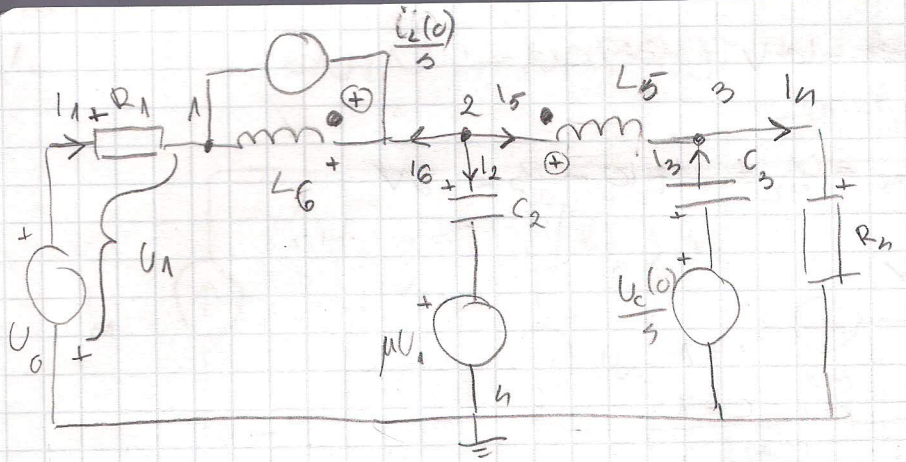


Elementi - samo pasivni → 6

moraju postaviti smjerove struja da bi svi imali isto rješenje

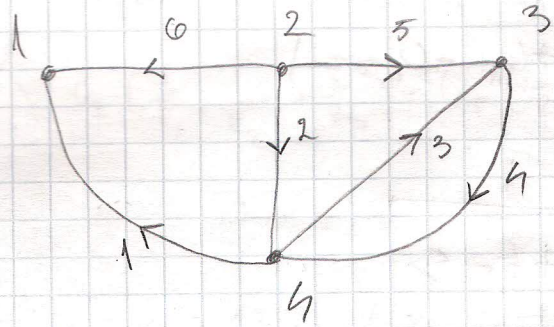
3 vrste matrica - za varijable

- za stavljanje elemenata

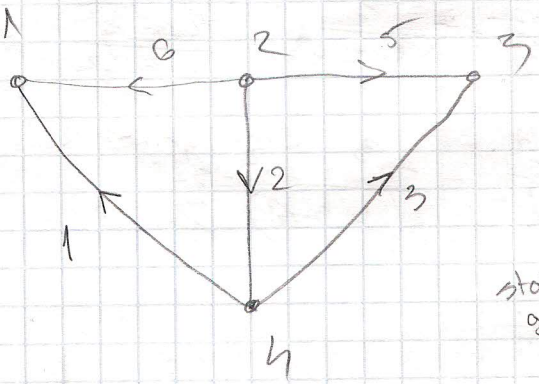
-

orijentirani graf - služi za opisivanje izgleda mreže

jedna grana ima 1 element ⇒ N_b broj grana = 6



N_v = broj čvorova = 4



stablo - najmanji broj grana koji će spojit sve čvorove

6, 5, 3 → spone

broj stablenih grana ← $N_t = N_v - 1$

broj spona ← $N_s = N_b - N_t$

$A \rightarrow (N_v - 1) \times N_b = 3 \times 6$

uzemljeni čvor ne ulazi u matricu

matrica incidencija - odnos grana i čvorova

ulazi -1 izlazi 1 nema - 0

$$A = \begin{bmatrix} -1 & 0 & 0 & 0 & 0 & -1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & -1 & 1 & -1 & 0 \end{bmatrix} \begin{matrix} č_1 \\ č_2 \\ č_3 \end{matrix}$$

$g_1 \quad g_2 \quad g_3 \quad g_4 \quad g_5 \quad g_6$

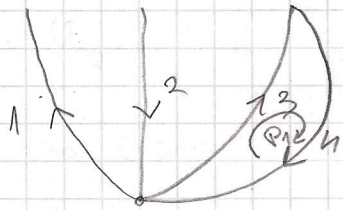
S = spojna matrica, u nju ulaze petlje

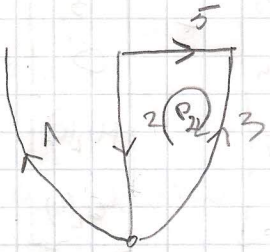
$S \rightarrow N_s \times N_b = 3 \cdot 6$

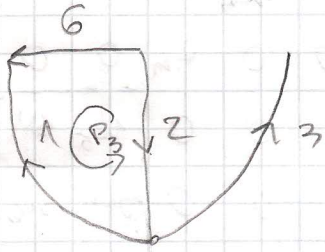
$$S = \left[\begin{array}{cccc|cc} 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & -1 & -1 & 0 & 1 & 0 \\ -1 & -1 & 0 & 0 & 0 & 1 \end{array}\right] \begin{matrix} P_1 \\ P_2 \\ P_3 \end{matrix}$$

$g_1\ g_2\ g_3\ g_4\ g_5\ g_6$ ↘ jedinična matrica ako smo pravilno radili

stablo ne čini petlju, dodavanjem spone dobivamo petlju







smjer petlje je u smjeru spone

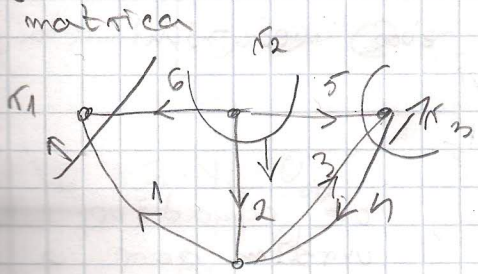
grana u smjeru petlje 1, kontra -1, nemaju veze 0

$Q \rightarrow N_t \times N_b = 3 \times 6$ matrica rezova

$$Q = \left[\begin{array}{ccc|ccc} 1 & 0 & 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & -1 & 1 & 0 \end{array}\right] \begin{matrix} r_1 \\ r_2 \\ r_3 \end{matrix}$$

$g_1\ g_2\ g_3\ g_4\ g_5\ g_6$

jedinična matrica



svaki rez treba prerezat jednu stabljenu granu i ne mora nužno bit ravan

- rez je u smjeru one grane koju smo prerezali

u smjeru reza -1, kontra -1, nema -0

matrice strujno-naponskih odnosa

$$U_b = Z_b I_b + U_{ob}$$

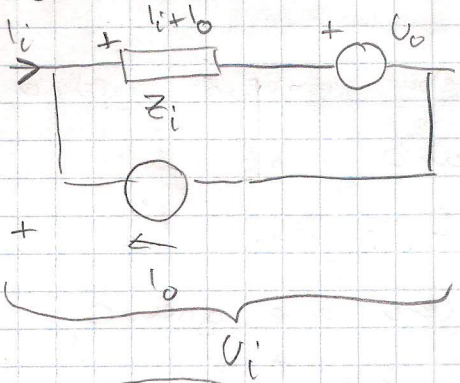
$$I_b = Y_b U_b + I_{ob}$$

$$\begin{bmatrix} U_1 \\ U_2 \\ U_3 \\ U_4 \\ U_5 \\ U_6 \end{bmatrix} = \left[\begin{array}{cccccc} R_1 & 0 & 0 & 0 & 0 & 0 \\ \mu R_1 & \frac{1}{sC_2} & 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{sC_3} & 0 & 0 & 0 \\ 0 & 0 & 0 & R_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & sL_5 & sM \\ 0 & 0 & 0 & 0 & sM & sL_6 \end{array}\right] \cdot \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \\ I_5 \\ I_6 \end{bmatrix} + \begin{bmatrix} -U_0 \\ -\mu U_0 \\ -\frac{U_c(0)}{s} \\ 0 \\ Mi_L(0) \\ Li_L(0) \end{bmatrix}$$

6×6 jer je 6 grana

6 struja grana

jedna grana mora imati jedan element, mogu mu biti pridijeljeni jedan naponski i jedan strujni izvor



$U_i = Z_i(I_i + I_0) + U_0$ ↗ paziti dali se poklapa sa strujom I_i

$U_1 = I_1 \cdot R_1 - U_0$

$U_2 = I_2 \cdot \frac{1}{sC_2} + \mu U_1$

$U_3 = I_3 \frac{1}{sC_3} \cdot I_3 - \frac{U_c(0)}{s}$

$U_4 = R_4 I_4$

$U_6 = \left(I_6 + \frac{I_L(0)}{s}\right) sL_6 + sM I_5$ ↗ zbog međuinduktiviteta

$U_5 = I_5 sL_5 + sM\left(I_6 + \frac{I_L(0)}{s}\right)$

ove jednadžbe uvrstim gore u matrice

točkica prebaci plus onako kako ga vidi

ako strujni početni uvjet imamo na zavojnici koja ima međuinduktivitet ostavimo ga tako jer ako ga prebacimo u naponski moramo ga staviti i u drugu zavojnicu

$U_2 = \frac{1}{sC_2} \cdot I_2 + \mu \cdot R_1 I_1 - \mu U_0$ jer je ovisan naponski izvor

ne smije postojati ovisnost napona o naponu, ali može o strujama

$$I_6 = \frac{1}{sL_6} U_6 - \frac{i_L(0)}{s} - \frac{M}{L_6} I_5$$

$$U_b = Z_b I_b + U_{ob}$$

$$I_b = Y_b U_b + I_{ob}$$

iz njih se mogu odrediti ostale matrične jednadžbe

$$Z_p I_p = U_{op}$$

$$Z_p = S \cdot Z_b \cdot S^T$$

$$Y_b = Z_b^{-1}$$

$$U_{op} = -S U_{ob} = S \cdot Z_b I_{ob}$$

} za petlje

- za čvorove koristimo matricu A, a za rezave Q

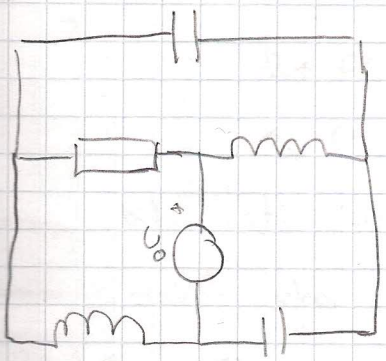
$$Y_n U_n = I_{on}$$

$$Y_n = Q \cdot Y_b \cdot Q^T$$

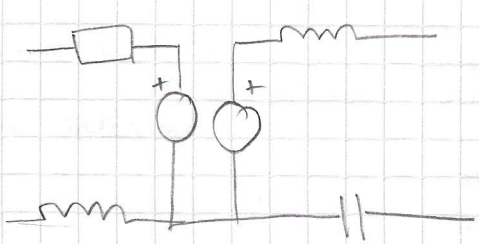
$$\frac{1}{\frac{R_1}{sC_2} - 0 - \mu R_1} \begin{bmatrix} \frac{1}{sC_2} & -\mu R_1 \\ -0 & R_1 \end{bmatrix}^T = \frac{sC_2}{R_1} \begin{bmatrix} \frac{1}{sC_2} & -0 \\ -\mu R_1 & R_1 \end{bmatrix} = \begin{bmatrix} \frac{1}{R_1} & 0 \\ \mu s C_2 & sC_2 \end{bmatrix}$$

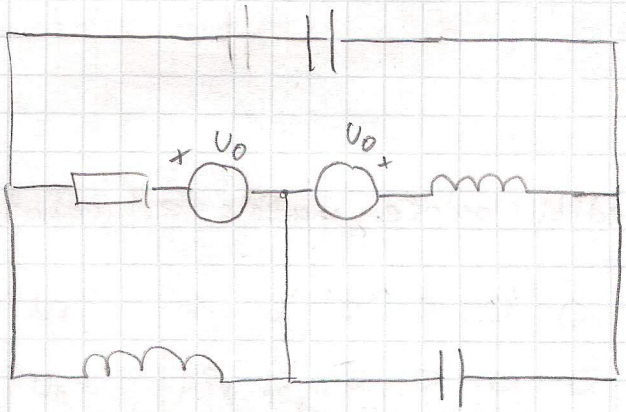
$$Y_b = \begin{bmatrix} \frac{1}{R_1} & 0 & 0 & 0 & 0 & 0 \\ \mu s C_2 & sC_2 & 0 & 0 & 0 & 0 \\ 0 & 0 & sC_3 & 0 & 0 & 0 \\ 0 & 0 & 0 & \frac{1}{R_4} & 0 & 0 \\ 0 & 0 & 0 & 0 & & \\ 0 & 0 & 0 & 0 & & \end{bmatrix}$$

$$I_{on} = Q \cdot Y_b \cdot U_{ob}$$



~~se~~ izvor nije s mičim u seriji → pomicanje izvora

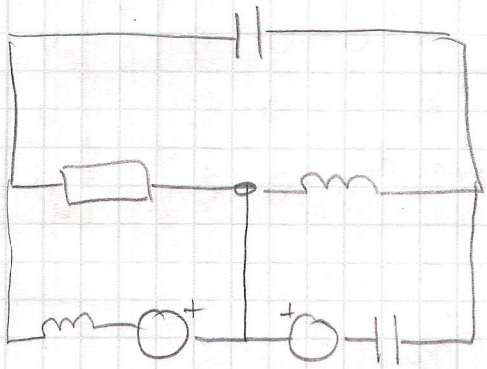


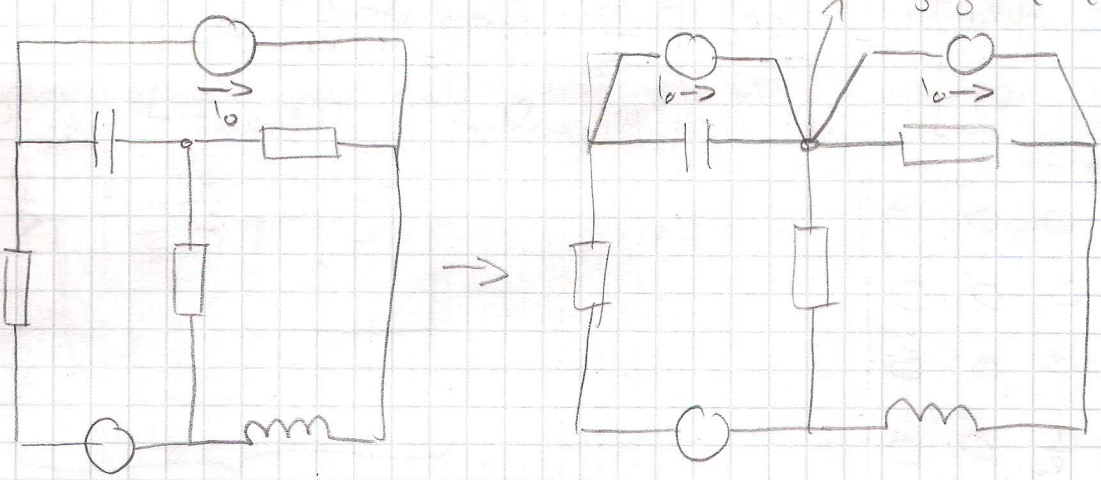


smjerovi izvora ostaju isti

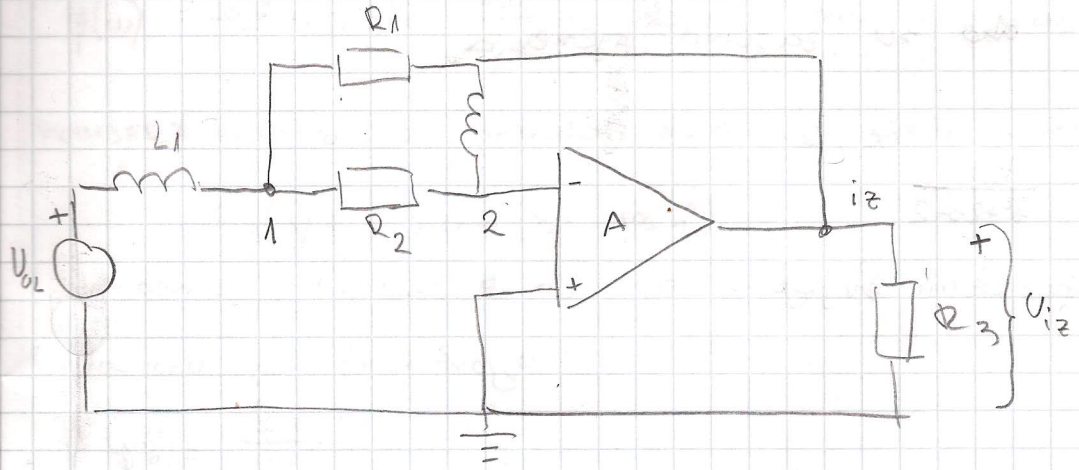
paziti ako imamo neki drugi ovisni izvor jer onda mijenjamo napone i struje

ili:





PAUZA



$R_1 = R_2 = 2$

$L_1 = 1$

$L_2 = 2$

$R_3 = 3$

$A \to \infty$

$T(s) = \frac{U_{iz}(s)}{U_{ul}(s)}$ najčešće se to traži

najčešće se koristi metoda napona čvorova

1. $U_1\left(\frac{1}{sL_1} + \frac{1}{R_2} + \frac{1}{R_1}\right) - U_2 \frac{1}{R_2} - U_{iz} \cdot \frac{1}{R_1} = U_{ul} \frac{1}{sL_1}$

2. $U_2\left(\frac{1}{R_2} + \frac{1}{sL_2}\right) - U_1 \cdot \frac{1}{R_2} - U_{iz} \frac{1}{sL_2} = 0$

} rješimo jednadžbu

$U_2 = 0$

$U_{iz} = U_{ul} \cdot \frac{2s}{s^2+2s+2}$

$T(s) = \frac{-2s}{s^2+2s+2}$ prijenosna funkcija

→ polovi ⇒ nazivnik = 0

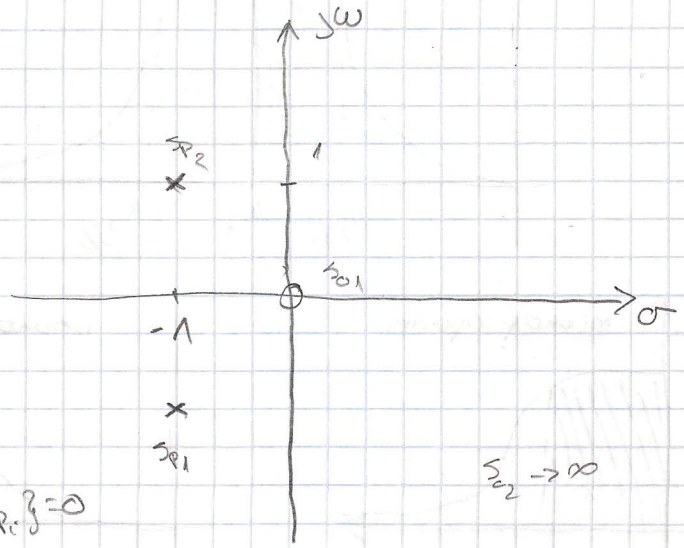
$s^2+2s+2 = 0 \qquad s_{1,2} = \frac{-2 \pm j2}{2}$

jednoliko koliko imamo spremnika energije toliko je stupnja ova jednadžba

→ nula ⇒ brojnik = 0

$2s = 0$

$s_{01} = 0 \qquad s_{02} \to \infty$



mora biti isti broj polova i nula

sustav je stabilan ako je svim polovima

$\mathrm{Re}\{s_{pi}\} < 0$

granično stabilan: barem jedan pol $\mathrm{Re}\{s_{pi}\} = 0$

nestabilan barem jedan $\mathrm{Re}\{s_{pi}\} > 0$

$T(s) = \frac{\Pi(s - s_{0i})}{\Pi(s - s_{pi})} \cdot K$ ako su zadana rješenja

$T(s) = \frac{(s-0)(s\to\infty)}{(s+1+j)(s+1-j)} \cdot K = \frac{ks}{s^2+2s+2}$

$T(1) = \frac{2}{5}$ zadan početni uvjet

$T(1) = \frac{k \cdot 1}{1+2+2} = \frac{-k}{5}$

$k = -2$

FREKVENCIJSKA KARAKTERISTIKA

- nakon nekog vremena frekvencije dođu na 0
- dok se to ne dogodi traje prijelazna pojava

$T(j\omega) = T(s)|_{s=j\omega} = \frac{-2j\omega}{(j\omega)^2+2j\omega+2} = \frac{-2j\omega}{2-\omega^2+2j\omega} = |T(j\omega)| e^{j \arg T(j\omega)}$

$= A(\omega) \angle \varphi(\omega)$

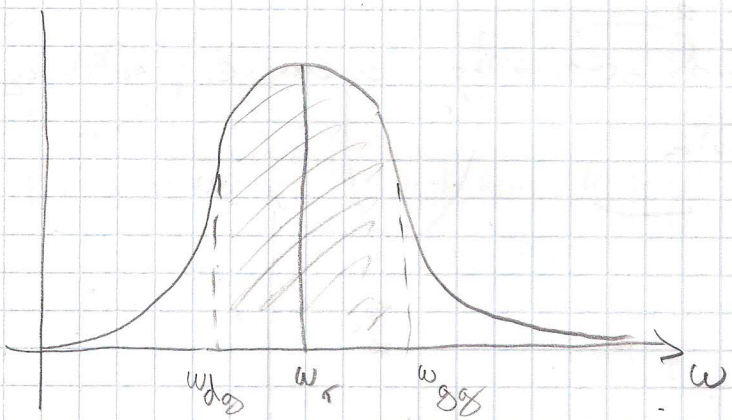
$A(\omega) = \left| \frac{-2j\omega}{2-\omega^2+2j\omega} \right| = \frac{2\omega}{\sqrt{(2-\omega^2)^2 + 4\omega^2}}$

amplituda je pozitivan realni broj

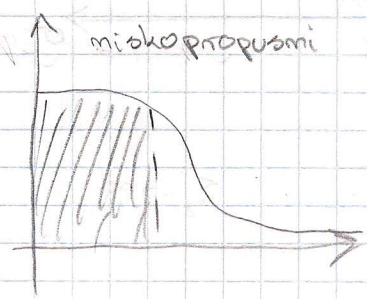
$A(\omega)_{[dB]} = 20 \log A\omega = 20 \log 2\omega - 20 \log \sqrt{(2-\omega^2)^2 + (2\omega)^2}$

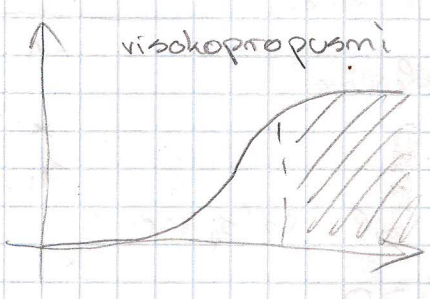
$A(\omega = 0) = 0$

$A(\omega \to \infty) = 0$



Pojasno propusni filtar





$\varphi(\omega) = -90^\circ - \operatorname{arctg}\frac{2\omega}{2-\omega^2}$ paziti na kvadrant

PRIMJER: Kolika je pobuda ako je odziv u stacionarnom stanju:

$$u_{iz}(t) = 5{,}2\cos(3t - 10{,}4^\circ)$$

prirodne frekvencije su se prigušile i sustav se ponaša kao da mu je frekvencija 3

$$T(j\omega_0) = \frac{\underline{U}_{iz}}{\underline{U}_{UL}}$$

$$\underline{U}_{iz} = 5{,}2\angle -10{,}4^\circ \qquad \omega_0 = 3$$

$$\underline{U}_{UL} = \frac{\underline{U}_{iz}}{T(j3)}$$

$$A(3) = \frac{2\cdot 3}{\sqrt{(2-9)^2 + 2\cdot 3)^2}} = 0{,}65$$

$$\varphi(3) = -90^\circ - \operatorname{arctg}\frac{6}{-7} = -90 - (-40{,}6 + 180^\circ) = 130{,}6$$

$$\underline{U}_{UL} = \frac{5{,}2\angle -10{,}4^\circ}{0{,}65\angle -130{,}6} = 8\angle -150^\circ$$

$$u_{UL}(t) = 8\cos(3t - 150^\circ)$$