with $\zeta = 0.7$. Display this value of K in the Command Window.

   (c) Determine the closed-loop system transfer function $T_P(s)$ of the feedback system for the value of proportional gain K determined in Part (b) using `feedback` and `tf`. Display $T_P(s)$ in the Command Window.

   (d) Display in the Command Window the output of the `stepinfo` command using the closed-loop transfer function object created in Part (c).

   (e) Plot in Figure 2 (using `figure` and `step` commands) the unit step response for the closed-loop transfer function object created in Part (c).

2. **PID-Control Design** – Assume that the LFC compensation is a PID controller with transfer function $G_c(s) = K_1 + \frac{K_2}{s} + K_3 s$. You are to design a PID controller that yields the same damping ratio as in Part 1 ($\zeta = 0.7$) but with a settling time of $T_s = 2$ seconds.

   (a) **PD-Control Design**

      i. Using the steps outlined in class, design a PD controller (of the form $G_c(s) = s + z_c$) to achieve a settling time of $T_s = 2$ seconds while keeping the damping ratio at approximately $\zeta = 0.7$. Display this value of z_c in the Command Window.

      ii. Using the `rlocus` command, plot the root locus (as the proportional gain K is varied) of the PD-compensated system in Figure 3 (using the `figure` command). Figure 3 should include the lines of constant damping ratio corresponding to $\zeta = 0.7$ by using the `sgrid` command.

      iii. Using Figure 3, determine the value of proportional gain K that will result in dominant closed-loop poles that meet the transient-response requirement of a settling time of $T_s = 2$ seconds while keeping the damping ratio at approximately $\zeta = 0.7$. Display this value of K in the Command Window.

      iv. Determine the closed-loop system transfer function $T_{PD}(s)$ of the PD-compensated system for the value of proportional gain K determined in Part (iii) using `feedback` and `tf`. Display $T_{PD}(s)$ in the Command Window.

      v. Display in the Command Window the output of the `stepinfo` command using the closed-loop transfer function object created in Part (iv).

      vi. Plot in Figure 4 (using the `figure` and `step` commands) the unit step response for the closed-loop transfer function object created in Part (iv).

   (b) **PI-Control Design**

      i. Using the steps outlined in class, design a PI controller (of the form $G_c(s) = \frac{s+z_c}{s}$) to reduce the steady-state error (of the PD-compensated system designed in Part (a)) to zero while keeping the damping ratio at approximately $\zeta = 0.7$. Display this value of z_c in the Command Window.

      ii. Using the `rlocus` command, plot the root locus (as the proportional gain K is varied) of the PID-compensated system in Figure 5 (using the `figure` command). Figure 5 should include the lines of constant damping ratio corresponding to $\zeta = 0.7$ by using the `sgrid` command.

      iii. Using Figure 5, determine the value of proportional gain K that will result in approximately the same dominant closed-loop poles determined in Part (a). Display this value of K in the Command Window.

      iv. Determine the closed-loop system transfer function $T_{PID}(s)$ of the PID-compensated system for the value of proportional gain K determined in Part (iii) using `feedback` and `tf`. Display $T_{PID}(s)$ in the Command Window.

      v. Display in the Command Window the output of the `stepinfo` command using the closed-loop transfer function object created in Part (iv).

      vi. Plot in Figure 6 (using the `figure` and `step` commands) the unit step response for the closed-loop transfer function object created in Part (iv).