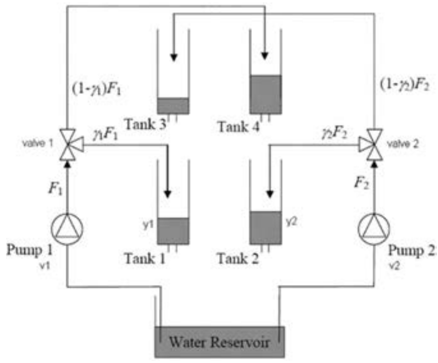
Tutorial problem

Prob 1. Consider the quadruple tank system where levels of tank1 and tank2 are manipulated by voltages supplied to the pumps.



1. Derive Dynamic model
2. Derive Nonlinear state space model in vector-matrix form
3. Derive Linear state space model in vector-matrix form
4. Compute state transition matrix using the following data

Data: A_1, A_3 = 28 cm^2 , A_2, A_4 = 32 cm^2, a_1, a_3 = 0.071 cm^2, a_2, a_4 = 0.057 cm^2 , k_1, k_2 = 3.33, 3.35, v_1, v_2 = 3.0, 3.0, γ_1, γ_2 = 0.7, 0.6

Prob 2. Consider the following dynamic model of a reactor

$$\frac{dC_A}{dt} = 10 - C_A - 3.5 \times 10^7 \exp\left(-\frac{6000}{T}\right) C_A$$
$$\frac{dT}{dt} = 298 - 1.3T + 4.2 \times 10^8 \exp\left(-\frac{6000}{T}\right) C_A + 0.3T_c$$

The control objective is to control T by manipulating T_c.

1. Plot steady state input(T_c)-output(T) curve for T ranging 300 to 400 K.
2. Derive linear state space model for steady state T = 320 K
3. Compute state transition matrix
4. Derive the expression for dynamic response of T for unit step change in T_c.

Prob 3. Consider the following dynamic model of a bioreactor

$$\frac{dc_1}{dt} = \frac{0.5c_1c_2}{0.1 + c_2} - uc_1$$

$$\frac{dc_2}{dt} = 4u - uc_2 - \frac{1.25c_1c_2}{0.1 + c_2}$$

1. Find the optimum value of u to maximize rate of cell production per unit reactor volume, uc_1.
2. Derive linear state space model using the optimum operating condition obtained in (1).
3. Compute state transition matrix using results of (2).

Prob 4. Consider the following dynamic model of van-de-vusse reactor

$$\frac{dC_A}{dt} = 10u - \left(u + \frac{5}{6}\right) C_A - \frac{1}{6} C_A^2$$
$$\frac{dC_B}{dt} = \frac{5}{6} C_A - \left(\frac{5}{3} + u\right) C_B$$

1. Find the optimum value of u to maximize production of B (i.e, C_B).
2. Derive linear state space model using steady state value of u=2.
3. Compute state transition matrix using results of (2).

Prob 5. The model of a chemical process gives the following Process Transfer function.

$$G(s) = \frac{180}{(s+2)(s+3)(s+4)(s+5)}$$

a) Find an equivalent first order with dead time (FODT) model using moment method.
b) Find an equivalent second order with dead time model having equal time constants $\frac{K\, e^{-\theta s}}{(\tau s+1)^2}$ using moment method.

Prob 6. The following data is generated from a process unit by giving unit step change in the input at time t=0. The first row is time (t) in min and the second row is change in output.

0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0
0	0.1	1.5	4.2	7.2	9.8	11.6	12.9	13.7	14.2	14.5	14.7	14.8	14.9	14.9	15.0	15.0

1. Find first order with dead time (FODT) model using a) Ziegler-Nichols b) Smith's method c) Sundaresan method d) Nishikawa method
2. Compare the Mean Absolute Prediction Error(MAPE)

Prob 7. Consider the transfer function $G(s) = \frac{120(s+6)(s+7)}{(s+2)(s+3)(s+4)(s+5)}$

Derive state space model in

a) Controllable canonical form
b) Jordon canonical form
c) Observable canonical form