

$$\begin{cases} \dot{C}_A(t) &= \frac{q_0}{V} \cdot (C_{Af} - C_A(t)) - k_0 \cdot \exp\left(-\frac{E}{R \cdot T(t)}\right) \cdot C_A(t) \\ \dot{T}(t) &= \frac{q_0}{V} \cdot (T_f - T(t)) + \frac{(-\Delta H_r) \cdot k_0}{\rho \cdot C_p} \cdot \exp\left(-\frac{E}{R \cdot T(t)}\right) \cdot C_A(t) + \frac{UA}{V \cdot \rho \cdot C_p} \cdot (T_c(t) - T(t)) \\ \dot{T}_c(t) &= \frac{T_r(t) - T_c(t)}{\tau_c} \end{cases} \quad (1)$$

$$\bar{x} = \begin{cases} \bar{C}_A &= 0.5054 \\ \bar{T} &= 315.5491 \\ \bar{T}_c &= 308 \end{cases} \quad (2)$$

$$0 = \frac{\bar{T}_r - \bar{T}_c}{\tau_c} = \frac{\bar{T}_r - 308}{\tau_c} \quad (3)$$

$$\bar{u} = \bar{T}_r = 308$$

$$\begin{cases} \delta \dot{x}(t) &\simeq f_x(\bar{x}, \bar{u}) \delta x(t) + f_u(\bar{x}, \bar{u}) \delta u(t) \\ \delta y(t) &\simeq g_x(\bar{x}, \bar{u}) \delta x(t) + g_u(\bar{x}, \bar{u}) \delta u(t) \end{cases} \quad (4)$$

$$f_x(\bar{x}, \bar{u}) = A = \begin{bmatrix} \frac{\delta f_1}{\delta x_1} & \frac{\delta f_1}{\delta x_2} & \frac{\delta f_1}{\delta x_3} \\ \frac{\delta f_2}{\delta x_1} & \frac{\delta f_2}{\delta x_2} & \frac{\delta f_2}{\delta x_3} \\ \frac{\delta f_3}{\delta x_1} & \frac{\delta f_3}{\delta x_2} & \frac{\delta f_3}{\delta x_3} \end{bmatrix}_{\substack{x=\bar{x} \\ u=\bar{u}}} \quad (5)$$

$$f_u(\bar{x}, \bar{u}) = B = \begin{bmatrix} \frac{\delta f_1}{\delta u} \\ \frac{\delta f_2}{\delta u} \\ \frac{\delta f_3}{\delta u} \end{bmatrix}_{\substack{x=\bar{x} \\ u=\bar{u}}} \quad (6)$$

$$g_x(\bar{x}, \bar{u}) = C = \begin{bmatrix} \frac{\delta g}{\delta x_1} & \frac{\delta g}{\delta x_2} & \frac{\delta g}{\delta x_3} \end{bmatrix}_{\substack{x=\bar{x} \\ u=\bar{u}}} \quad (7)$$

$$g_u(\bar{x}, \bar{u}) = D = \left. \frac{\delta g}{\delta u} \right|_{\substack{x=\bar{x} \\ u=\bar{u}}}$$

$$\begin{cases} \dot{C}_A(t) &= \frac{q_0}{V} \cdot (C_{Af} - C_A(t)) - k_0 \cdot \exp\left(-\frac{E}{R \cdot T(t)}\right) \cdot C_A(t) \\ \dot{T}(t) &= \frac{q_0}{V} \cdot (T_f - T(t)) + \frac{(-\Delta H_r) \cdot k_0}{\rho \cdot C_p} \cdot \exp\left(-\frac{E}{R \cdot T(t)}\right) \cdot C_A(t) + \frac{UA}{V \cdot \rho \cdot C_p} \cdot (T_c(t) - T(t)) \\ \dot{T}_c(t) &= \frac{T_r(t) - T_c(t)}{\tau_c} \\ y(t) &= C_A(t) \end{cases} \quad (8)$$

$$A = \begin{bmatrix} -k_0 \cdot \exp\left(\frac{-E}{R \cdot \bar{T}}\right) - \frac{q_0}{V} & -\frac{T_c \cdot E \cdot k_0}{R} \exp\left(\frac{-E}{R \cdot \bar{T}}\right) \cdot \frac{1}{\bar{T}^2} & 0 \\ \frac{-\Delta H_r \cdot k_0}{\rho C_p} \cdot \exp\left(\frac{-E}{R \cdot \bar{T}}\right) & -\frac{q_0}{V} + \left(\frac{\bar{C}_A \cdot (-\Delta H_r) \cdot k_0}{\rho \cdot C_p} \exp\left(\frac{E}{R \cdot \bar{T}}\right) \cdot \frac{E}{R \cdot \bar{T}^2}\right) - \frac{UA}{V \cdot \rho \cdot C_p} & \frac{UA}{V \cdot \rho \cdot C_p} \\ 0 & 0 & -\frac{1}{\tau_c} \end{bmatrix} \quad (9)$$

$$\begin{aligned}
B &= \begin{bmatrix} 0 \\ 0 \\ \frac{1}{\tau_c} \end{bmatrix} \\
C &= \begin{bmatrix} 1 & 0 & 0 \end{bmatrix} \\
D &= 0
\end{aligned}$$

$$\begin{aligned}
\min_{\mathbf{u}} \quad & J(x(k), u(.)) = \sum_{j=0}^{N-1} \|x(j)\|_Q^2 + \|u(j)\|_R^2 + \|x(N)\|_S^2 \\
\text{s.t.} \quad & x(0) = x(k) \\
& x(0) = x(k) \quad \text{con } Q = Q' \geq 0, S = S' \geq 0, R = R' > 0. \\
& x(j+1) = Ax(j) + Bu(j) \\
& x(j) \in \mathcal{X}, u(j) \in \mathcal{U} \\
& x(N) \in \mathbb{X}_f
\end{aligned} \tag{10}$$

$$\text{dove } x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} C_A \\ T \\ T_c \end{bmatrix}, \text{ e } u = T_r$$

$$\begin{aligned}
& x \in \mathcal{X} \text{ dato da:} \\
& 0.38 - \overline{C}_A < x_1 < 0.95 - \overline{C}_A \\
& -0.1254[mol/l] < x_1 < 0.446[mol/l]
\end{aligned} \tag{11}$$

$$\begin{aligned}
& u \in \mathcal{U} \text{ dato da:} \\
& 280 - \overline{T}_r < u < 310 - \overline{T}_r \\
& -28[K] < u < 2[K]
\end{aligned} \tag{12}$$