Sistemas e controle
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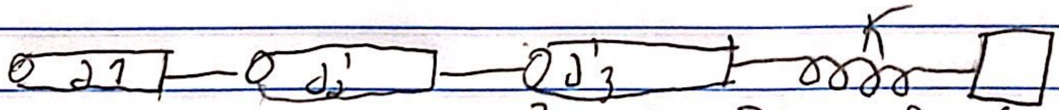
2) São 3 fatores primordiais para um motor CC: Velocidade, Torque e Tensão. A tensão V aplicada ao motor faz o eixo rodar a uma velocidade ω e possui esta relação $\omega = j \cdot V$, onde j é uma constante de proporcionalidade. A rotação do eixo gera um torque T que é proporcional à corrente da armadura e tem a relação $T = K \cdot I$ onde K é a constante de torque. Um valor alto de K limita a corrente a um valor baixo. Como o torque é proporcional à velocidade, podemos traçar um gráfico de torque x velocidade conforme o gráfico apresentado. Dessa forma utilizamos o gráfico para saber das propriedades do motor e conseguir controlar a sua velocidade de rotação ou seu torque

3b -

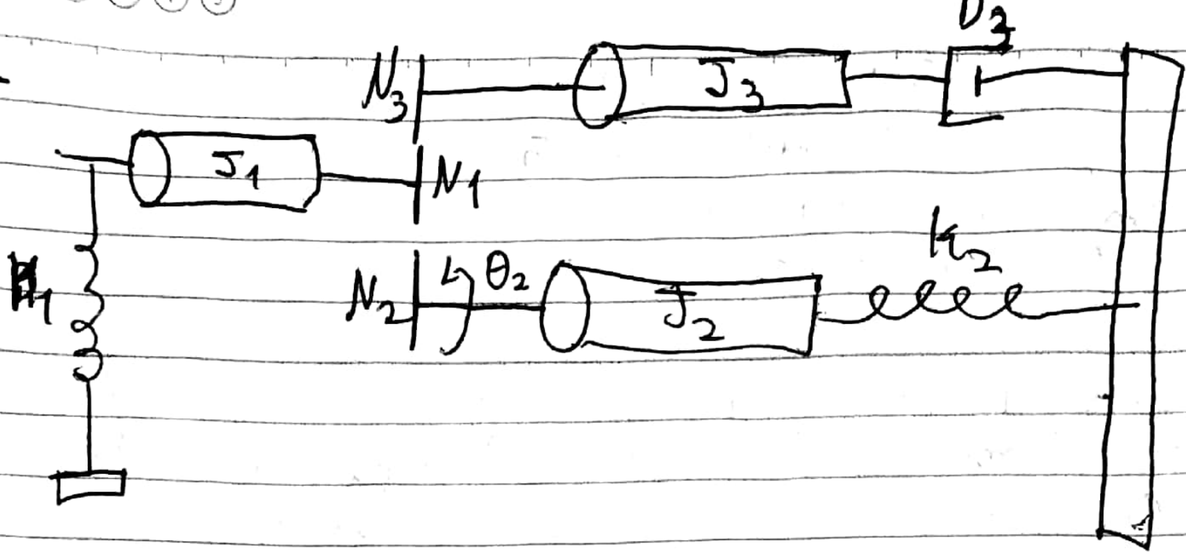


$$\left\{\left[J_1 + J_1\left(\frac{N_2}{N_1}\right)^2 + J_3\left(\frac{N_3}{N_4}\right)^2\right]s^2 + \left[f_2 + f_1\left(\frac{N_2}{N_1}\right)^2 + f_3\left(\frac{N_3}{N_4}\right)^2\right]s + \left[K\left(\frac{N_3}{N_4}\right)^2\right]\right\}\theta_2(s) = T(s)\,\frac{N_2}{N_1}$$

$$3T(s) = \left\{\left[1 + 2 \cdot 3^2 + 16\left(\frac{1}{4}\right)^2\right]s^2 + \left[2 + 3^2 + 32\left(\frac{1}{4}\right)^2 + 32\left(\frac{1}{4}\right)^2\right]s + 64\left(\frac{1}{4}\right)^2\right\}\theta_2$$

$$G(s) = \frac{3}{20s^2 + 13s + 4}$$

37-



$$J_3' = J_3 \cdot \left(\frac{N_1}{N_3} \cdot \frac{N_2}{N_1}\right)^2 \qquad D_3' = D_3 \left(\frac{N_1}{N_3} \cdot \frac{N_2}{N_1}\right)^2$$

$$J_1' = J_1 \left(\frac{N_2}{N_1}\right)^2 \qquad K_1' = K_1 \left(\frac{N_2}{N_1}\right)^2$$

$$T(s) \cdot \frac{50}{5} = \left\{\left[150 + 100 \cdot \left(\frac{5}{25} \cdot \frac{50}{5}\right)^2 + 3 \cdot \left(\frac{50}{5}\right)^2\right] s^2 + \left[500 \left(\frac{5}{25} \cdot \frac{50}{5}\right)^2\right] s + \left[300 + 3 \cdot \left(\frac{50}{5}\right)^2\right]\right\} \theta_2$$

$$G(s) = \frac{10}{850 s^2 + 2000 s + 400}$$

38-

$$T(s)\,\frac{\overset{110}{N_2}}{\underset{26}{N_1}}\cdot\frac{\overset{120}{N_4}}{\underset{23}{N_3}} = \left\{\left[26\right]s + \left[2\cdot\left(\frac{120}{23}\right)^2\right]\right\}\theta_4$$

$$G(s) = \frac{22{,}07}{26s + 10{,}43}$$

39 - $$T(s)\,\frac{20}{5}\cdot\frac{10}{40} = \left\{\left[1\cdot\frac{10}{40}\right]s^2 + \left[0{,}02 + 2\cdot\frac{10}{40}\right]s + \left[2\cdot\frac{10}{40}\right]\right\}\theta_L$$

$$G(s) = \frac{1}{0{,}25s^2 + 0{,}502s + 0{,}5}$$

40-

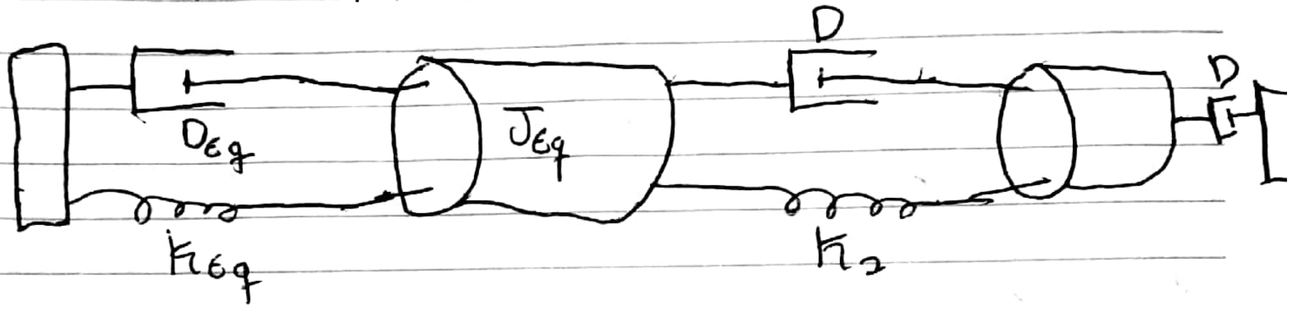
$$J_{TOT} = J_a + J_1 + (J_2 + J_3)\left(\frac{N_1}{N_2}\right)^2 + (J_4 + J_L)\left(\frac{N_3}{N_4}\cdot\frac{N_1}{N_2}\right)^2$$

$$D_{TOT} = D\cdot\left(\frac{N_1}{N_2}\right)^2 + D_L\cdot\left(\frac{N_3}{N_4}\cdot\frac{N_1}{N_2}\right)^2$$

$$K_{TOT} = K\left(\frac{N_1}{N_2}\right)^2$$

$$G(s) = \frac{1}{J_{TOT}\cdot s^2 + D_{TOT}\cdot s + K_{TOT}}$$

41-



$$\left[J_{Eq}s^2 + (D_{Eq} + D)s + K_2 + K_{Eq}\right]\theta_5 - \left[Ds + K_2\right]\theta_6 = 0$$

$$-\left[K_2 + Ds\right]\theta_5 + \left[J_6 s^2 + 2Ds + K_2\right]\theta_6 = T(s)$$

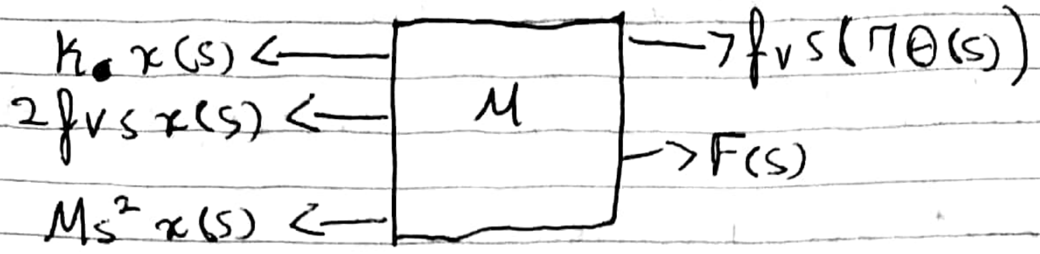
$$\frac{\theta_6}{\theta_5} = \frac{J_{Eq}s^2 + (D_{Eq} + D)s + (K_2 + K_{Eq})}{Ds + K_2} \qquad \frac{\theta_5}{\theta_1} = \frac{N_1}{N_2}\cdot\frac{N_3}{N_4}$$

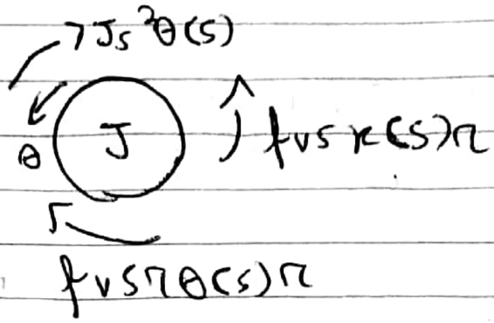
$$G(s) = \frac{\theta_6}{\theta_1} = \frac{N_1 N_3}{N_2 N_4}\cdot\frac{J_{Eq}s^2 + (D_{Eq} + D)s + K_2 + K_{Eq}}{Ds + K_2}$$

$$J_{eq} = \left[J_1\left(\frac{N_4 N_2}{N_3 N_1}\right)^2 + (J_2 + J_3)\left(\frac{N_4}{N_3}\right)^2 + J_4 + J_5\right.$$

$$K_{eq} = K_1\left(\frac{N_4}{N_3}\right)^2 \qquad D_{Eq} = D\left[\left(\frac{N_4 N_2}{N_3 N_1}\right)^2 + \left(\frac{N_4}{N_3}\right)^2 + 1\right]$$

42 -





$$\begin{cases} (Ms^2 + 2f_v s + K_2)X(s) - f_v r s\Theta(s) = F(s) \\ -f_v r s X(s) + (Js^2 + f_v r^2 s)\Theta(s) = 0 \end{cases}$$

$$\frac{\Theta(s)}{F(s)} = \frac{f_v r}{JMs^3 + (2Jf_v r^2)s^2 + (JK_2 + f_v^2 r^2)s + K_2 f_v r^2}$$

44 -

$$\begin{cases} (J_1 s^2 + K_1)\Theta_1(s) - K_1\Theta_2(s) = T(s) \\ -K_1\Theta_1(s) + (J_2 s^2 + D_3 s + K_1)\Theta_2(s) + F(s)r - D_3 s\Theta_3(s) = 0 \\ -D_3 s\Theta_2(s) + (J_2 s^2 + D_3 s)\Theta_3(s) = 0 \end{cases}$$

Sendo:

$$F(s) = (Ms^2 + f_v s + K_2)X(s) = (Ms^2 + f_v s + K_2)r\Theta(s)$$

data
fecha

$$\begin{cases} (J_1 s^2 + K_1)\theta_1(s) - K_1\theta_2(s) = T(s) \\ -K_1\theta_1(s) + [(J_2 + M r^2)s^2 + (D_3 + f_v r^2)s + (K_1 + K_2 r^2)]\theta_2(s) - D_3 s\theta_3(s) = 0 \\ -D_3 s\theta_2(s) + (J_3 s^2 + D_3 s)\theta_3(s) = 0 \end{cases}$$

$$\theta_2(s) = \frac{K_1 (J_3 s^2 + D_3 s) T(s)}{\Delta}$$

$$\frac{\theta_2(s)}{T(s)} = \frac{K_1 (J_3 s^2 + D_3 s)}{\Delta} \qquad X(s) = r\theta_2(s)$$

$$\frac{X(s)}{T(s)} = \frac{r K_1 (J_3 s^2 + D_3 s)}{\Delta}$$

45- $\frac{K_t}{R_a} = \frac{T_{stall}}{E_a} = \frac{150}{50} = 3 \quad K_b = \frac{E_a}{\omega_{nl}} = \frac{50}{100} = \frac{1}{2}$

$$J_m = 4 + 36\left(\frac{1}{3}\right)^2 = 8 \, ; \; D_m = 8 + 36\left(\frac{1}{3}\right)^2 = 12$$

$$\frac{\theta_m(s)}{E_a(s)} = \frac{3/8}{s\left(s + \frac{1}{8}\left(12 + \frac{3}{2}\right)\right)} = \frac{3/8}{s\left(s + \frac{27}{16}\right)}$$

$$\theta_L(s) = \frac{1}{3}\theta_m(s)$$

46-

$$\frac{K_t}{R_a} = \frac{T_s}{E_a} = \frac{5}{5} = 1; \quad K_b = \frac{E_a}{\omega} = \frac{5}{\frac{600}{\pi} 2\pi \frac{1}{60}} = \frac{1}{4}$$

$$J_m = 18\left(\frac{1}{4}\right)^2 + 4\left(\frac{1}{2}\right)^2 + 1 = \frac{25}{8}$$

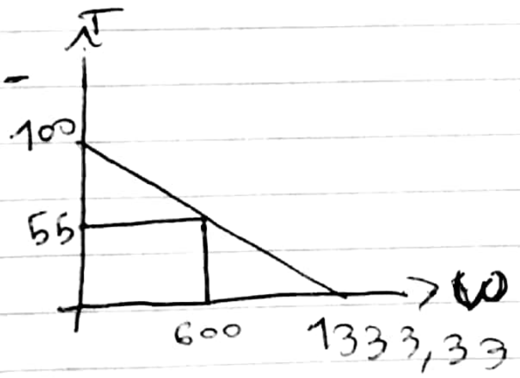
$$D_m = 36\left(\frac{1}{4}\right)^2 = \frac{9}{4}$$

$$\frac{\theta_m(s)}{E_a(s)} = \frac{8/25}{s\left(s + \frac{8}{25}\left(\frac{9}{4} + \frac{1}{4}\right)\right)} = \frac{8}{25s\left(s + \frac{4}{5}\right)}$$

$$\theta_2(s) = \frac{1}{4}\theta_m(s)$$

$$G(s) = \frac{8}{100s\left(s + \frac{4}{5}\right)}$$

47-



$$\frac{K_t}{R_a} = \frac{T_{stall}}{E_a} = \frac{100}{12}; \quad K_b = \frac{12}{1333,33}$$

$$J_m = 7 + 105\left(\frac{1}{6}\right)^2 = 9,92; \quad D_m = 3$$

$$\frac{\theta_m(s)}{E_a(s)} = \frac{\frac{100}{12} \cdot \frac{1}{9,92}}{s\left(s + \frac{1}{9,92} \cdot 3,075\right)} = \frac{0,84}{s(s+0,31)}$$

$$\theta_L(s) = \frac{1}{6}\theta_m(s)$$

$$\frac{\theta_L(s)}{E_a(s)} = \frac{0,14}{s+(s+0,31)}$$