INDIAN INSTITUTE OF TECHNOLOGY–KHARAGPUR

Mid-Spring Semester 2016-17 (Closed Book)

Course No.: CH 61016
Course Title: Process Dynamics and Control

Max. Time: 2 hrs
Total Marks: 30

Answer all questions

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1. (a) Define the nonminimum phase system with an example? Why is it called so?

(b) Consider the following open-loop system:

$$G_P = \frac{5e^{-2s}}{3s+1}$$

Derive a feedback controller expression (physically realizable) by using the direct synthesis approach.

[(1+1)+4+(2+1)+2+4=15]

(c) Derive the discrete form of the PID controller that can avoid the proportional and derivative kick.

(d) Set point weighting is introduced in the PD controller. List its effects in terms of merits and demerits.

(e) Developing the closed-loop block diagram for a cascade controller, derive its closed-loop transfer function in generalized form.

2. The following reactions are taking place in a constant volume(V) continuous stirred tank reactor.

A→ B → C ; 2A → D ;

The feed to the reactor contains only A. B is the desired product and both A and C are undesired product. The dynamic model of the process is given below:

$$\dot{C}_A = \frac{F}{V}(C_{Af} - C_A) - 5C_A - C_A^2$$

$$\dot{C}_B = -\frac{F}{V}C_B + 5C_A - 10C_B$$

$$\dot{C}_C = -\frac{F}{V}C_C + 10C_B$$

$$\dot{C}_D = -\frac{F}{V}C_D + 0.5C_A^2$$

It is desired to maximize the production of B by manipulating F/V in spite of disturbances in C_{Af}.

a) Obtain the linear state space model for the system

b) Obtain transfer function model for the system from the state space model.

c) Perform steady state analysis and comment on the nature of the transfer functions may be obtained for the process.

[2+3+1]

[Please Turn Over]

3. (a) Consider the transfer function system defined by the following equation

$$\frac{Y(s)}{U(s)} = \frac{b_0 s^n + b_1 s^{n-1} + \cdots \ldots \ldots \ldots + b_{n-1}s + b_n}{s^n + a_1 s^{n-1} + \cdots \ldots \ldots \ldots + a_{n-1}s + a_n}$$

Derive the following controllable canonical form of the state-space representation for this transfer function system:

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \\ \vdots \\ \dot{x}_n \end{bmatrix} = \begin{bmatrix} 0 & 1 & 0\cdots & 0 \\ 0 & 0 & 1 & 0 \\ \vdots & \vdots & & \ddots \\ -a_n & -a_{n-1} & \cdots & -a_1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 1 \end{bmatrix} U \quad and \quad Y = \begin{bmatrix} b_n - a_n b_0 & b_{n-1} - a_{n-1} b_0 & \cdots & b_1 - a_1 b_0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix} + b_0 U$$

(b) Prove the invariance of eigenvalues in case of linear transformation X=PZ for the state equation $\dot{X} = AX + BU$ and the transformed equation.

[3+1]

4. Consider the transfer function

$$\frac{y(s)}{u(s)} = \frac{s + 0.8}{s^2 + 1.3s + 0.4}$$

a) Obtain the state space representation of the system in the controllable canonical form and discuss the controllability and observability of the system

b) Obtain the state space representation of the system in the observable canonical form and discuss the controllability and observability of the system

c) Is there any difference between the controllability and observability of the system for a) and b)? If so, state the reason.

[2+2+1]

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