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(01) a) $e(t \to \infty) = 0$ $\quad w(t \to \infty) = w_r$

$V(t \to \infty) = K_{ff} w_r$

$K_{ff} w_r = R\, i(t \to \infty) + V_b \quad *$

$T = K_t \cdot i \qquad V_B = K_t w$ (1)

$J\dot{w} = K_t i - bw \quad ; \quad \dot{w}(t \to \infty) = 0 \qquad w(t \to \infty) = w_r$

$$i(t \to \infty) = \frac{b w_r}{K_t} \quad (2)$$

(1) e (2) em *

$$K_{ff} w_r = R \frac{b w_r}{K_t} + K_t w_r$$

$$K_{ff} = \frac{Rb}{K_t} + K_t$$

b) $K_{ff} w_r + K_p w_r - K_p w = R i + V_b$

$V_b = K_t \cdot w$

$i = \frac{J \dot{w}}{K_t} + \frac{b w}{K_t}$

$\frac{RJ}{K_t} \dot{w} + \left(\frac{Rb}{K_t} + K_p + K_t \right) w - (K_{ff} + K_p) w_r = 0$

$T = \frac{RJ}{Rb + K_p K_t + K_t^2}$

$Rb + K_p K_t + K_t^2 = \frac{RJ}{T}$

$K_p = \frac{RJ}{TK_t} - \frac{Rb}{K_t} - K_t$

(Q2) $V = Ri + K_t \cdot w$

$J\dot{w} = K_t \cdot i - bw$

$V = K_t \cdot w + \frac{R}{K_t}(J\dot{w} + bw)$, $w = \dot{\theta}$

$K_v\left(K_p(\theta_r - \theta) - \dot{\theta}\right) = K_t\dot{\theta} + \frac{RJ}{K_t}\ddot{\theta} + \frac{Rb}{K_t}\dot{\theta}$

$K_v K_p \theta_r - K_v K_p \theta - K_v\dot{\theta} = K_t\theta + \frac{RJ}{K_t}\ddot{\theta} + \frac{Rb}{K_t}\dot{\theta}$

$\frac{RJ}{K_t}\ddot{\theta} + \left(K_t + K_v + \frac{Rb}{K_t}\right)\dot{\theta} + K_v K_p \theta = K_v K_p \theta_r$

$\ddot{\theta} + \left(\frac{K_t^2 + K_t K_v + Rb}{RJ}\right)\dot{\theta} + \frac{K_v K_p K_t}{RJ}\theta = \frac{K_v K_p K_t}{RJ}\theta_r$

$\omega_n^2 = \frac{K_v K_p K_t}{RJ}$ $\qquad K_p K_v = \frac{\omega_n^2 RJ}{K_t}$

$2\xi\omega_n RJ = K_t^2 + K_t K_v + Rb$

$K_v = \frac{2\xi\omega_n RJ - K_t - Rb}{K_t}$

$K_p = \frac{\omega_n^2 RJ}{K_t} \cdot \frac{K_t}{2\xi\omega_n RJ - K_t^2 - Rb} = \frac{\omega_n^2 RJ}{2\xi\omega_n RJ - K_t^2 - Rb}$

Q3

$$\frac{d}{dt}\begin{bmatrix} h \\ \psi \end{bmatrix} = A\begin{bmatrix} h \\ \psi \end{bmatrix} + B h_r$$

$$h = C\begin{bmatrix} h \\ \psi \end{bmatrix} + D h_r$$

$$C = \begin{bmatrix} 1 & 0 \end{bmatrix} \qquad D = 0$$

$$\left.\begin{aligned} \dot{h} &= v \\ \dot{v} &= u \end{aligned}\right\} \quad \dot{v} = K_\psi K_p h_r - K_\psi K_p h - K_\psi \psi$$

$$\frac{d}{dt}\begin{bmatrix} h \\ v \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -K_\psi K_p & -K_\psi \end{bmatrix}\begin{bmatrix} h \\ \psi \end{bmatrix} + \begin{bmatrix} 0 \\ K_\psi K_p \end{bmatrix} h_r$$

A

B