PR-6.

TF-3101- Dinamika sistem dan Simulasi

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Kontribusi utama:

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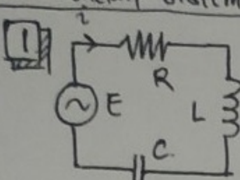
I. Permodelan Sistem Fisis

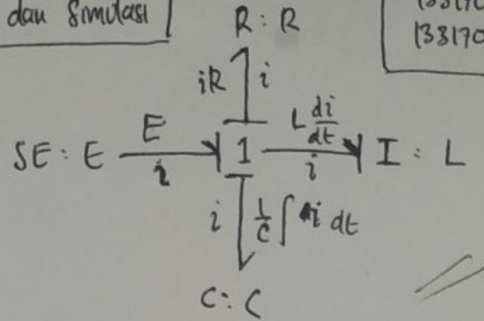
1



a). effort: E
flow: i

b) Source Effort: E
capacitance: C
resistance: R.
inertance: L

c.)
d.)



e). $V_L = L\frac{di}{dt} \longrightarrow V_L = L\frac{d^2q}{dt^2}$

$V_C = \frac{1}{C}\int i\,dt \longrightarrow V_C = \frac{1}{C}\int \frac{dq}{dt}\,dt$

$i = \frac{dq}{dt}$

$V_R = iR = R\frac{dq}{dt}$ $\qquad V_C = \frac{q}{C}$

f). g) $E = V_R + V_L + V_C$

$E = R\frac{dq}{dt} + L\frac{d^2q}{dt} + \frac{q}{C} \longrightarrow \frac{di}{dt} = \frac{E}{L} - \frac{R}{L}i - \frac{q}{CL}$

$\frac{dq}{dt} = i$

h). $\begin{bmatrix} di/dt \\ dq/dt \end{bmatrix} = \begin{bmatrix} -R/L & -1/CL \\ 1 & 0 \end{bmatrix}\begin{bmatrix} i \\ q \end{bmatrix} + \begin{bmatrix} 1/L \\ 0 \end{bmatrix}E$

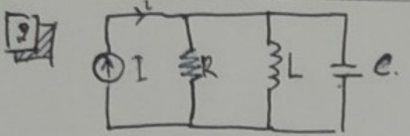
input $\dot{X} = A\ X + B\ \cancel{u}$

$y = C\ X + DU$

didefinisikan output adalah V_R, V_L, dan V_C

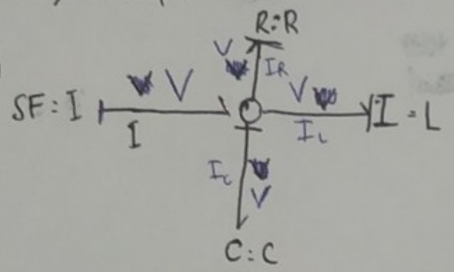
$\Rightarrow \begin{bmatrix} V_R \\ V_L \\ V_C \end{bmatrix} = \begin{bmatrix} 0 & R & 0 \\ L & 0 & 0 \\ 0 & 0 & \frac{1}{C} \end{bmatrix}\begin{bmatrix} \frac{di}{dt} \\ \frac{dq}{dt} \\ q \end{bmatrix}$

2



a & b). Sama seperti no. 1.

c & d)



e) $I_L = \frac{1}{L}\int_0^t V\,dt \Rightarrow V = L\frac{dI_L}{dt} \Rightarrow$ Definisikan $x_1 = \int_0^t V\,dt$

$I_C = C\frac{dV}{dt}$ $\qquad \frac{dI_L}{dt} = \frac{V}{L}$ $\qquad x_2 = V = \dot{x}_1$

$I_R = I - I_L - I_C \Rightarrow \frac{\dot{X}_1}{R} = I - \frac{X_1}{L} - C\ddot{X}_1$ $\qquad x_3 = \frac{dV}{dt} = \dot{x}_2$

$V = I_R R = L\frac{dI_L}{dt} = \frac{q_C}{C}$

jika didefinisikan output adalah I_R, I_L, I_C

g) $\Rightarrow \begin{bmatrix} I_R \\ I_L \\ I_C \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{R} & 0 \\ \frac{1}{L} & 0 & 0 \\ 0 & 0 & C \end{bmatrix}\begin{bmatrix} X_1 \\ \dot{X}_1 \\ \ddot{X}_1 \end{bmatrix}$

Matriks output - input

$\begin{bmatrix} \ddot{X}_1 \\ \dot{X}_1 \end{bmatrix} = \begin{bmatrix} -\frac{1}{RC} & -\frac{1}{LC} \\ 1 & 0 \end{bmatrix}\begin{bmatrix} \dot{X}_1 \\ X_1 \end{bmatrix} + \begin{bmatrix} 1 \\ 0 \end{bmatrix} I$

matriks input - state

cara kedua

e) dan f)

$e_R = i_R R$

$e_L = L\frac{di_L}{dt}$

$e_C = \frac{1}{C}\int i_C\,dt$

$i_R = \frac{e_R}{R}$

$i_L = \frac{1}{L}\int e_L\,dt$

$i_C = C\frac{de_C}{dt}$

$e_L = e_C = e_R$

$\frac{di_L}{dt} = \frac{e_C}{L}$

$I = i_L + i_C + i_R$

$I = \frac{e_C}{R} + C\frac{de_C}{dt} + i_L$

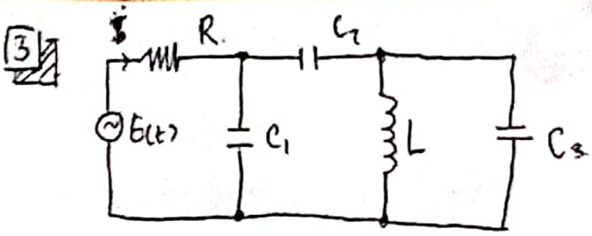
$I = \frac{L}{R}\frac{di_L}{dt} + C\frac{de_C}{dt} + i_L$

$I = \frac{e_C}{R} + C\frac{de_C}{dt} + i_L$

$\frac{de_C}{dt} = \frac{I}{C} - \frac{e_C}{RC} - \frac{i_L}{C}$

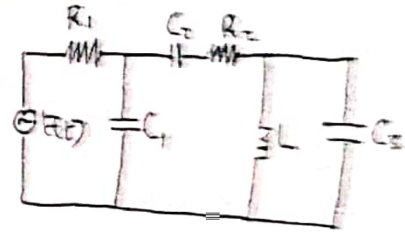
g) $\begin{bmatrix} \frac{di_L}{dt} \\ \frac{de_C}{dt} \end{bmatrix} = \begin{bmatrix} 0 & \frac{1}{L} \\ -\frac{1}{C} & -\frac{1}{RC} \end{bmatrix}\begin{bmatrix} i_L \\ e_C \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{C} \end{bmatrix} I$

3

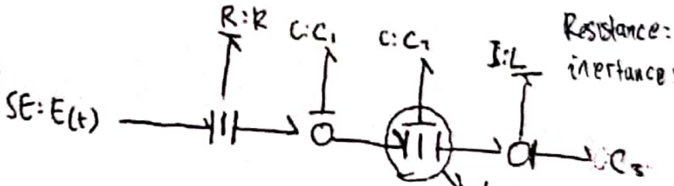


a). effort = tegangan (E)
flow = Arus (i)

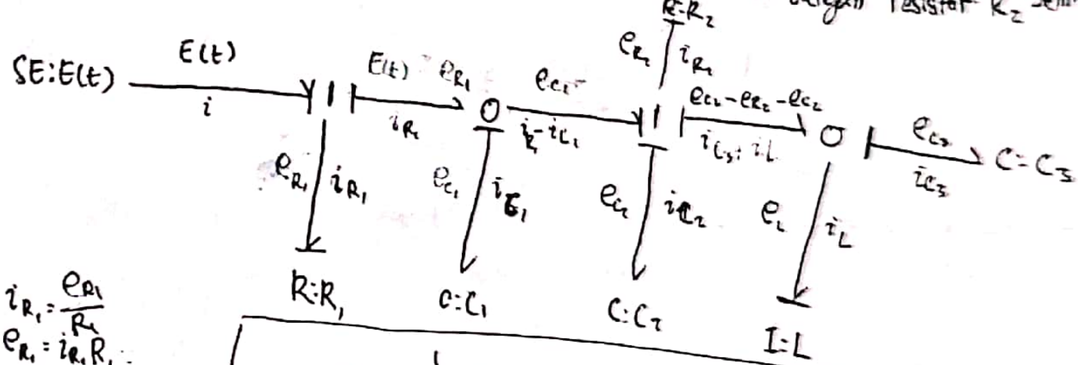
b). Source : SE: E(t)
Capacitance: $C_1, C_2, \& C_3$
Resistance: R
inertance: L



c)



tidak kausal, seri kan C_2 dengan resistor R_2 sehingga bond graph =



$i_{R_1} = \frac{e_{R_1}}{R_1}$

$e_{R_1} = i_{R_1} R_1$

$e_{C_1} = \frac{1}{C_1}\int i_{C_1}\, dt$

$i_{C_1} = C_1 \frac{de_{C_1}}{dt}$

$e_{C_2} = \frac{1}{C_2}\int i_{C_2}\, dt$

$i_{C_2} = C_2 \frac{de_{C_2}}{dt}$

$e_{R_2} = i_{R_2} R_2$

$i_{R_2} = \frac{e_{R_2}}{R_2}$

$e_L = L\frac{di_L}{dt}$

$i_L = \frac{1}{L}\int e_L\, dt$

$e_{C_3} = \frac{1}{C_3}\int i_{C_3}\, dt$

$i_{C_3} = C_3 \frac{de_{C_3}}{dt}$

$e_{C_1} = E_{(t)} - e_{R_1}$

$e_{C_1} = E_{(t)} - i_{R_1} R_1 = E_{(t)} - R_1(i_{C_1} + i_{C_2}) = E_{(t)} - R_1 C_1 \frac{de_{C_1}}{dt} - R_1 C_2 \frac{de_{C_2}}{dt}$

$i_{R_1} = i$

$i_{R_2} = i_{C_2} = i_{R_1} - i_{C_1} = i_{C_3} + i_L$

$e_{C_3} = e_{C_1} - e_{R_2} - e_{C_2} \rightarrow e_{C_1} = e_{R_2} + e_{C_2} + e_{C_3}$

$e_{C_1} = i_{R_2} R_2 + e_{C_2} + e_{C_3}$

$e_{C_1} = R_2 C_2 \frac{de_{C_2}}{dt} + e_{C_2} + e_{C_3}$

$$\boxed{\frac{de_{C_2}}{dt} = \frac{e_{C_1}}{R_2 C_2} - \frac{e_{C_2}}{R_2 C_2} - \frac{e_{C_3}}{R_2 C_2} \quad \ldots (1)}$$

$i_{C_2} = i_{C_3} + i_L$

$C_2 \frac{de_{C_2}}{dt} = C_3 \frac{de_{C_3}}{dt} + i_L$

$\frac{e_{C_1}}{R_2} - \frac{e_{C_2}}{R_2} - \frac{e_{C_3}}{R_2} = C_3 \frac{de_{C_3}}{dt} + i_L$

$$\boxed{\frac{de_{C_3}}{dt} = \frac{e_{C_1}}{R_2 C_3} - \frac{e_{C_2}}{R_2 C_3} - \frac{e_{C_3}}{R_2 C_3} - \frac{i_L}{C_3} \quad \ldots (2)}$$

$e_L = e_{C_3}$

$L\frac{di_L}{dt} = e_{C_3}$

$$\boxed{\frac{di_L}{dt} = \frac{e_{C_3}}{L} \quad \ldots (3)}$$

$e_{C_1} = E_{(t)} - R_1 C_1 \frac{de_{C_1}}{dt} - R_1 C_2 \frac{de_{C_2}}{dt}$

$e_{C_1} = E_{(t)} - R_1 C_1 \frac{de_{C_1}}{dt} - \frac{R_1}{R_2} e_{C_1} + \frac{R_1}{R_2} e_{C_2} + \frac{R_1}{R_2} e_{C_3}$

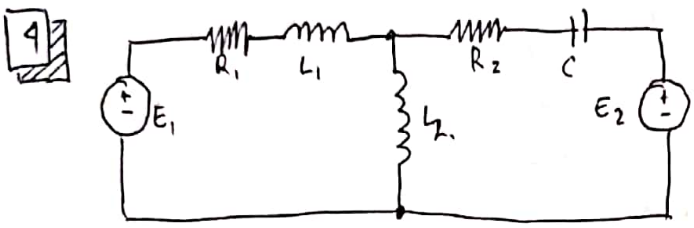
$$\boxed{\frac{de_{C_1}}{dt} = \frac{E(t)}{R_1 C_1} - \frac{e_{C_1}}{R_1 C_1} - \frac{e_{C_1}}{R_2 C_1} + \frac{e_{C_2}}{R_2 C_1} + \frac{e_{C_3}}{R_2 C_1} \quad \ldots (4)}$$

State Space:

$$\begin{bmatrix} \frac{de_{c_1}}{dt} \\ \frac{de_{c_2}}{dt} \\ \frac{de_{c_3}}{dt} \\ \frac{di_L}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{C_1}\left(\frac{1}{R_1}+\frac{1}{R_2}\right) & \frac{1}{R_2C_1} & \frac{1}{R_2C_1} & 0 \\ \frac{1}{R_2C_2} & -\frac{1}{R_2C_2} & -\frac{1}{R_2C_2} & 0 \\ \frac{1}{R_2C_3} & -\frac{1}{R_2C_3} & -\frac{1}{R_2C_3} & -\frac{1}{C_3} \\ 0 & 0 & \frac{1}{L} & 0 \end{bmatrix} \begin{bmatrix} e_{c_1} \\ e_{c_2} \\ e_{c_3} \\ i_L \end{bmatrix} + \begin{bmatrix} \frac{1}{R_1C_1} \\ 0 \\ 0 \\ 0 \end{bmatrix} E(t)$$

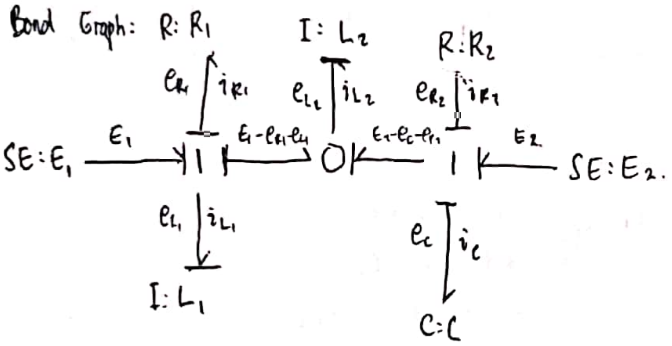
Kontribusi utama:
(Alif R. M. / 13317072)

4



Effort : V (tegangan)
Flow : I (arus)
Source: E_1, E_2
Capacitance: C
Resistance: R_1, R_2
Inertance L_1, L_2.

Bond Graph:



Variabel Keadaan: i_{L_1}, i_{L_2}, e_c

$e_{R_1} = i_{R_1} \cdot R_1$

$i_{R_1} = \frac{e_{R_1}}{R_1}$

$e_{L_1} = L_1 \frac{di_{L_1}}{dt}$

$i_{L_1} = \frac{1}{L_1}\int e_{L_1}\, dt$

$e_{L_2} = L_2 \frac{di_{L_2}}{dt}$

$i_{L_2} = \frac{1}{L_2} \frac{di_{L_2}}{dt}$

$e_{R_2} = i_{R_2} \cdot R_2$

$i_{R_2} = \frac{e_{R_2}}{R_2}$

$e_c = \frac{1}{C}\int i_c\, dt$

$i_c = C \frac{de_c}{dt}$

$E_1 = e_{R_1} + e_{L_1} + e_{L_2}$

$i_{R_1} = i_{L_1} = i_{L_2} - i_c$

$i_{L_2} = i_{L_1} + i_c$

$i_{L_2} = i_{L_1} + C \frac{de_c}{dt}$

$$\boxed{\frac{de_c}{dt} = \frac{i_{L_2}}{C} - \frac{i_{L_1}}{C} \quad \ldots (1)}$$

$E_1 = R_1 i_{R_1} + L_1 \frac{di_{L_1}}{dt} + L_2 \frac{di_{L_2}}{dt}$

$E_1 = R_1 i_{L_1} + L_1 \frac{di_{L_1}}{dt} + L_2 \frac{di_{L_2}}{dt}$

$E_2 = e_{R_2} + e_c + e_{L_2}$

$i_{R_2} = i_c = i_{L_2} - i_{L_1}$

$E_1 = e_{R_1} + e_{L_1} + E_2 - e_{R_2} - e_c$

$E_1 = i_{R_1} R_1 + L_1 \frac{di_{L_1}}{dt} + E_2 - i_{R_2} R_2 - e_c$

$E_1 = i_{L_1} R_1 + L_1 \frac{di_{L_1}}{dt} + E_2 - i_c R_2 - e_c$

$L_1 \frac{di_{L_1}}{dt} = E_1 - E_2 - i_{L_1} R_1 + e_c + C \frac{de_c}{dt} R_2$

$\frac{di_{L_1}}{dt} = \frac{E_1 - E_2}{L_1} - \frac{R_1}{L_1} i_{L_1} + \frac{e_c}{L_1} + \frac{\cancel{C}}{L_1}\left(\frac{i_{L_2}}{\cancel{C}} - \frac{i_{L_1}}{\cancel{C}}\right) R_2$

$$\boxed{\frac{di_{L_1}}{dt} = \frac{E_1 - E_2}{L_1} - \frac{R_1}{L_1} i_{L_1} - \frac{R_2 i_{L_1}}{L_1} + \frac{R_2 i_{L_2}}{L_1} + \frac{e_c}{L_1} \ldots (2)}$$

$\cancel{E_1} = \cancel{R_1 i_{L_1}} + L_2 \frac{di_{L_2}}{dt} + \cancel{E_1} - E_2 - \cancel{R_1 i_{L_1}} - R_2 i_{L_1} + R_2 i_{L_2} + e_c$

$$\boxed{\frac{di_{L_2}}{dt} = \frac{E_2}{L_2} + \frac{R_2}{L_2} i_{L_1} - \frac{R_2 i_{L_2}}{L_2} - \frac{e_c}{L_2} \quad \ldots (3)}$$

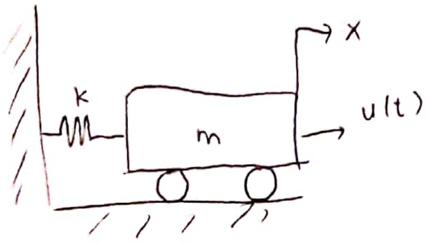
Scanned by CamScanner

State Space :

$$\begin{bmatrix} \frac{di_{L1}}{dt} \\ \frac{di_{L2}}{dt} \\ \frac{de_c}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{(R_1+R_2)}{L_1} & \frac{R_2}{L_1} & \frac{1}{L_1} \\ \frac{R_2}{L_2} & -\frac{R_2}{L_2} & -\frac{1}{L_2} \\ -\frac{1}{C} & \frac{1}{C} & 0 \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ e_c \end{bmatrix} + \begin{bmatrix} \frac{1}{L_1} & -\frac{1}{L_1} \\ 0 & \frac{1}{L_2} \\ 0 & 0 \end{bmatrix} \begin{bmatrix} E_1 \\ E_2 \end{bmatrix}$$

Kontribusi utama :
(M. Iqbal A. A. /13317007)

$\boxed{I}$ (5.)



$$SE \xrightarrow{(a)} S \xrightarrow{(c)} I : m$$
$$S \xrightarrow{(b)} C : \frac{1}{k}$$

(a) $e_1 = SE$

(b) $e_2 = k \int f_2 \, dt$

$$\frac{1}{k} e_2 = \int f_2 \, dt$$

$$\frac{d}{dt}\left(\frac{1}{k} e_2\right) = \frac{d}{dt}\left(\int f_2 \, dt\right)$$

$$\frac{1}{k}\frac{de_2}{dt} = f_2 \implies e_2 = x_1, \quad f_2 = x_2$$

$$\frac{1}{k}\frac{dx_1}{dt} = x_2$$

(c) $e_3 = m \cdot \dfrac{df_3}{dt}$

$$\frac{1}{m} e_3 = \frac{df_3}{dt}$$

$$\int\left(\frac{1}{m} e_3\right) dt = \int \frac{df_3}{dt} \cdot dt$$

$$\frac{1}{m}\int e_3 \, dt = f_3$$

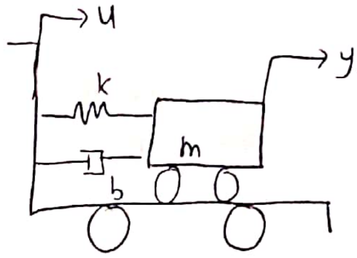
$$\Rightarrow SE = x_1 + m \frac{dx_2}{dt}$$

$$\frac{dx_1}{dt} = k x_2$$

$$\frac{dx_2}{dt} = \frac{1}{m}(SE - x_1)$$

$$\begin{bmatrix} \frac{dx_1}{dt} \\ \frac{dx_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & k \\ -\frac{1}{m} & 0 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{m} \end{bmatrix} SE$$

(6.)



$$SF \xrightarrow{(a)} P \xrightarrow{(c)} S \xrightarrow{(e)} R : b$$
$$P \xrightarrow{(b)} I : m \qquad S \xrightarrow{(d)} C : \frac{1}{k}$$

(a) $SF = f_1$

(b) $e_2 = m \dfrac{df_2}{dt}$

$$\frac{1}{m} e_2 = \frac{df_2}{dt}$$

$$\int \frac{1}{m} e_2 \, dt = \int \frac{df_2}{dt} \, dt$$

$$\frac{1}{m}\int e_2 \, dt = f_2$$

(d) $e_4 = k \int f_4 \, dt$

$$\frac{1}{k} e_4 = \int f_4 \, dt$$

$$\frac{d}{dt}\left(\frac{1}{k} e_4\right) = \frac{d}{dt}\int f_4 \, dt$$

$$\frac{1}{k}\frac{de_4}{dt} = f_4$$

(e) $e_5 = f_5 \, b.$

$$f_5 = \frac{1}{b} e_5$$

$e_4 = x_i$

$f_2 = x_2$

(P) $e_1 = e_2 = e_3$

$f_1 = f_2 + f_3$

(S) $e_3 = e_4 + e_5$

$f_3 = f_4 = f_5$

$\Rightarrow SF - x_2 = \frac{1}{K} \frac{dx_1}{dt}$

$\frac{dx_1}{dt} = k\,(SF - x_2)$

$\Rightarrow m \frac{dx_2}{dt} = x_1 + b \cdot \frac{1}{K} \cdot \frac{dx_1}{dt}$

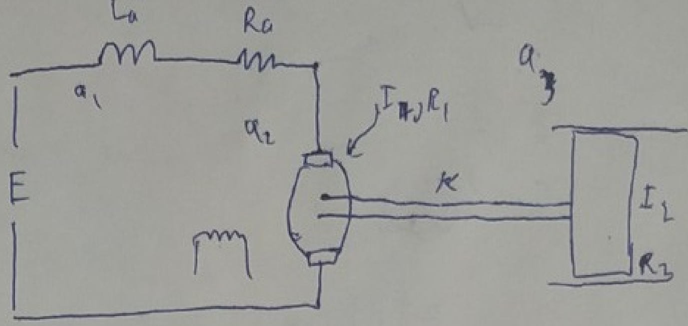
$= x_1 + b\,(SF - x_2)$

$\frac{dx_2}{dt} = \frac{1}{m}\,(x_1 + b \cdot SF - b x_2)$

$$\begin{bmatrix} \frac{dx_1}{dt} \\ \frac{dx_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & -k \\ \frac{1}{m} & -\frac{b}{m} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} k \\ \frac{b}{m} \end{bmatrix} SF$$

⑦ a) effort : E, τ

flow : I, ω



b). SE : E

C : k,

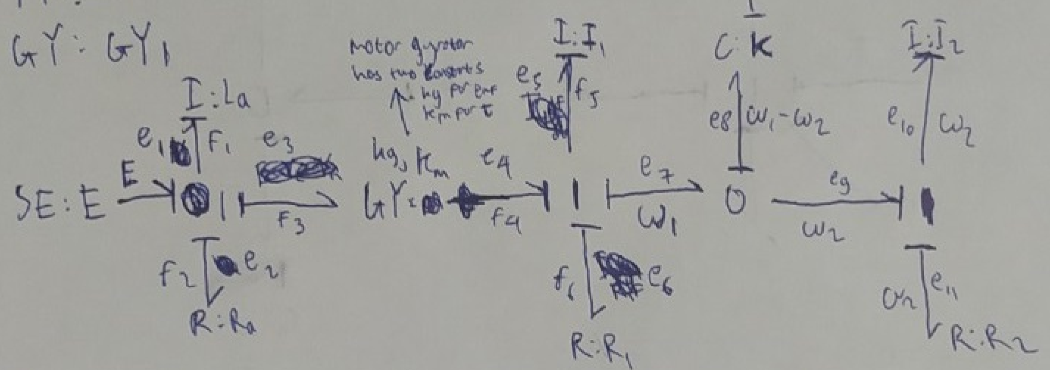
R : R_a, R_1, R_2

I : L_a, I_1, I_2

TF : –

GY : GY_1

c)



d) $e_1 = L_a \dfrac{df_1}{dt}$

$e_2 = f_2 R_a$

$e_3 = E - e_1 - e_2$

$f_1 = f_2 = f_3 = i$

$e_5 = I_1 \dfrac{df_5}{dt}$

$e_6 = f_6 R_1$

$f_4 = f_5 = f_6 = \omega_1$

$e_4 = \tau_m = i k_m$

$e_{10} = I_2 \dfrac{d\omega_2}{dt}$

$e_{11} = R_2 \omega_2$

$e_7 = e_8 = e_9$

① $E = iR_a + L_a \dfrac{di}{dt} + k_g \omega_1$

$\dfrac{di}{dt} = \dfrac{E}{L_a} - \dfrac{R_a i}{L_a} - \dfrac{k_g}{L_a}\omega_1$

$i k_m = I_1 \dfrac{d\omega_1}{dt} + R_1 \omega_1$

② $\dfrac{d\omega_1}{dt} = \dfrac{i k_m}{I_1} - \dfrac{R_1 \omega_1}{I_1}$

$e_9 = I_2 \dfrac{d\omega_2}{dt} + R_2 \omega_2$

$e_9 = k(\theta_1 - \theta_2) = k\int \omega\, dt$

$\Rightarrow k(\theta_1 - \theta_2) = I_2 \dfrac{d\omega_2}{dt} + R_2\omega_2$

③ $\dfrac{d\omega_2}{dt} = \dfrac{k(\theta_1-\theta_2)}{I_2} - \dfrac{R_2\omega_2}{I_2}$

diterntukan variabel keadaan i, θ_1, $\dot\theta_1$, θ_2, $\dot\theta_2$

$$\begin{bmatrix} \frac{di}{dt} \\ \frac{d\theta_1}{dt} \\ \frac{d\omega_1}{dt} \\ \frac{d\theta_2}{dt} \\ \frac{d\omega_2}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R_a}{L_a} & 0 & -\frac{k_g}{L_a} & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ \frac{k_m}{I_1} & 0 & -\frac{R_1}{I_1} & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & \frac{k}{I_2} & 0 & -\frac{k}{I_2} & -\frac{R_2}{I_2} \end{bmatrix} \begin{bmatrix} i \\ \theta_1 \\ \dot\theta_1 \\ \theta_2 \\ \dot\theta_2 \end{bmatrix} + \begin{bmatrix} \frac{1}{L_a} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} E$$

$\dfrac{de_9}{dt} = k(\omega_1 - \omega_2)$

$k(\theta_1 - \theta_2) = e_9$

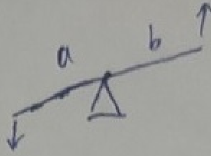
$\dfrac{d\omega_2}{dt} = \dfrac{e_9}{I_2} - \dfrac{R_2}{I_2}\omega_2$

⇓ reducing state variables

$$\begin{bmatrix} \frac{di}{dt} \\ \frac{d\omega_1}{dt} \\ \frac{d\omega_2}{dt} \\ \frac{de_9}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{R_a}{L_a} & -\frac{k_g}{L_a} & 0 & 0 \\ \frac{k_m}{I_1} & -\frac{R_1}{I_1} & 0 & 0 \\ 0 & 0 & -\frac{R_2}{I_2} & \frac{1}{I_2} \\ 0 & k & -k & 0 \end{bmatrix} \begin{bmatrix} i \\ \omega_1 \\ \omega_2 \\ e_9 \end{bmatrix} + \begin{bmatrix} \frac{1}{L_a} \\ 0 \\ 0 \\ 0 \end{bmatrix} E$$

(8) a) effort : F
flow : V

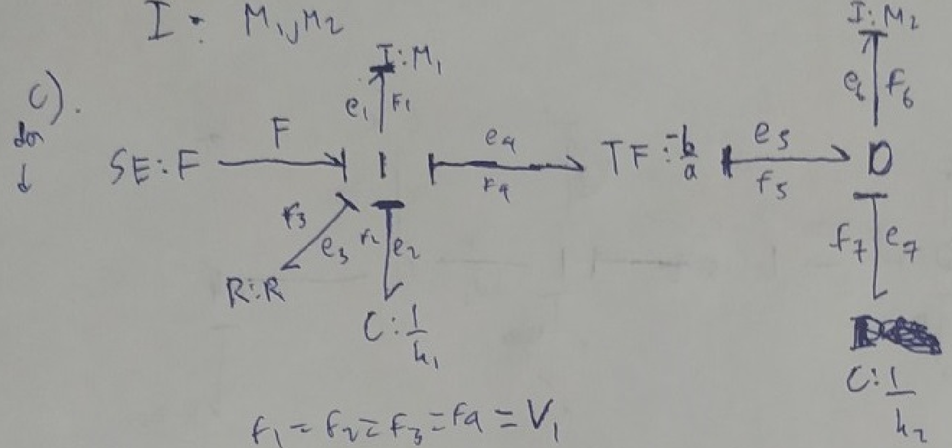
b). SE : F
C : k_1, k_2
R : R
TF : TF1 (leverage) : $-\frac{b}{a}$ (trans)



Asumsi lever datar saat $x_1 = 0$, $x_2 = 0$

GY : -
I : M_1, M_2

c).



$f_1 = f_2 = f_3 = f_4 = V_1$

$F = e_1 + e_2 + e_3 + e_4$

$e_1 = M_1 \frac{df_1}{dt} = M_1 \frac{dv_1}{dt}$

$\frac{de_2}{dt} = kv_1$ $\quad e_2 = k_1 x_1$
$k_1(x_1 - 0)$ $\quad \frac{de_2}{dt} = k_1 v_1$ (3)

$e_3 = R f_3 = RV_1$

$F = M_1 \frac{dv_1}{dt} + e_2 + Rv_1 + e_4$

$e_5 = -\frac{b}{a} e_4$

$f_5 = -\frac{a}{b} f_4 = -\frac{a}{b} V_1$

$e_6 = M_2 \frac{df_6}{dt} = M_2 \frac{dv_2}{dt}$, $f_6 = v_2$

$e_7 = M_2 \frac{dv_2}{dt}$

(4) $\Rightarrow \frac{dv_2}{dt} = \frac{e_7}{M_2}$

$\Rightarrow \frac{de_7}{dt} = k_2 f_7$

$e_6 = e_7 = e_5 = -\frac{b}{a} e_4 \Rightarrow e_4 = -\frac{a}{b} e_7$

e) (1) $F = M_1 \frac{dv_1}{dt} + e_2 + Rv_1 - \frac{a}{b} e_7$

$f_5 = f_6 + f_7$

$f_7 = f_5 - f_6$

$f_7 = -\frac{a}{b} v_1 - v_2$

$\frac{dv_1}{dt} = \frac{F}{M_1} - \frac{e_2}{M_1} - \frac{Rv_1}{M_1} + \frac{a\, e_7}{bM_1}$

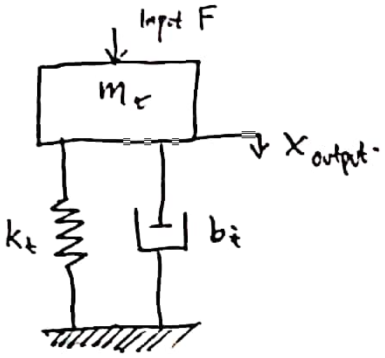
4 state variables : e_2, v_1, e_7, v_2

$\frac{de_7}{dt} = k_2 \left(-\frac{a}{b} v_1 - v_2\right)$ (2)

g) h

$$\begin{bmatrix} \frac{de_2}{dt} \\ \frac{dv_1}{dt} \\ \frac{de_7}{dt} \\ \frac{dv_2}{dt} \end{bmatrix} = \begin{bmatrix} 0 & k_1 & 0 & 0 \\ -\frac{1}{M_1} & -\frac{R}{M_1} & \frac{a}{b} & 0 \\ 0 & -\frac{k_2 a}{b} & 0 & -k_2 \\ 0 & 0 & \frac{1}{M_2} & 0 \end{bmatrix} \begin{bmatrix} e_2 \\ v_1 \\ e_7 \\ v_2 \end{bmatrix} + \begin{bmatrix} 0 \\ \frac{1}{M_1} \\ 0 \\ 0 \end{bmatrix} F$$

$\boxed{1}$



overshoot: 9,26 %

$t_{overshoot}$: 8,79 s

$t_{settling}$ = 13,3 s

step responsa,

c). estimasi nilai m_t, b_t, dan k_t

$$m_t \frac{d^2x}{dt^2} = -b_t \frac{dx}{dt} - k_t x + F$$

$$m s^2 X = -b_t s X - k_t X + F$$

$$X(m_t s^2 + b_t s + k_t) = F$$

$$\frac{X}{F} = \frac{1}{m_t s^2 + b_t s + k_t} \Rightarrow \frac{1/m_t}{s^2 + \frac{b_t}{m_t}s + \frac{k_t}{m_t}} \approx \frac{K\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$\rightarrow K\omega_n^2 = \frac{1}{m_t} \rightarrow m_t = \frac{1}{K\omega_n^2} = \frac{1}{5\cdot 10^{-3}(0{,}448)^2} = 1002{,}05$ kg

$\boxed{m_t \approx 1000 \text{ kg.}}$

$\rightarrow \frac{b_t}{m_t} = 2\zeta\omega_n \Rightarrow b_t = 2\zeta\omega_n m_t = 544{,}7$

$\boxed{b_t \approx 545 \text{ Ns/m.}}$

$\rightarrow \frac{k_t}{m_t} = \omega_n^2 \Rightarrow k_t = m_t \cdot \omega_n^2 = 201{,}115$

$\boxed{k_t \approx 200 \text{ N/m}}$

a). fungsi transfer dari gambar: (orde 2)

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

b). dari gambar, perkirakan K, ω_n, dan ζ

$\boxed{K = 5 \times 10^{-3}}$

$$t_{peak} = \frac{\pi}{\omega_d} = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}}$$

$$M_p = e^{-\frac{\pi\zeta}{\sqrt{1-\zeta}}} \longrightarrow 9{,}26\% = e^{-\frac{\pi\zeta}{\sqrt{1-\zeta}}}$$

$$\ln(M_p) = -\frac{\pi\zeta}{\sqrt{1-\zeta^2}}$$

$$(\ln(M_p))^2 = \frac{\pi^2\zeta^2}{1-\zeta^2}$$

$$(1-\zeta^2)(\ln(M_p))^2 = \pi^2\zeta^2$$

$$\zeta^2(\pi^2 + [\ln(M_p)]^2) = (\ln(M_p))^2$$

$$\boxed{\zeta = \sqrt{\frac{\ln^2(M_p)}{\pi^2 + [\ln(M_p)]^2}} = \sqrt{\frac{\ln^2(0{,}0926)}{\pi^2 + \ln^2(0{,}0926)}} = 0{,}604 \approx 0{,}6.}$$

$$t_{peak} = \frac{\pi}{\omega_n\sqrt{1-\zeta^2}} \rightarrow \omega_n = \frac{\pi}{t_{peak}\sqrt{1-\zeta^2}} = \frac{\pi}{8{,}79\sqrt{1-(0{,}604)^2}} = 0{,}448 \rightarrow \boxed{\omega_n \approx 0{,}45 \text{ rad/s}}$$

d) State space :

$$m\frac{d^2x}{dt^2} = -b\frac{dx}{dt} - kx + F$$

$$\frac{d^2x}{dt^2} = -\frac{b}{m}\frac{dx}{dt} - \frac{k}{m}x + \frac{F}{m}$$

$$\begin{bmatrix} \frac{d^2x}{dt^2} \\ \frac{dx}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{b}{m} & -\frac{k}{m} \\ 1 & 0 \end{bmatrix}\begin{bmatrix} \frac{dx}{dt} \\ x \end{bmatrix} + \begin{bmatrix} \frac{1}{m} \\ 0 \end{bmatrix}F$$

Kontribusi utama:

(M. Iqbal A. A. / 13317007)

e). eigen value persamaan sistem

$$\vec{A}\vec{x} = \lambda\vec{x}$$

$$\begin{bmatrix} -\frac{b}{m} & -\frac{k}{m} \\ 1 & 0 \end{bmatrix}\vec{x} = \lambda\vec{x}$$

$$-\frac{b}{m}\frac{dx}{dt} - \frac{k}{m}x = \lambda\frac{dx}{dt}$$

$$\frac{dx}{dt} = \lambda x$$

$$\boxed{\frac{dx}{dt} - \lambda x = 0} \quad \boxed{-\left(\frac{b}{m}+\lambda\right)\frac{dx}{dt} - \frac{k}{m}x = 0}$$

$$\begin{bmatrix} -\left(\frac{b}{m}+\lambda\right) & -\frac{k}{m} \\ 1 & -\lambda \end{bmatrix} = 0$$

determinan :

$$\begin{vmatrix} -\left(\frac{b}{m}+\lambda\right) & -\frac{k}{m} \\ 1 & -\lambda \end{vmatrix} = 0$$

$$\lambda^2 + \frac{b}{m}\lambda + \frac{k}{m} = 0$$

$$\lambda_{1,2} = \frac{-\frac{b}{m} \pm \sqrt{\left(\frac{b}{m}\right)^2 - \frac{4k}{m}}}{2}$$

$$\left.\begin{aligned} \lambda_1 &= -0{,}27 + 0{,}36i \\ \lambda_2 &= -0{,}27 - 0{,}36i \end{aligned}\right\} \lambda_{1,2} = -0{,}27 \pm 0{,}36i$$

(stabil, $\lambda < 0$)