XMUT315 Control Systems Engineering

Tutorial 8: Analysis with Nyquist Diagram

A. Construction of Nyquist Diagram

1. Given a first-order system with its transfer function equation:

$$G(s) = \frac{1}{s+4}$$

   Derive the equation needed for sketching the Nyquist diagram. List the points required for sketching the Nyquist diagram. Sketch the Nyquist diagram of the system. [20 marks]

2. The Nyquist diagram can be created directly from the transfer function equation of the control system.

   a. Rather than using the real and imaginary equations, determine the steps for creating a Nyquist diagram for a second-order system by deriving the gain and phase angle of the frequency response of the system. [12 marks]

   b. Using the equations obtained in part (a), sketch the Nyquist diagram of the following control system given below. [24 marks]

$$G(s) = \frac{1}{s^2 + 2s + 10}$$

3. Given a second-order system with the following transfer function equation:

$$G(s) = \frac{K}{(s+1)^2}$$

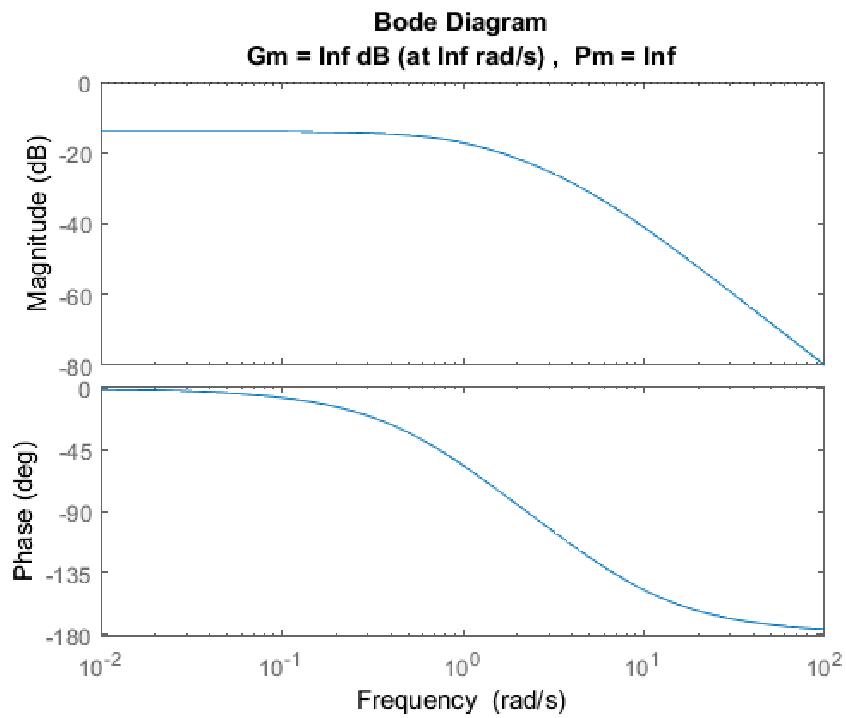
   a. Assume $K = 1$, plot the root locus diagram of the system in MATLAB. [6 marks]

   b. Convert from the root locus diagram to Bode plot and Nyquist diagram. [24 marks]

4. Nyquist diagram can be created from the results of the frequency response (gain and phase shift) of the Bode plots. To save time in performing this conversion, typically we pick only several interesting points from the Bode plots.

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

Given in the figure below the Bode plots of a control system with the transfer function as shown above.



a. Create the Nyquist diagram of the control system from the Bode plots. [12 marks]

b. Although both approaches are frequency response analysis methods, describe at least two differences between Bode plots and Nyquist diagram for determining the stability of the control systems. [4 marks]

5. Given a second-order system with the following transfer function equation:

$$G(s) = \frac{K}{(s+1)^2}$$

Sketch the Nyquist diagram of the system for $K = 1$ and $K = 2$. [8 marks]

B. Analysis with Nyquist Diagram

6. Using MATLAB simulation, perform stability analysis of the following control systems with Nyquist diagram method: [18 marks]

   a. System 1

   $$G(s) = \frac{1}{s(s+3)(s+5)}$$

   b. System 2

   $$G(s) = \frac{(s+2)}{s^2}$$

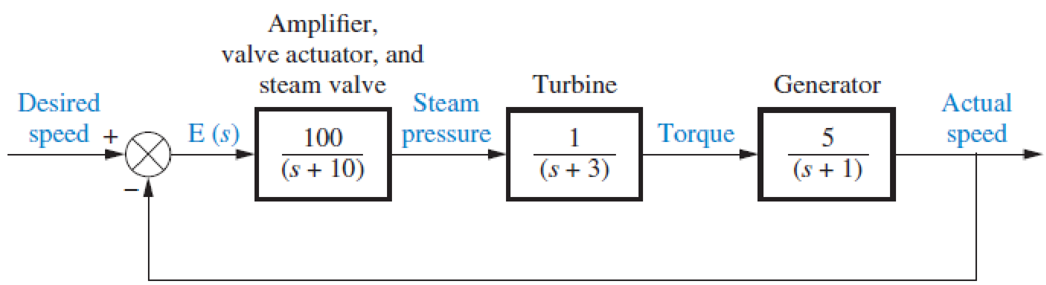
   c. System 2

   $$G(s) = \frac{(s+3)(s+5)}{(s-2)(s-4)}$$

7. Beside the encirclement analysis in Nyquist diagram, determining gain and phase margins from the Nyquist diagram would allow us to analyse the stability of the given control systems.

   a. Describe how you determine the gain and phase margins in Nyquist diagram. [4 marks]

   b. Using MATLAB simulation, indicate the gain and phase margins in the Nyquist diagram of the following control system below. Determine the gain and phase margins of the system. [8 marks]



C. Nichols Chart

8. For example, assume the transfer function of a control system is given below:

   $$G(s) = \frac{K}{s(s+1)(s+2)}$$

   a. Describe what is a Nichols chart? [2 marks]

   b. Draw a Nichols chart of the system given above when $K = 1$. [20 marks]

9. Using simulation in MATLAB (hint: use `nichols()` function for plotting Nichols chart in MATLAB), plot the Nichols charts and also determine the stability of the following control systems.

   a. System 1 [8 marks]

   b. System 2 [8 marks]

$$G(s) = \frac{5}{s(s+2)(s+3)} \qquad\qquad G(s) = \frac{5}{(s+0.5)(s+1)(s+1.5)}$$

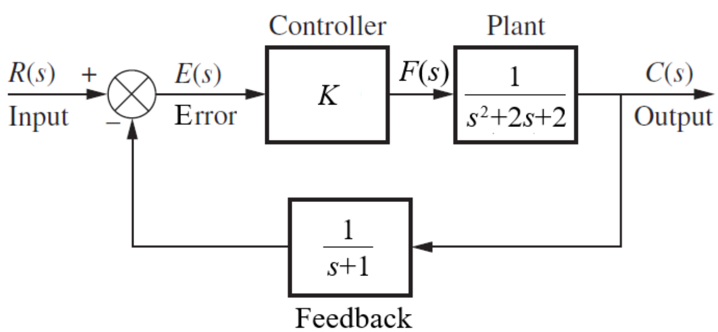
D. Design with Nyquist Diagram

10. Describe the following methods if they are used for designing the control systems and outline their step-by-step design procedures.

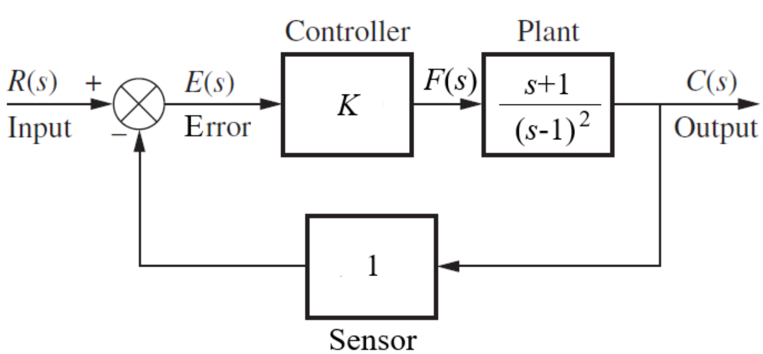
    a. Nyquist diagram. [6 marks]

    b. Nichols chart. [6 marks]

11. Draw the Nyquist plot for the system in the figure below. Using the Nyquist stability criterion, determine the range of K for which the system is stable. Consider both positive and negative values of K. [12 marks]



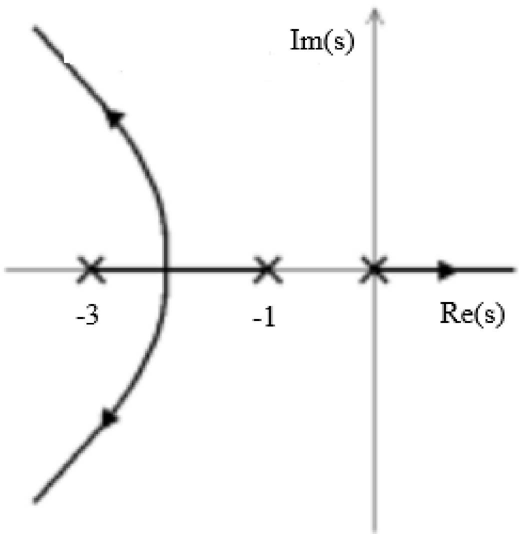
12. For a given control system as shown in the block diagram below, its root locus diagrams are also outlined below for two conditions of the gain of the system (e.g. negative and positive gains).



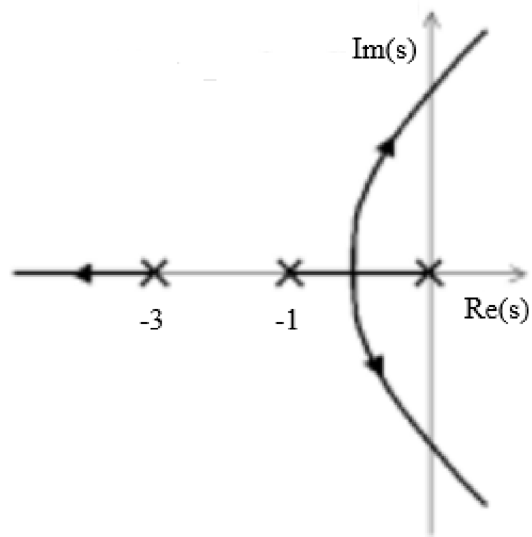
    a. Determine the Nyquist plot and apply the Nyquist criterion. [6 marks]

    b. Calculate the range of values of K (e.g. positive and negative) for which the system will be stable. Evaluate the number of roots in the RHP for those values of K for which the system is unstable. [16 marks]

The root locus diagram of the system is as shown in the figures below for $K < 0$ and $K > 0$.



Root Locus (K<0)



Root Locus (K>0)