PRIJENOS I DISTRIBUCIJA ELEKTRIČNE ENERGIJE

6. NADOMJESNI MODELI ELEKTROENERGETSKIH VODOVA

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6. NADOMJESNI MODELI ELEKTROENERGETSKIH VODOVA

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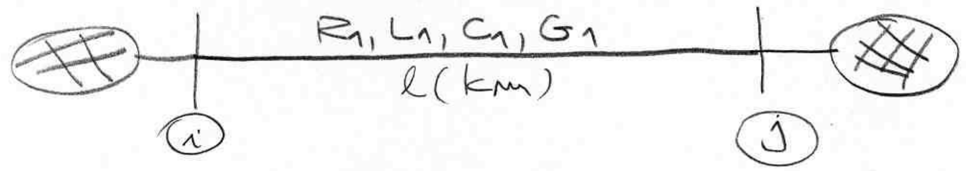
6.1 NADOMJESNI MODELI (SHEME) ELEKTROENERGETSKIH VODOVA

ELEKTROENERGETSKI VOD



- MATRICA JEDINIČNIH KONSTANTI EE VODA
- PRIMJENOM METODE SIMETRIČNIH KOMPONENATA NA SIMETRIČNI EE VOD, ODREDI SE:

a) UZDUŽNU JEDINIČNU IMPEDANCIJU KOMPONENTI EE VODA

$$\left[\vec{Z}_1^{012}\right] = \begin{bmatrix} \vec{Z}_1^{00} & & \\ & \vec{Z}_1^{11} & \\ & & \vec{Z}_1^{22} \end{bmatrix}$$

b) UZDUŽNU JEDINIČNU ADMITANCIJU KOMPONENATA EE VODA

$$\left[\vec{Y}_1^{012}\right] = \begin{bmatrix} \vec{Y}_1^{00} & & \\ & \vec{Y}_1^{11} & \\ & & \vec{Y}_1^{22} \end{bmatrix}$$

PRI ČEMU JE: $\vec{Z}_1^{11} = \vec{Z}_1^{22} = \vec{Z}_1$ $\quad \vec{Y}_1^{11} = \vec{Y}_1^{22} = \vec{Y}_1$

$\vec{Z}_1$ = JEDINIČNA UZDUŽNA POGONSKA IMPEDANCIJA VODA

$\vec{Y}_1$ = JEDINIČNA POPREČNA POGONSKA ADMITANCIJA VODA

- EE VOD ZADANIH JEDINIČNIH KONSTANTI I ZADANE DULJINE VODA l (km) PRIKAZUJEMO:
  - NADOMJESNIM ČETVEROPOLOM ZA DIREKTNI SUSTAV
  - NADOMJESNIM ČETVEROPOLOM ZA NULTI SUSTAV

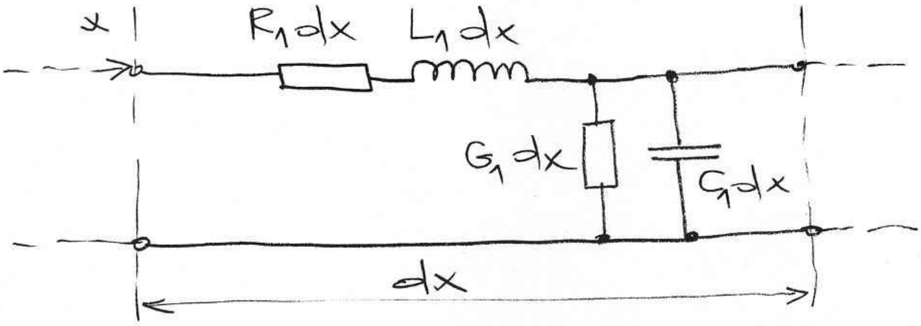
- AKO JE EE VOD SIMETRIČAN I HOMOGEN, TADA JE NADOMJESNI ČETVEROPOL EE VODA SIMETRIČAN:

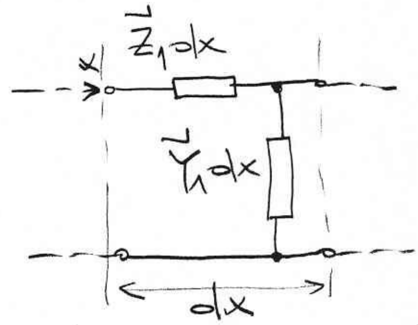
  Π ČETVEROPOL

  T ČETVEROPOL

TEMELJNI (IZVORNI) NADOMJESNI MODELI EE VODOVA

1. MODELI EE VODA SA RASPODIJELJENIM PARAMETRIMA





TELEGRAFSKE JEDNADŽBE

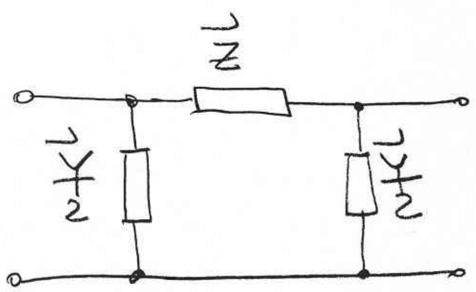
PRIJENOSNE JEDNADŽBE I / II / III OBLIK

II. OBLIK

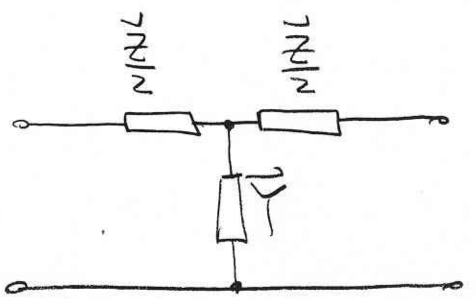
$$\vec{V} = \vec{V}_2 \, ch\, \vec{\gamma} x + \vec{Z}_c \vec{I}_2 \, sh\, \vec{\gamma} x$$

$$\vec{I} = \vec{I}_2 \, ch\, \vec{\gamma} x + \frac{\vec{V}_2}{\vec{Z}_c} \, sh\, \vec{\gamma} x$$

2. MODELI EE VODA SA KONCENTRIRANIM PARAMETRIMA



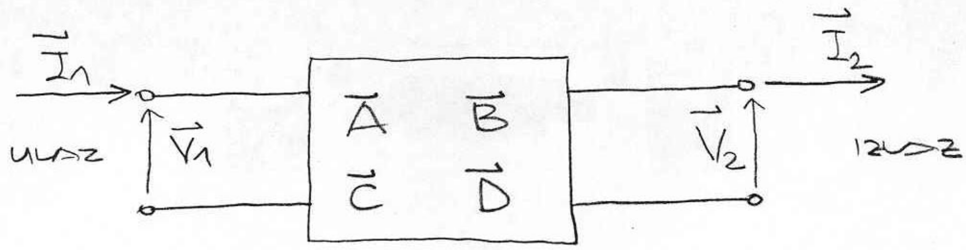
Π- model



T- model

6.2 PRIMJENA TEORIJE ČETVEROPOLA

PRIJENOSNE JEDNADŽBE ČETVEROPOLA



$\vec{A}, \vec{B}, \vec{C}, \vec{D}$ OPĆE KONSTANTE PRIJENOSA

PRIJENOSNE JEDNADŽBE ČETVEROPOLA :

$$\vec{V}_1 = \vec{A}\,\vec{V}_2 + \vec{B}\,\vec{I}_2$$
$$\vec{I}_1 = \vec{C}\,\vec{V}_2 + \vec{D}\,\vec{I}_2$$

$$\begin{bmatrix} \vec{V}_1 \\ \vec{I}_1 \end{bmatrix} = \begin{bmatrix} \vec{A} & \vec{B} \\ \vec{C} & \vec{D} \end{bmatrix} \begin{bmatrix} \vec{V}_2 \\ \vec{I}_2 \end{bmatrix}$$

$$[L] = \begin{bmatrix} \vec{A} & \vec{B} \\ \vec{C} & \vec{D} \end{bmatrix}$$ LANČANA MATRICA

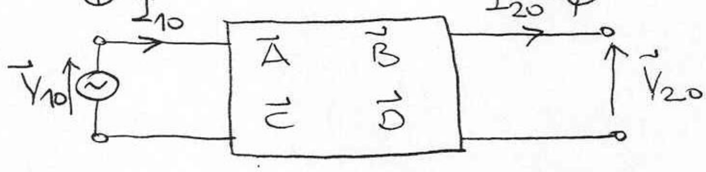
SIMETRIČAN ČETVEROPOL : $\vec{A} = \vec{D}$

RECIPROČAN ČETVEROPOL : $\det \begin{bmatrix} \vec{A} & \vec{B} \\ \vec{C} & \vec{D} \end{bmatrix} = \vec{A}\vec{D} - \vec{B}\vec{C} = 1$

PASIVAN ČETVEROPOL : $\begin{bmatrix} \vec{V}_2 \\ \vec{I}_2 \end{bmatrix} = \begin{bmatrix} \vec{A} & \vec{B} \\ \vec{C} & \vec{D} \end{bmatrix}^{-1} \begin{bmatrix} \vec{V}_1 \\ \vec{I}_1 \end{bmatrix}$

ODREĐIVANJE OPĆIH KONSTANTI PRIJENOSA (PARAMETARA ČETVEROPOLA)

a) POKUS PRAZNOG HODA

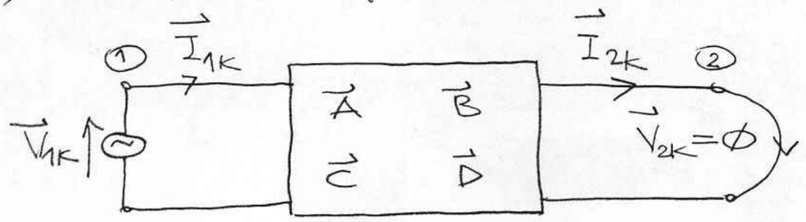


$$\begin{bmatrix} \vec{V}_{10} \\ \vec{I}_{10} \end{bmatrix} = \begin{bmatrix} \vec{A} & \vec{B} \\ \vec{C} & \vec{D} \end{bmatrix} \begin{bmatrix} \vec{V}_{20} \\ \phi \end{bmatrix}$$

$$\vec{V}_{10} = \vec{A}\,\vec{V}_{20} \qquad \vec{A} = \frac{\vec{V}_{10}}{\vec{V}_{20}}$$

$$\vec{I}_{10} = \vec{C}\,\vec{V}_{20} \qquad \vec{C} = \frac{\vec{I}_{10}}{\vec{V}_{20}}$$

b) POKUS KRATKOG SPOJA

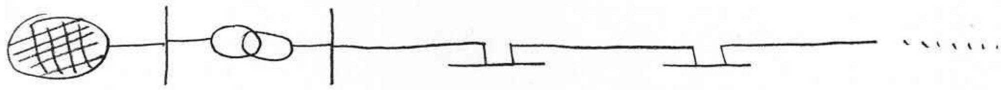


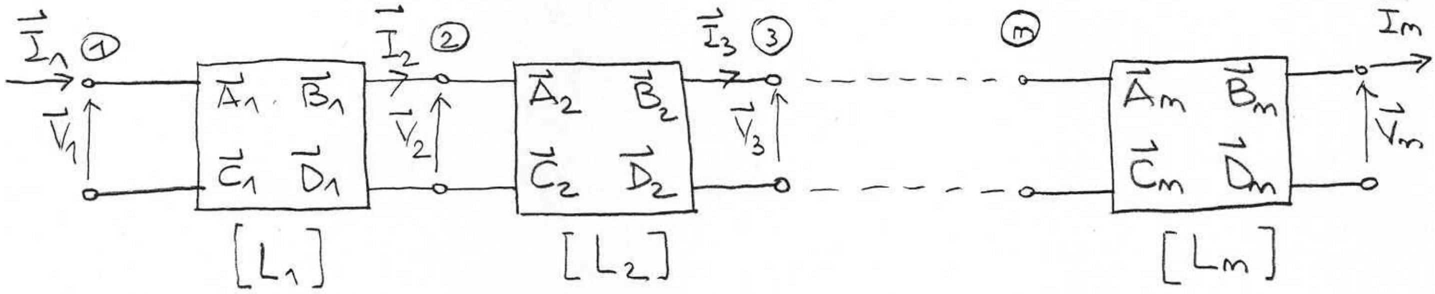
$$\begin{bmatrix} \vec{V}_{1k} \\ \vec{I}_{1k} \end{bmatrix} = \begin{bmatrix} \vec{A} & \vec{B} \\ \vec{C} & \vec{D} \end{bmatrix} \begin{bmatrix} \emptyset \\ \vec{I}_{2k} \end{bmatrix}$$

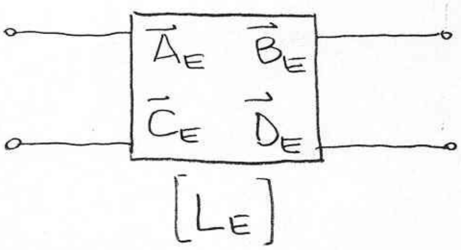
$$\vec{V}_{1k} = \vec{B}\,\vec{I}_{2k} \qquad \vec{B} = \frac{\vec{V}_{1k}}{\vec{I}_{2k}}$$

$$\vec{I}_{1k} = \vec{D}\,\vec{I}_{2k} \qquad \vec{D} = \frac{\vec{I}_{1k}}{\vec{I}_{2k}}$$

LANAC ČETVEROPOLA



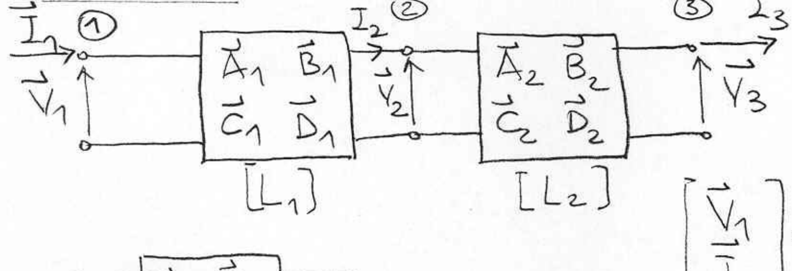




$[L_E]$ EKVIVALENTNA LANČANA MATRICA

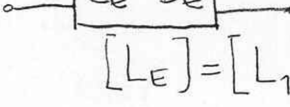
$$[L_E] = [L_1][L_2] \cdots [L_m]$$

PRIMJER:



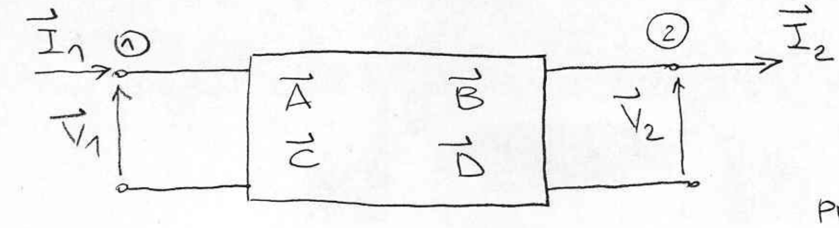
$$\begin{bmatrix} \vec{V}_1 \\ \vec{I}_1 \end{bmatrix} = \begin{bmatrix} \vec{A}_E & \vec{B}_E \\ \vec{C}_E & \vec{D}_E \end{bmatrix} \begin{bmatrix} \vec{V}_3 \\ \vec{I}_3 \end{bmatrix}$$

$$\begin{bmatrix} \vec{V}_1 \\ \vec{I}_1 \end{bmatrix} = \begin{bmatrix} \vec{A}_1 & \vec{B}_1 \\ \vec{C}_1 & \vec{D}_1 \end{bmatrix} \begin{bmatrix} \vec{A}_2 & \vec{B}_2 \\ \vec{C}_2 & \vec{D}_2 \end{bmatrix} \begin{bmatrix} \vec{V}_3 \\ \vec{I}_3 \end{bmatrix}$$



$$[L_E] = [L_1][L_2] = \begin{bmatrix} \vec{A}_1\vec{A}_2 + \vec{B}_1\vec{C}_2 & \vec{A}_1\vec{B}_2 + \vec{B}_1\vec{D}_2 \\ \vec{C}_1\vec{A}_2 + \vec{D}_1\vec{C}_2 & \vec{C}_1\vec{B}_2 + \vec{D}_1\vec{D}_2 \end{bmatrix}$$

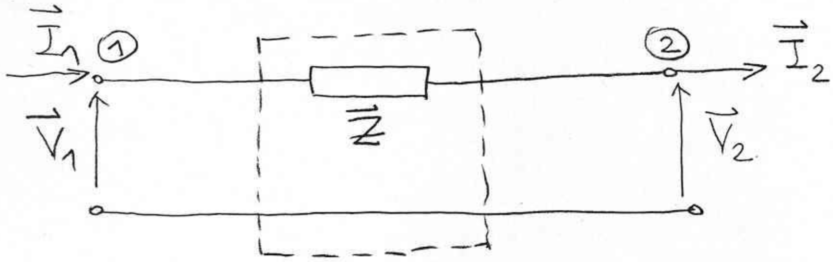
OPĆE KONSTANTE ELEMENTARNIH ČETVEROPOLA



$$\begin{bmatrix}\vec V_1\\ \vec I_1\end{bmatrix} = \begin{bmatrix}\vec A & \vec B\\ \vec C & \vec D\end{bmatrix}\begin{bmatrix}\vec V_2\\ \vec I_2\end{bmatrix}$$

PRIJENOSNE JEDNADŽBE

a) UZDUŽNA IMPEDANCIJA



PRIJENOSNE JEDNADŽBE

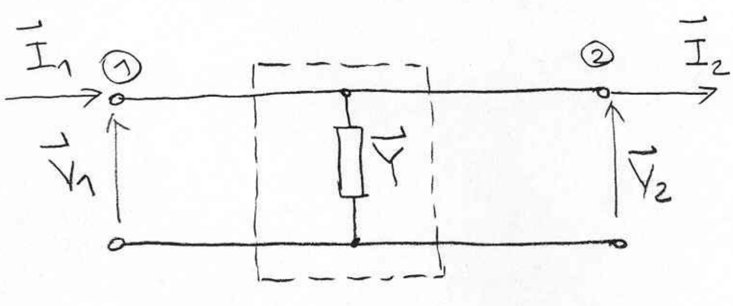
$$\vec V_1 = \vec A\,\vec V_2 + \vec B\,\vec I_2 \qquad \vec V_1 = 1\cdot\vec V_2 + \vec Z\,\vec I_2$$
$$\vec I_1 = \vec C\,\vec V_2 + \vec D\,\vec I_2 \qquad \vec I_1 = 0\,\vec V_2 + 1\cdot\vec I_2$$

$$\vec A = 1 \qquad \vec B = \vec Z$$
$$\vec C = 0 \qquad \vec D = 1$$

$$[L_Z] = \begin{bmatrix}1 & \vec Z\\ 0 & 1\end{bmatrix}$$

ČETVEROPOL JE SIMETRIČAN ($\vec A = \vec D$) I RECIPROČAN ($\det[L_Z]=1$).

b) POPREČNA ADMITANCIJA



PRIJENOSNE JEDNADŽBE

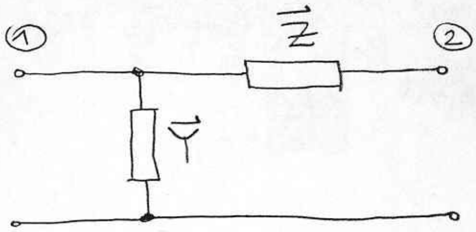
$$\vec V_1 = \vec A\,\vec V_2 + \vec B\,\vec I_2 \qquad \vec V_1 = 1\cdot\vec V_2 + 0\,\vec I_2$$
$$\vec I_1 = \vec C\,\vec V_2 + \vec D\,\vec I_2 \qquad \vec I_1 = \vec Y\,\vec V_2 + 1\cdot\vec I_2$$

$$\vec A = 1 \qquad \vec B = 0$$
$$\vec C = \vec Y \qquad \vec D = 1$$

$$[L_Y] = \begin{bmatrix}1 & 0\\ \vec Y & 1\end{bmatrix}$$

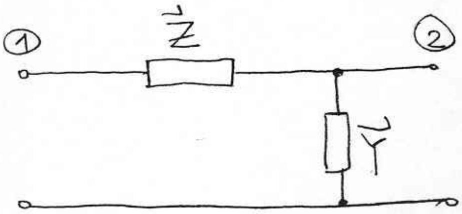
ČETVEROPOL JE SIMETRIČAN ($\vec A = \vec D$) I RECIPROČAN ($\det[L_Y]=1$).

Γ - SHEMA ČETVEROPOLA



$$[L_\Gamma] = [L_Y][L_Z]$$

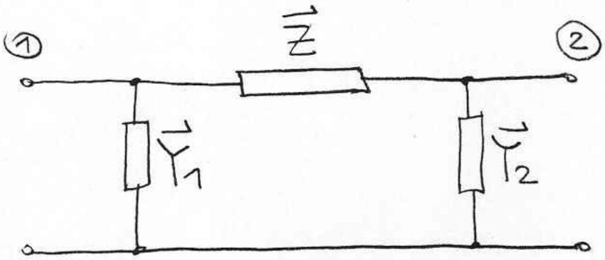
$$[L_\Gamma] = [L_Y][L_Z] = \begin{bmatrix} 1 & 0 \\ \vec{Y} & 1 \end{bmatrix}\begin{bmatrix} 1 & \vec{Z} \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & \vec{Z} \\ \vec{Y} & \vec{Y}\vec{Z}+1 \end{bmatrix}$$



$$[L_\Gamma] = [L_Z][L_Y]$$

$$[L_\Gamma] = [L_Z][L_Y] = \begin{bmatrix} 1 & \vec{Z} \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ \vec{Y} & 1 \end{bmatrix} = \begin{bmatrix} 1+\vec{Z}\vec{Y} & \vec{Z} \\ \vec{Y} & 1 \end{bmatrix}$$

Π - SHEMA ČETVEROPOLA



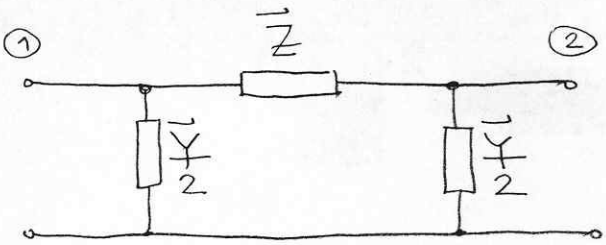
$$[L_\Pi] = [L_{Y_1}][L_Z][L_{Y_2}]$$

$$[L_\Pi] = [L_{Y_1}][L_Z][L_{Y_2}] = \begin{bmatrix} 1 & 0 \\ \vec{Y}_1 & 1 \end{bmatrix}\begin{bmatrix} 1 & \vec{Z} \\ 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 \\ \vec{Y}_2 & 1 \end{bmatrix} =$$

$$= \begin{bmatrix} 1 & \vec{Z} \\ \vec{Y}_1 & 1+\vec{Y}_1\vec{Z} \end{bmatrix}\begin{bmatrix} 1 & 0 \\ \vec{Y}_2 & 1 \end{bmatrix} = \begin{bmatrix} 1+\vec{Z}\vec{Y}_2 & \vec{Z} \\ \vec{Y}_1+\vec{Y}_2(1+\vec{Y}_1\vec{Z}) & 1+\vec{Y}_1\vec{Z} \end{bmatrix}$$

$$[L_\Pi] = \begin{bmatrix} 1+\vec{Z}\vec{Y}_2 & \vec{Z} \\ \vec{Y}_1+\vec{Y}_2(1+\vec{Y}_1\vec{Z}) & 1+\vec{Y}_1\vec{Z} \end{bmatrix}$$

Π - SHEMA ZA EL. EN. VOD



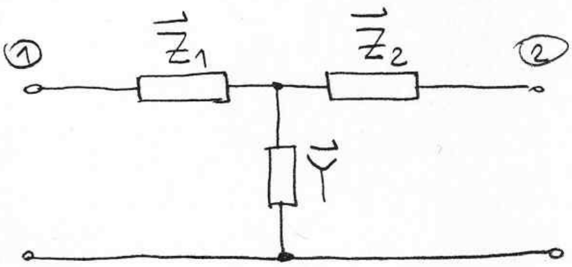
$$[L_{DV}] = [L_{Y/2}][L_Z][L_{Y/2}]$$

$$[L_{DV}] = [L_{Y/2}][L_Z][L_{Y/2}] = \begin{bmatrix} 1 & 0 \\ \vec{Y}/2 & 1 \end{bmatrix} \begin{bmatrix} 1 & \vec{Z} \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \vec{Y}/2 & 1 \end{bmatrix} =$$

$$= \begin{bmatrix} 1 & \vec{Z} \\ \frac{\vec{Y}}{2} & 1 + \frac{\vec{Y}}{2}\vec{Z} \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \frac{\vec{Y}}{2} & 1 \end{bmatrix} = \begin{bmatrix} 1 + \vec{Z}\frac{\vec{Y}}{2} & \vec{Z} \\ \frac{\vec{Y}}{2} + \frac{\vec{Y}}{2}\left(1 + \frac{\vec{Y}}{2}\vec{Z}\right) & 1 + \frac{\vec{Y}}{2}\vec{Z} \end{bmatrix}$$

$$[L_{DV}] = \begin{bmatrix} 1 + \vec{Z}\frac{\vec{Y}}{2} & \vec{Z} \\ \frac{\vec{Y}}{2} + \frac{\vec{Y}}{2}\left(1 + \vec{Z}\frac{\vec{Y}}{2}\right) & 1 + \vec{Z}\frac{\vec{Y}}{2} \end{bmatrix}$$

T- SHEMA ČETVEROPOLA



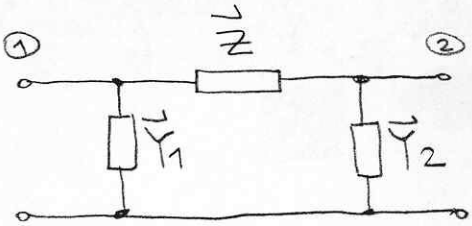
$$[L_T] = [L_{Z_1}][L_Y][L_{Z_2}]$$

$$[L_T] = [L_{Z_1}][L_Y][L_{Z_2}] = \begin{bmatrix} 1 & \vec{Z}_1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 \\ \vec{Y} & 1 \end{bmatrix} \begin{bmatrix} 1 & \vec{Z}_2 \\ 0 & 1 \end{bmatrix}$$

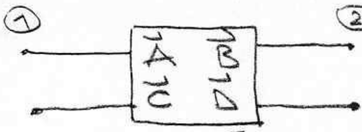
$$= \begin{bmatrix} 1 + \vec{Z}_1 \vec{Y} & \vec{Z}_1 \\ \vec{Y} & 1 \end{bmatrix} \begin{bmatrix} 1 & \vec{Z}_2 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 + \vec{Z}_1 \vec{Y} & \vec{Z}_2(1 + \vec{Z}_1 \vec{Y}) + \vec{Z}_1 \\ \vec{Y} & \vec{Y}\vec{Z}_2 + 1 \end{bmatrix}$$

$$[L_T] = \begin{bmatrix} 1 + \vec{Z}_1 \vec{Y} & \vec{Z}_2(1 + \vec{Z}_1 \vec{Y}) + \vec{Z}_1 \\ \vec{Y} & \vec{Y}\vec{Z}_2 + 1 \end{bmatrix}$$

ODREĐIVANJE PARAMETARA Π-SHEME ČETVEROPOLA
AKO SU POZNATE OPĆE KONSTANTE



POZNATO : $\vec{A}, \vec{B}, \vec{C}, \vec{D}$



$$[L_{\Pi}] = \begin{bmatrix} \vec{A} & \vec{B} \\ \vec{C} & \vec{D} \end{bmatrix} = \begin{bmatrix} 1+\vec{Z}\vec{Y}_2 & \vec{Z} \\ \vec{Y}_1+\vec{Y}_2(1+\vec{Z}\vec{Y}_1) & 1+\vec{Z}\vec{Y}_1 \end{bmatrix}$$

$\vec{A} = 1+\vec{Z}\vec{Y}_2$ $\qquad$ $\vec{Y}_2 = \dfrac{\vec{A}-1}{\vec{Z}}$

$\vec{B} = \vec{Z}$ $\qquad$ $\vec{Z} = B$

$\vec{C} = \vec{Y}_1+\vec{Y}_2(1+\vec{Z}\vec{Y}_1)$

$\vec{D} = 1+\vec{Z}\vec{Y}_1$ $\qquad$ $\vec{Y}_1 = \dfrac{D-1}{\vec{Z}}$

$\vec{A}, \vec{B}, \vec{C}, \vec{D}$ $\qquad$ $\vec{Z} = B$ $\qquad$ $\vec{Y}_1 = \dfrac{D-1}{B}$ $\qquad$ $\vec{Y}_2 = \dfrac{A-1}{B}$

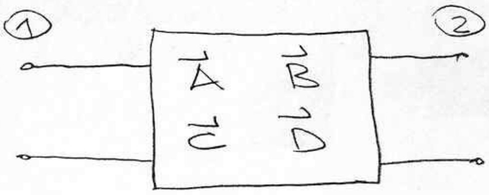
$$C = \vec{Y}_1+\vec{Y}_2(1+\vec{Z}\vec{Y}_1) = \frac{D-1}{B} + \frac{A-1}{B}\left(1+B\,\frac{D-1}{B}\right)$$

$$= \frac{D-1}{B} + \frac{A-1}{B}\,D = \frac{D-1}{B} + \frac{AD-D}{B} = \frac{D-1+AD-D}{B} = \frac{AD-1}{B}$$

$C = \dfrac{AD-1}{B}$ $\qquad$ $BC = AD-1$

$AD - BC = 1$

OPĆE KONSTANTE DUGOG EL. EN. VODA



$$\vec{V}_1 = \vec{A}\,\vec{V}_2 + \vec{B}\,\vec{I}_2$$

$$\vec{I}_1 = \vec{C}\,\vec{V}_2 + \vec{D}\,\vec{I}_2$$

PRIJENOSNE JEDNADŽBE ČETVEROPOLA

PRIJENOSNE JEDNADŽBE EL. EN. VODA (III OBLIK)

$$\vec{V}_1 = \vec{V}_2\,\mathrm{ch}\,\Theta + \vec{Z}\,\vec{I}_2\,\frac{\mathrm{sh}\,\Theta}{\Theta} \qquad \Theta = \vec{\gamma}\cdot l = \sqrt{\vec{Z}_1\vec{Y}_1}\cdot l$$

$$\vec{I}_1 = \vec{V}_2\,\vec{Y}\,\frac{\mathrm{sh}\,\Theta}{\Theta} + \vec{I}_2\,\mathrm{ch}\,\Theta \qquad \Theta = \sqrt{\vec{Z}\cdot\vec{Y}}$$

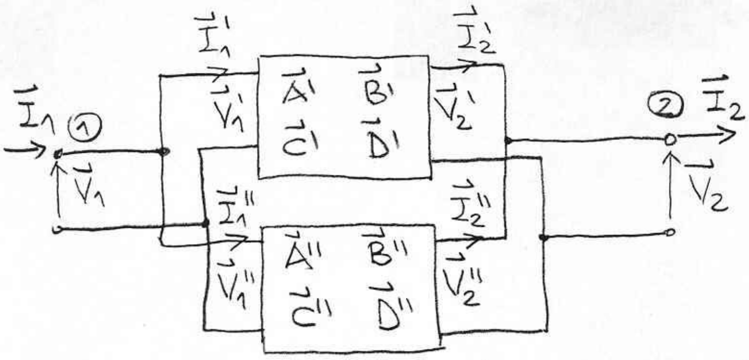
$$\vec{A} = \mathrm{ch}\,\Theta \qquad \vec{B} = \vec{Z}\,\frac{\mathrm{sh}\,\Theta}{\Theta} = \vec{Z}\,\frac{\mathrm{sh}\sqrt{\vec{Z}\cdot\vec{Y}}}{\sqrt{\vec{Z}\cdot\vec{Y}}} = \sqrt{\frac{\vec{Z}}{\vec{Y}}}\,\mathrm{sh}\sqrt{\vec{Z}\cdot\vec{Y}}$$

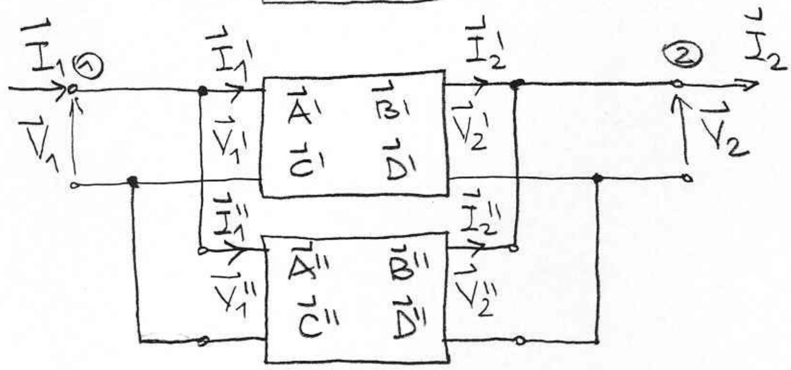
$$\vec{C} = \vec{Y}\,\frac{\mathrm{sh}\,\Theta}{\Theta} = \vec{Y}\,\frac{\mathrm{sh}\sqrt{\vec{Z}\vec{Y}}}{\sqrt{\vec{Z}\vec{Y}}} = \sqrt{\frac{\vec{Y}}{\vec{Z}}}\,\mathrm{sh}\sqrt{\vec{Z}\cdot\vec{Y}} \qquad \vec{D} = \mathrm{ch}\,\Theta$$

$$\left[L_{DV}\right] = \begin{bmatrix} \mathrm{ch}\,\Theta & \vec{Z}\,\frac{\mathrm{sh}\,\Theta}{\Theta} \\ \vec{Y}\,\frac{\mathrm{sh}\,\Theta}{\Theta} & \mathrm{ch}\,\Theta \end{bmatrix} = \begin{bmatrix} \mathrm{ch}\sqrt{\vec{Z}\vec{Y}} & \sqrt{\frac{\vec{Z}}{\vec{Y}}}\,\mathrm{sh}\sqrt{\vec{Z}\cdot\vec{Y}} \\ \sqrt{\frac{\vec{Y}}{\vec{Z}}}\,\mathrm{sh}\sqrt{\vec{Z}\vec{Y}} & \mathrm{ch}\sqrt{\vec{Z}\vec{Y}} \end{bmatrix}$$

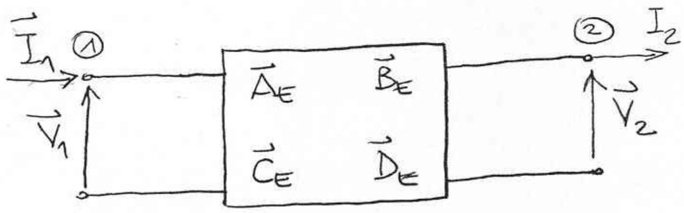
PARALELNI SPOJ PRIJENOSNIH SUSTAVA

PARALELNI SPOJ ČETVEROPOLA



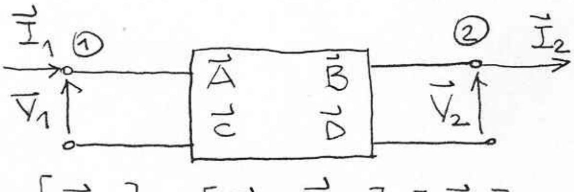


$$\vec{V}_1 = \vec{V}_1' = \vec{V}_1''$$
$$\vec{V}_2 = \vec{V}_2' = \vec{V}_2''$$
$$\vec{I}_1 = \vec{I}_1' + \vec{I}_1''$$
$$\vec{I}_2 = \vec{I}_2' + \vec{I}_2''$$



$$\vec{V}_1 = \vec{A}_E\vec{V}_2 + \vec{B}_E\vec{I}_2$$
$$\vec{I}_1 = \vec{C}_E\vec{V}_2 + \vec{D}_E\vec{I}_2$$

JEDAN ČETVEROPOL OPĆENITO:



$$\begin{bmatrix}\vec{V}_1\\ \vec{I}_1\end{bmatrix} = \begin{bmatrix}\vec{A} & \vec{B}\\ \vec{C} & \vec{D}\end{bmatrix}\begin{bmatrix}\vec{V}_2\\ \vec{I}_2\end{bmatrix}$$

PRIJENOSNE JEDNADŽBE ČETVEROPOLA

$$\begin{bmatrix}\vec{I}_1\\ \vec{I}_2\end{bmatrix} = \underbrace{\begin{bmatrix}\vec{Y}_{11} & \vec{Y}_{12}\\ \vec{Y}_{21} & \vec{Y}_{22}\end{bmatrix}}_{\text{MATRICA ADMITANCIJA ČVORIŠTA}}\begin{bmatrix}\vec{V}_1\\ \vec{V}_2\end{bmatrix}$$

$$\vec{V}_1 = \vec{A}\vec{V}_2 + \vec{B}\vec{I}_2$$
$$\vec{I}_1 = \vec{C}\vec{V}_2 + \vec{D}\vec{I}_2$$

$$\vec{I}_1 = \vec{Y}_{11}\vec{V}_1 + \vec{Y}_{12}\vec{V}_2$$
$$\vec{I}_2 = \vec{Y}_{21}\vec{V}_1 + \vec{Y}_{22}\vec{V}_2$$

$$\vec{V}_1 = \vec{A}\vec{V}_2 + \vec{B}\vec{I}_2 \quad \rightarrow \quad \vec{I}_2 = \frac{1}{\vec{B}}\vec{V}_1 - \frac{\vec{A}}{\vec{B}}\vec{V}_2 \qquad (1)$$

$$\vec{I}_1 = \vec{C}\vec{V}_2 + \vec{D}\vec{I}_2 = \vec{C}\vec{V}_2 + \frac{\vec{D}}{\vec{B}}\vec{V}_1 - \frac{\vec{A}\vec{D}}{\vec{B}}\vec{V}_2$$

$$= \left(\vec{C} - \frac{\vec{A}\vec{D}}{\vec{B}}\right)\vec{V}_2 + \frac{\vec{D}}{\vec{B}}\vec{V}_1$$

$$\det\begin{vmatrix}\vec{A} & \vec{B}\\ \vec{C} & \vec{D}\end{vmatrix} = 1 \Rightarrow \vec{A}\vec{D} - \vec{B}\vec{C} = 1 \qquad \frac{\vec{A}\vec{D}}{\vec{B}} - \vec{C} = \frac{1}{\vec{B}}$$

$$\vec{I}_1 = \frac{\vec{D}}{\vec{B}}\vec{V}_1 - \frac{1}{\vec{B}}\vec{V}_2 \qquad (2.)$$

PARALELNI SPOJ DVA ČETVEROPOLA :

$$\vec{I}_1' = \frac{\vec{D}'}{\vec{B}'}\vec{V}_1 - \frac{1}{\vec{B}'}\vec{V}_2 \qquad \vec{I}_2' = \frac{1}{\vec{B}'}\vec{V}_1 - \frac{\vec{A}'}{\vec{B}'}\vec{V}_2$$

$$\vec{I}_1'' = \frac{\vec{D}''}{\vec{B}''}\vec{V}_1 - \frac{1}{\vec{B}''}\vec{V}_2 \qquad \vec{I}_2'' = \frac{1}{\vec{B}''}\vec{V}_1 - \frac{\vec{A}''}{\vec{B}''}\vec{V}_2$$

$$\vec{I}_1 = \vec{I}_1' + \vec{I}_1'' \qquad \vec{I}_2 = \vec{I}_2' + \vec{I}_2''$$

$$\vec{I}_1 = \left(\frac{\vec{D}'}{\vec{B}'} + \frac{\vec{D}''}{\vec{B}''}\right)\vec{V}_1 - \left(\frac{1}{\vec{B}'} + \frac{1}{\vec{B}''}\right)\vec{V}_2$$

$$\vec{I}_1 = \left(\vec{Y}_{11}' + \vec{Y}_{11}''\right)\vec{V}_1 - \left(\vec{Y}_{12}' + \vec{Y}_{12}''\right)\vec{V}_2$$

$$\vec{I}_2 = \left(\frac{1}{\vec{B}'} + \frac{1}{\vec{B}''}\right)\vec{V}_1 - \left(\frac{\vec{A}'}{\vec{B}'} + \frac{\vec{A}''}{\vec{B}''}\right)\vec{V}_2$$

$$\vec{I}_2 = \left(\vec{Y}_{21}' + \vec{Y}_{21}''\right)\vec{V}_1 - \left(\vec{Y}_{22}' + \vec{Y}_{22}''\right)\vec{V}_2$$

$$\vec{I}_1 = \vec{Y}_{11}\vec{V}_1 + \vec{Y}_{12}\vec{V}_2$$

$$\vec{I}_2 = \vec{Y}_{21}\vec{V}_1 + \vec{Y}_{22}\vec{V}_2$$

$$\vec{I}_2 = \vec{Y}_{21}\vec{V}_1 + \vec{Y}_{22}\vec{V}_2$$

$$\vec{V}_1 = \frac{1}{\vec{Y}_{21}}\left(\vec{I}_2 - \vec{Y}_{22}\vec{V}_2\right) = -\frac{\vec{Y}_{22}}{\vec{Y}_{21}}\vec{V}_2 + \frac{1}{\vec{Y}_{21}}\vec{I}_2$$

$$\vec{V}_1 = \vec{A}_E\vec{V}_2 + \vec{B}_E\vec{I}_2$$

$$\vec{A}_E = -\frac{\vec{Y}_{22}}{\vec{Y}_{21}} \qquad B_E = \frac{1}{\vec{Y}_{21}}$$

$$\vec{I}_1 = \vec{Y}_{11}\vec{V}_1 + \vec{Y}_{12}\vec{V}_2 = \vec{Y}_{11}\left(-\frac{\vec{Y}_{22}}{\vec{Y}_{21}}\vec{V}_2 + \frac{1}{\vec{Y}_{21}}\vec{I}_2\right) + \vec{Y}_{12}\vec{V}_2$$

$$\vec{I}_1 = \left(\vec{Y}_{12} - \frac{\vec{Y}_{11}\vec{Y}_{22}}{\vec{Y}_{21}}\right)\vec{V}_2 + \frac{\vec{Y}_{11}}{\vec{Y}_{21}}\vec{I}_2$$

$$\vec{I}_1 = \vec{C}_E\vec{V}_2 + \vec{D}_E\vec{I}_2$$

$$\vec{C}_E = \vec{Y}_{12} - \frac{\vec{Y}_{11}\vec{Y}_{22}}{\vec{Y}_{21}} \qquad \vec{D}_E = \frac{\vec{Y}_{11}}{\vec{Y}_{21}}$$

$$\vec{A}_E = -\frac{\vec{Y}_{22}}{\vec{Y}_{21}} = -\frac{-\frac{\vec{A}'}{\vec{B}'} - \frac{\vec{A}''}{\vec{B}''}}{\frac{1}{\vec{B}'} + \frac{1}{\vec{B}''}} = \frac{\frac{\vec{A}'\vec{B}'' + \vec{A}''\vec{B}'}{\vec{B}'\vec{B}''}}{\frac{\vec{B}' + \vec{B}''}{\vec{B}'\vec{B}''}} = \frac{\vec{A}'\vec{B}'' + \vec{A}''\vec{B}'}{\vec{B}' + \vec{B}''}$$

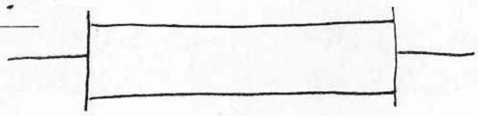
$$\vec{B}_E = \frac{1}{\vec{Y}_{21}} = \frac{1}{\frac{1}{\vec{B}'} + \frac{1}{\vec{B}''}} = \frac{\vec{B}'\vec{B}''}{\vec{B}' + \vec{B}''}$$

$$\vec{D}_E = \frac{\vec{Y}_{11}}{\vec{Y}_{21}} = \frac{\frac{\vec{D}'}{\vec{B}'} + \frac{\vec{D}''}{\vec{B}''}}{\frac{1}{\vec{B}'} + \frac{1}{\vec{B}''}} = \frac{\frac{\vec{D}'\vec{B}'' + \vec{D}''\vec{B}'}{\vec{B}'\vec{B}''}}{\frac{\vec{B}' + \vec{B}''}{\vec{B}'\vec{B}''}} = \frac{\vec{D}'\vec{B}'' + \vec{D}''\vec{B}'}{\vec{B}' + \vec{B}''}$$

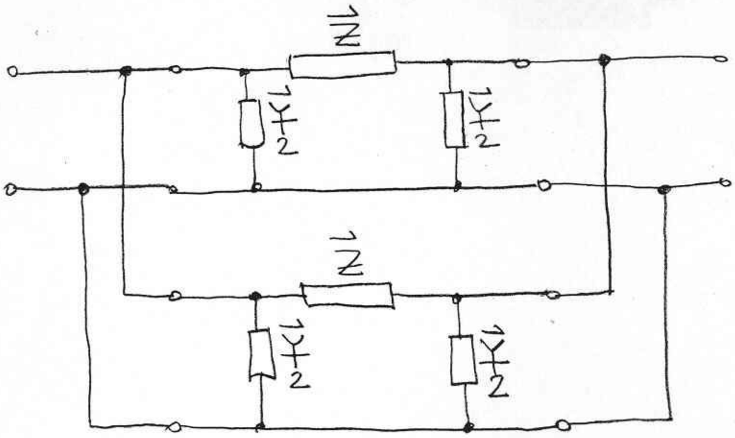
$$\vec{C}_E = \vec{Y}_{12} - \frac{\vec{Y}_{11}\vec{Y}_{22}}{\vec{Y}_{21}} = \frac{\vec{Y}_{12}\vec{Y}_{21} - \vec{Y}_{11}\vec{Y}_{22}}{\vec{Y}_{21}} = \frac{\vec{Y}_{12}\vec{Y}_{21}}{\vec{Y}_{21}} - \frac{\vec{Y}_{11}\vec{Y}_{22}}{\vec{Y}_{21}} = \frac{\frac{\vec{Y}_{12}}{\vec{Y}_{21}}}{\vec{B}_E} + \vec{A}_E\vec{D}_E\vec{Y}_{21}$$

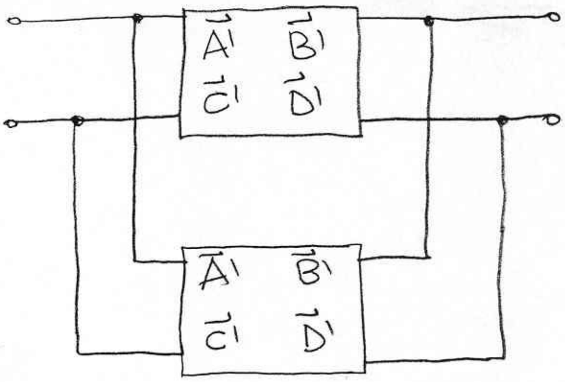
$$= \frac{-1}{\vec{B}_E} + \frac{\vec{A}_E\vec{D}_E}{\vec{B}_E} = \frac{\vec{A}_E\vec{D}_E - 1}{\vec{B}_E}$$

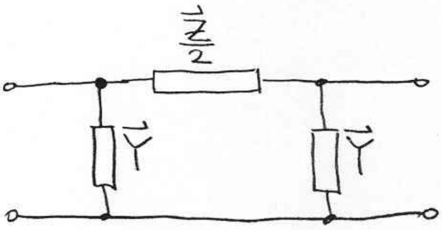
PRIMJER:

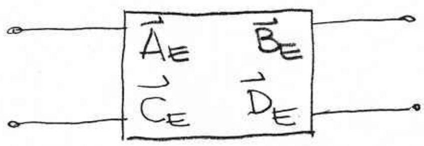


DVA PARALELNA JEDNAKA EL. EN. VODA









$$\vec{A}_E = \frac{\vec{A}'\vec{B}'' + \vec{A}''\vec{B}'}{\vec{B}' + \vec{B}''} = \frac{2\vec{A}'\vec{B}'}{2\vec{B}'} = \vec{A}'$$

$$\vec{B}_E = \frac{\vec{B}'\vec{B}''}{\vec{B}' + \vec{B}''} = \frac{(\vec{B}')^2}{2\vec{B}'} = \frac{\vec{B}'}{2}$$

$$\vec{D}_E = \frac{\vec{D}'\vec{B}'' + \vec{D}''\vec{B}'}{\vec{B}' + \vec{B}''} = \frac{2\vec{D}'\vec{B}'}{2\vec{B}'} = \vec{D}'$$

$$\vec{C}_E = \frac{\vec{A}_E\vec{D}_E - 1}{\vec{B}_E} = \frac{\vec{A}'\vec{D}' - 1}{\frac{\vec{B}'}{2}}$$

Π-SHEMA ČETVEROPOLA EL. EN. VODA

$$\vec{A}' = 1 + \vec{Z}\frac{\vec{Y}}{2}$$

$$\vec{B}' = \vec{Z}$$

$$\vec{C}' = \frac{\vec{Y}}{2} + \frac{\vec{Y}}{2}\left(1 + \vec{Z}\frac{\vec{Y}}{2}\right)$$

$$\vec{D}' = 1 + \vec{Z}\frac{\vec{Y}}{2}$$

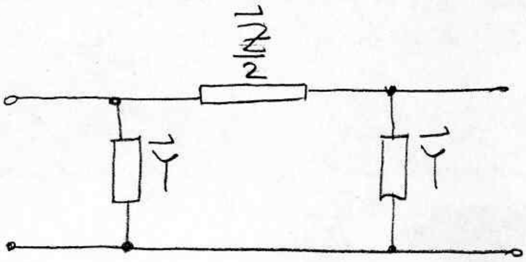
$$\vec{A}_E = \vec{A}' = 1 + \vec{Z}\frac{\vec{Y}}{2}$$

$$\vec{B}_E = \frac{\vec{B}'}{2} = \frac{\vec{Z}}{2}$$

$$\vec{D}_E = \vec{D}' = 1 + \vec{Z}\frac{\vec{Y}}{2}$$

$$\vec{C}_E = \frac{\vec{A}_E\vec{D}_E - 1}{\vec{B}_E} = \frac{\left(1 + \vec{Z}\frac{\vec{Y}}{2}\right)\left(1 + \vec{Z}\frac{\vec{Y}}{2}\right) - 1}{\vec{Z}/2} =$$

$$\vec{C}_E = \frac{1 + \vec{Z}\frac{\vec{Y}}{2} + \vec{Z}\frac{\vec{Y}}{2} + \vec{Z}^2\frac{\vec{Y}^2}{4} - 1}{\vec{Z}/2} = \frac{\frac{1}{2}\vec{Z}\left(\vec{Y} + \vec{Y} + \vec{Z}\frac{\vec{Y}^2}{2}\right)}{\frac{1}{2}\vec{Z}} = \vec{Y} + \vec{Y}\left(1 + \frac{\vec{Z}}{2}\vec{Y}\right)$$



$$[L_E] = \begin{bmatrix} 1+\vec{Z}\frac{\vec{Y}}{2} & \frac{\vec{Z}}{2} \\ \vec{Y}+\vec{Y}\left(1+\frac{\vec{Z}}{2}\vec{Y}\right) & 1+\vec{Z}\frac{\vec{Y}}{2} \end{bmatrix}$$

6.3 TOČAN Π - MODEL VODA

AKO SU ZADANI NAPON $\vec{V}_2$ I STRUJA $\vec{I}_2$ NA KRAJU VODA, ODREDIMO NAPON $\vec{V}_1$ I STRUJU $\vec{I}_1$ NA POČETKU VODA:

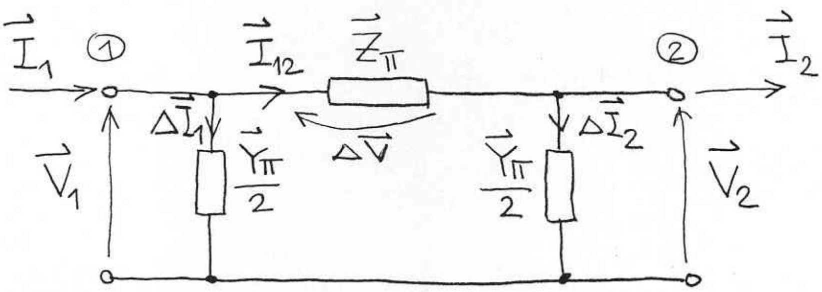
- PRIJENOSNE JEDNADŽBE II. OBLIKA

$$\vec{V} = \vec{V}_2 \operatorname{ch} \vec{\gamma} x + \vec{Z}_c \vec{I}_2 \operatorname{sh} \vec{\gamma} x$$
$$\vec{I} = \vec{I}_2 \operatorname{ch} \vec{\gamma} x + \frac{\vec{V}_2}{\vec{Z}_c} \operatorname{sh} \vec{\gamma} x$$

ZA $x = l$

$$\vec{V}_1 = \vec{V}_2 \operatorname{ch} \vec{\gamma} l + \vec{Z}_c \vec{I}_2 \operatorname{sh} \vec{\gamma} l \qquad (1.)$$
$$\vec{I}_1 = \vec{I}_2 \operatorname{ch} \vec{\gamma} l + \frac{\vec{V}_2}{\vec{Z}_c} \operatorname{sh} \vec{\gamma} l \qquad (2.)$$

- TOČAN Π - MODEL VODA



$$\vec{V}_2 = V_2 \angle 0^\circ$$
$$\vec{I}_2 = I_2 \angle \varphi$$

$\vec{Z}_\Pi$ - IMPEDANCIJA UZDUŽNE GRANE
$\vec{Y}_\Pi$ - ADMITANCIJA POPREČNE GRANE

$$\Delta \vec{I}_2 = \vec{V}_2 \frac{\vec{Y}_\Pi}{2}$$

$$\vec{I}_{12} = \vec{I}_2 + \Delta \vec{I}_2 = \vec{I}_2 + \vec{V}_2 \frac{\vec{Y}_\Pi}{2}$$

$$\Delta \vec{V} = \vec{I}_{12} \cdot \vec{Z}_\Pi = \left(\vec{I}_2 + \vec{V}_2 \frac{\vec{Y}_\Pi}{2} \right) \vec{Z}_\Pi$$

$$\vec{V}_1 = \vec{V}_2 + \Delta \vec{V} = \vec{V}_2 + \vec{I}_{12} \vec{Z}_\Pi = \vec{V}_2 + \left(\vec{I}_2 + \vec{V}_2 \frac{\vec{Y}_\Pi}{2} \right) \vec{Z}_\Pi$$

$$\vec{V}_1 = \vec{V}_2 + \vec{I}_2 \vec{Z}_\Pi + \vec{V}_2 \frac{\vec{Y}_\Pi}{2} \vec{Z}_\Pi$$

$$\vec{V}_1 = \vec{V}_2 \left(1 + \frac{\vec{Y}_\Pi}{2} \vec{Z}_\Pi \right) + \vec{I}_2 \vec{Z}_\Pi \qquad (3.)$$

$$\vec{I}_1 = \vec{I}_{12} + \Delta \vec{I}_1 = \vec{I}_2 + \vec{V}_2 \frac{\vec{Y}_\Pi}{2} + \vec{V}_1 \frac{\vec{Y}_\Pi}{2} \qquad (4.)$$

USPOREDBOM JEDNADŽBI (1.) I (3.), TE IZJEDNAČAVANJEM KOEFICIJENATA, DOBIVAMO:

$$\vec{Z}_\pi = \vec{Z}_c \, \mathrm{sh}\, \vec{\gamma} l$$

$$1 + \frac{\vec{Y}_\pi}{2} \vec{Z}_\pi = 1 + \frac{\vec{Y}_\pi}{2} \vec{Z}_c \, \mathrm{sh}\, \vec{\gamma} l = \mathrm{ch}\, \vec{\gamma} l$$

$$\frac{\vec{Y}_\pi}{2} \vec{Z}_c \, \mathrm{sh}\, \vec{\gamma} l = \mathrm{ch}\, \vec{\gamma} l - 1$$

$$\frac{\vec{Y}_\pi}{2} = \frac{1}{\vec{Z}_c} \frac{\mathrm{ch}\, \vec{\gamma} l - 1}{\mathrm{sh}\, \vec{\gamma} l}$$

VELIČINE ELEMENATA TOČNOG Π-MODELA VODA

$$\vec{Z}_\pi = \vec{Z}_c \, \mathrm{sh}\, \vec{\gamma} l \qquad \frac{\vec{Y}_\pi}{2} = \frac{1}{\vec{Z}_c} \frac{\mathrm{ch}\, \vec{\gamma} l - 1}{\mathrm{sh}\, \vec{\gamma} l}$$

UZEVŠI U OBZIR DA JE :

$$\Theta = \sqrt{\vec{Z} \vec{Y}} = \vec{\gamma} l \qquad \vec{\gamma} = \sqrt{\vec{Z}_1 \vec{Y}_1}$$

$$\vec{Z} = \vec{Z}_1 \cdot l \qquad \vec{Y} = \vec{Y}_1 \cdot l$$

$$\vec{Z}_c = \sqrt{\frac{\vec{Z}}{\vec{Y}}} = \sqrt{\frac{\vec{Z}}{\vec{Y}}} \sqrt{\frac{\vec{Z}}{\vec{Z}}} = \frac{\vec{Z}}{\Theta} = \frac{\vec{Z}/2}{\Theta/2}$$

$$\frac{1}{\vec{Z}_c} = \sqrt{\frac{\vec{Y}}{\vec{Z}}} = \sqrt{\frac{\vec{Y}}{\vec{Z}}} \sqrt{\frac{\vec{Y}}{\vec{Y}}} = \frac{\vec{Y}}{\Theta} = \frac{\vec{Y}/2}{\Theta/2}$$

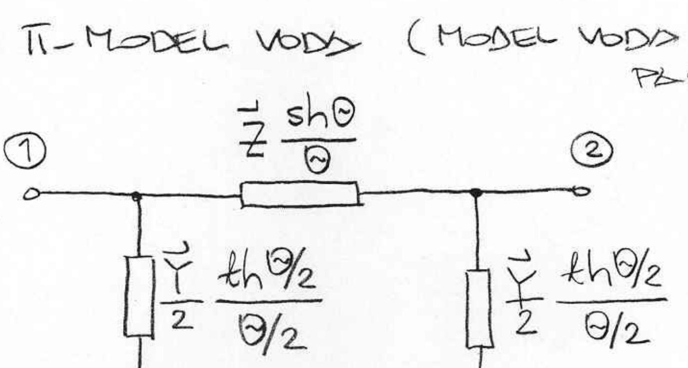
$$\frac{\mathrm{ch}\, \Theta - 1}{\mathrm{sh}\, \Theta} = \mathrm{th} \frac{\Theta}{2}$$

VELIČINE ELEMENATA TOČNOG Π-MODELA VODA :

$$\vec{Z}_\pi = \vec{Z}_c \, \mathrm{sh}\, \vec{\gamma} l = \frac{\vec{Z}}{\Theta} \mathrm{sh}\, \Theta = \vec{Z} \frac{\mathrm{sh}\, \Theta}{\Theta}$$

$$\frac{\vec{Y}_\pi}{2} = \frac{1}{\vec{Z}_c} \frac{\mathrm{ch}\, \vec{\gamma} l - 1}{\mathrm{sh}\, \vec{\gamma} l} = \frac{\vec{Y}/2}{\Theta/2} \frac{\mathrm{ch}\, \Theta - 1}{\mathrm{sh}\, \Theta} = \frac{\vec{Y}}{2} \frac{\mathrm{th}\, \Theta/2}{\Theta/2}$$

TOČAN Π-MODEL VODA (MODEL VODA S KONCENTRIRANIM PARAMETRIMA)



6.4 TOČAN T-MODEL VODA

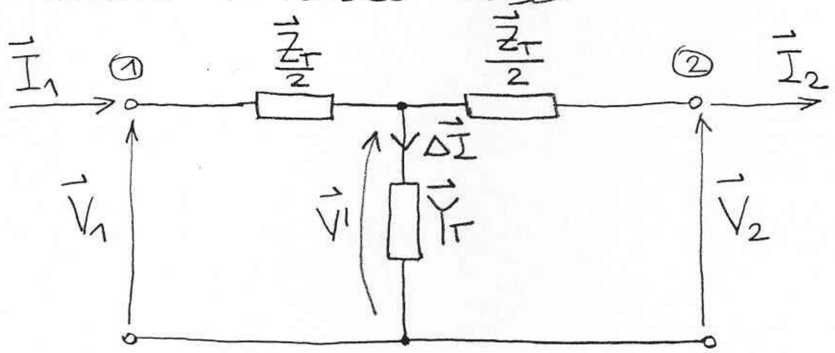
AKO SU ZADANI NAPON $\vec{V}_2$ I STRUJA $\vec{I}_2$ NA KRAJU VODA, ODREDIMO NAPON $\vec{V}_1$ I STRUJU $\vec{I}_1$ NA POČETKU VODA:

- PRIJENOSNE JEDNADŽBE II. OBLIKA ZA $x=l$

$$\vec{V}_1 = \vec{V}_2 \operatorname{ch} \vec{\gamma} l + \vec{Z}_c \vec{I}_2 \operatorname{sh} \vec{\gamma} l \qquad (1.)$$

$$\vec{I}_1 = \vec{I}_2 \operatorname{ch} \vec{\gamma} l + \vec{V}_2 \frac{1}{\vec{Z}_c} \operatorname{sh} \vec{\gamma} l \qquad (2.)$$

- TOČAN T-MODEL VODA



$$\vec{V}_2 = V_2 \angle 0$$

$$\vec{I}_2 = I_2 \angle \varphi$$

$\vec{Z}_T$ - IMPEDANCIJA UZDUŽNE GRANE

$\vec{Y}_T$ - ADMITANCIJA POPREČNE GRANE

$$\vec{V}' = \vec{V}_2 + \vec{I}_2 \frac{\vec{Z}_T}{2}$$

$$\Delta\vec{I} = \vec{V}' \vec{Y}_T = \left(\vec{V}_2 + \vec{I}_2 \frac{\vec{Z}_T}{2}\right) \vec{Y}_T$$

$$\vec{I}_1 = \vec{I}_2 + \Delta\vec{I} = \vec{I}_2 + \left(\vec{V}_2 + \vec{I}_2 \frac{\vec{Z}_T}{2}\right) \vec{Y}_T$$

$$\vec{I}_1 = \vec{I}_2 + \vec{V}_2 \vec{Y}_T + \vec{I}_2 \frac{\vec{Z}_T}{2} \vec{Y}_T$$

$$\vec{I}_1 = \vec{I}_2 \left(1 + \frac{\vec{Z}_T}{2} \vec{Y}_T\right) + \vec{V}_2 \vec{Y}_T \qquad (5.)$$

$$\vec{V}_1 = \vec{V}' + \vec{I}_1 \frac{\vec{Z}_T}{2} = \vec{V}_2 + \vec{I}_2 \frac{\vec{Z}_T}{2} + \vec{I}_1 \frac{\vec{Z}_T}{2} \qquad (6.)$$

USPOREDBOM JEDNADŽBI (2.) I (5.), TE IZJEDNAČAVANJEM KOEFICIJENATA DOBIVAMO:

$$\vec{Y}_T = \frac{1}{\vec{Z}_c} \operatorname{sh} \vec{\gamma} l$$

$$1 + \frac{\vec{Z}_T}{2} \vec{Y}_T = 1 + \frac{\vec{Z}_T}{2} \frac{1}{\vec{Z}_c} \operatorname{sh} \vec{\gamma} l = \operatorname{ch} \vec{\gamma} l$$

$$\frac{\vec{Z}_T}{2}\frac{1}{\vec{Z}_c}\,\mathrm{sh}\,\vec{\gamma}l = \mathrm{ch}\,\vec{\gamma}l - 1$$

$$\frac{\vec{Z}_T}{2} = \vec{Z}_c\,\frac{\mathrm{ch}\,\vec{\gamma}l-1}{\mathrm{sh}\,\vec{\gamma}l}$$

VELIČINE ELEMENATA TOČNOG T-MODELA VODA:

$$\vec{Y}_T = \frac{1}{\vec{Z}_c}\,\mathrm{sh}\,\vec{\gamma}l \qquad \frac{\vec{Z}_T}{2} = \vec{Z}_c\,\frac{\mathrm{ch}\,\vec{\gamma}l-1}{\mathrm{sh}\,\vec{\gamma}l}$$

UZEVŠI U OBZIR DA JE:

$$\Theta = \sqrt{\vec{Z}\cdot\vec{Y}} = \vec{\gamma}l \qquad \vec{\gamma} = \sqrt{\vec{Z}_1\vec{Y}_1}$$

$$\vec{Z}_c = \frac{\vec{Z}}{\Theta} = \frac{\vec{Z}/2}{\Theta/2}$$

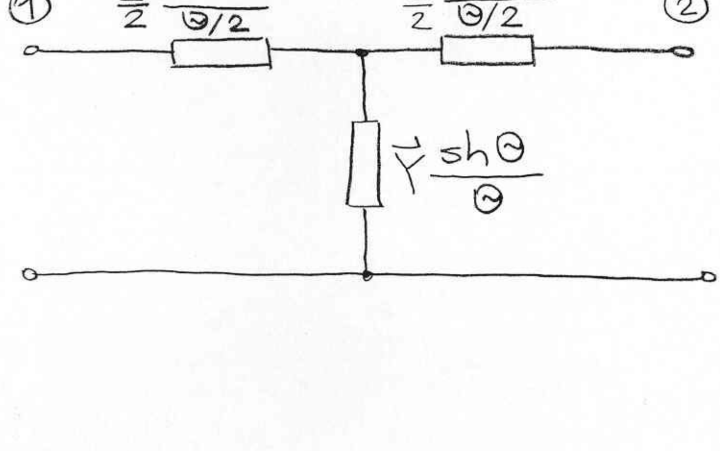
$$\frac{1}{\vec{Z}_c} = \frac{\vec{Y}}{\Theta} = \frac{\vec{Y}/2}{\Theta/2} \qquad \frac{\mathrm{ch}\,\Theta-1}{\mathrm{sh}\,\Theta} = \mathrm{th}\,\Theta/2$$

VELIČINE ELEMENATA TOČNOG T-MODELA VODA:

$$\vec{Y}_T = \frac{1}{\vec{Z}_c}\,\mathrm{sh}\,\vec{\gamma}l = \vec{Y}\,\frac{\mathrm{sh}\,\Theta}{\Theta}$$

$$\frac{\vec{Z}_T}{2} = \vec{Z}_c\,\frac{\mathrm{ch}\,\vec{\gamma}l-1}{\mathrm{sh}\,\vec{\gamma}l} = \frac{\vec{Z}/2}{\Theta/2}\,\frac{\mathrm{ch}\,\Theta-1}{\mathrm{sh}\,\Theta} = \frac{\vec{Z}}{2}\,\frac{\mathrm{th}\,\Theta/2}{\Theta/2}$$

TOČAN T-MODEL VODA (MODEL VODA S KONCENTRIRANIM PARAMETRIMA)



$$\frac{sh\Theta}{\Theta} = 1 + \frac{\Theta^2}{3!} + \frac{\Theta^4}{5!} + \frac{\Theta^6}{7!} + \ldots\ldots\ldots\ldots$$

$$\frac{th\frac{\Theta}{2}}{\frac{\Theta}{2}} = 1 - \frac{\Theta^2}{12} + \frac{\Theta^4}{120} - \frac{\Theta^6}{1186} + \frac{\Theta^8}{11700} -$$

$$ch\Theta = 1 + \frac{\Theta^2}{2!} + \frac{\Theta^4}{4!} + \ldots\ldots$$

6.5 PRIBLIŽAN Π-MODEL VODA
PRIBLIŽAN T-MODEL VODA

ZA KRATKE VODOVE $l < 200$ km :

$$\mathrm{sh}\,\Theta \approx \Theta$$
$$\mathrm{ch}\,\Theta \approx 1$$
$$\mathrm{th}\,\Theta \approx \Theta$$

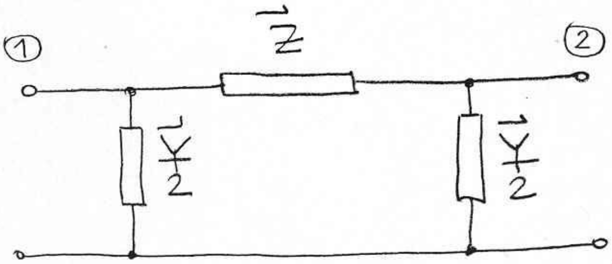
KOREKCIJSKI FAKTORI

$$\frac{\mathrm{sh}\,\Theta}{\Theta} \approx 1 \qquad \frac{\mathrm{th}\,\Theta/2}{\Theta/2} \approx 1$$

ZA EE VODOVE $l < 200$ km

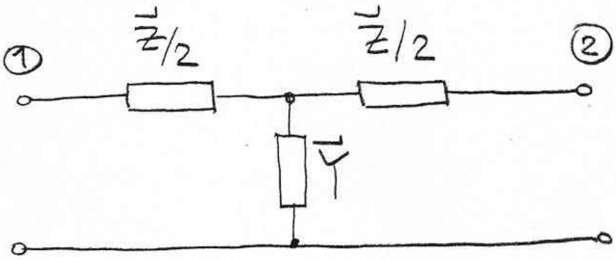
VELIČINE ELEMENATA PRIBLIŽNOG Π-MODELA VODA

$$\vec{Z}_\Pi = \vec{Z} = \vec{Z}_1 \cdot l$$
$$\frac{\vec{Y}_\Pi}{2} = \frac{\vec{Y}}{2} = \frac{\vec{Y}_1}{2} l$$



VELIČINE ELEMENATA PRIBLIŽNOG T-MODELA VODA

$$\vec{Y}_T = \vec{Y} = \vec{Y}_1 \cdot l$$
$$\frac{\vec{Z}_T}{2} = \frac{\vec{Z}}{2} = \frac{\vec{Z}_1}{2} l$$



TOČNOST PRIBLIŽNIH MODELA
ZA VODOVE DUŽINE $l < 200$ km GREŠKA $\Delta < 0{,}5\%$.

$$\frac{\mathrm{sh}\,\Theta}{\Theta} \approx 1\angle 0^\circ \qquad \frac{\mathrm{th}\,\Theta/2}{\Theta/2} \approx 1\angle 0^\circ$$

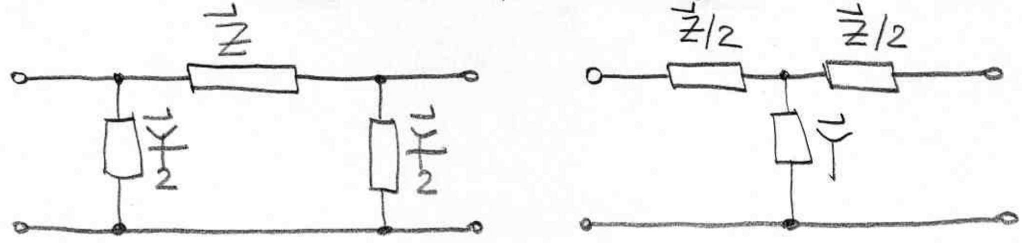
ZA EE VODOVE $l < 200$ km

AKO SU EE VODOVI $l > 200$ km , TREBA UZETI U OBZIR

- KOREKCIJSKE FAKTORE S REALNOM VRIJEDNOSTI
- EE VOD RASTAVITI NA LANAC ČETVEROPOLA SVAKI POJEDINAČNO $l' < 200$ km

DALJNJA ZANEMARENJA U NADOMJESNIM MODELIMA EE VODOVA

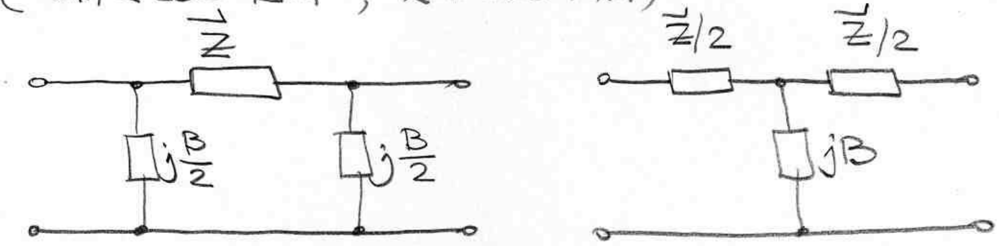
- VODOVI VRLO VISOKOG NAPONA – KONSTANTE R, L, C, G



$\vec{Z}=R+jX$

$\vec{Y}=G+jB$

- VODOVI VISOKOG NAPONA – KONSTANTE R, L, C
  ($U_m < 200$ km , $l < 200$ km)

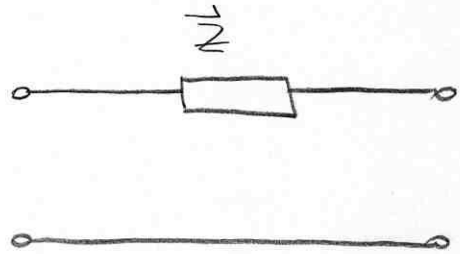


$\vec{Z}=R+jX$

$\vec{Y}=jB$

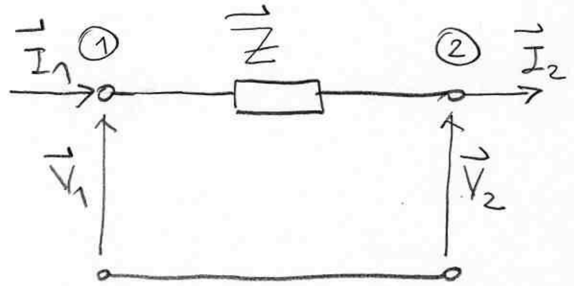
$G \cong 0$

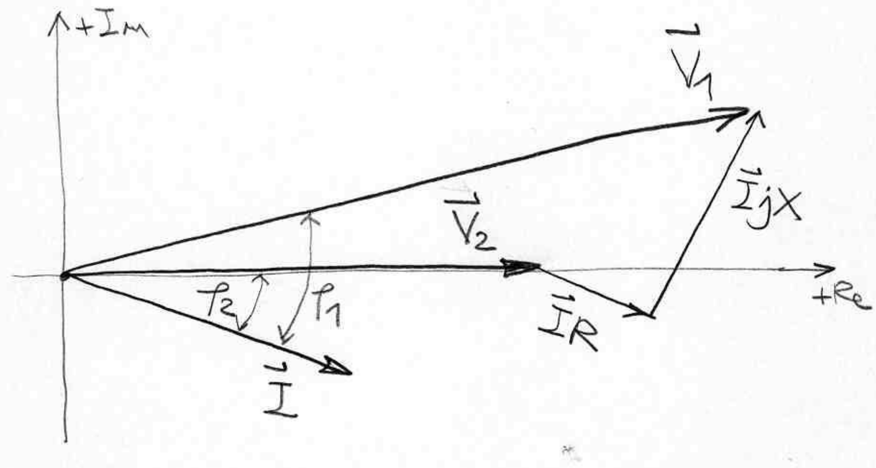
- VODOVI SREDNJEG I NISKOG NAPONA – KONSTANTE R, L



$\vec{Z}=R+jX$

$G \cong 0 \quad C \cong 0$





$\vec{I}_1=\vec{I}_2=\vec{I}$

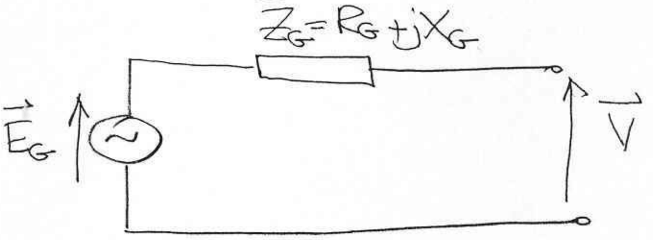
$\vec{V}_1=\vec{V}_2+\vec{I}\vec{Z}$

$\vec{Z}=R+jX$

6.6 NADOMJESNI MODELI TROFAZNIH SINKRONIH GENERATORA

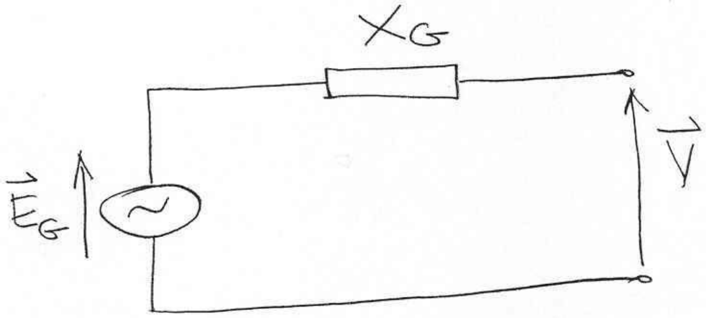
- MATEMATIČKO MODELIRANJE U STACIONARNOM POGONU I PRIJELAZNOM STANJU – SUSTAV JEDNADŽBI (PARKOVE KOMPONENTE)
  - 6 NAPONSKIH JEDNADŽBI
  - 6 JEDNADŽBI ZA MAGNETSKE TOKOVE
  - 1 DINAMIČKA JEDNADŽBA ROTORA

- NADOMJESNI MODEL SINKRONOG GENERATORA



$R_G \ll X_G$ (3-10% X_G)

R_G SE UZIMA U OBZIR SAMO KOD RAČUNANJA UDARNIH STRUJA KS.



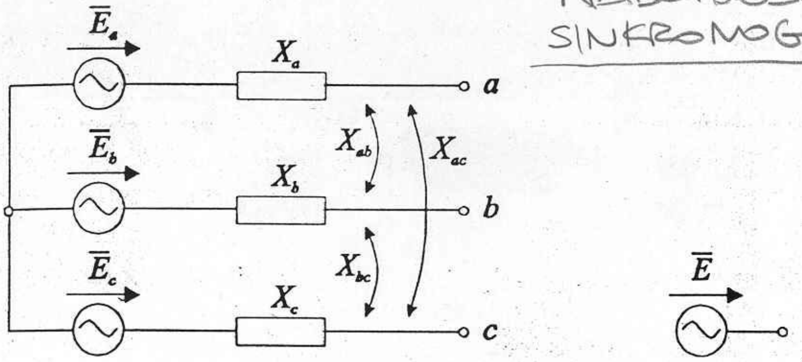
X_G – REAKTANCIJA GENERATORA

E_G – ELEKTROMOTORNA SILA GENERATORA

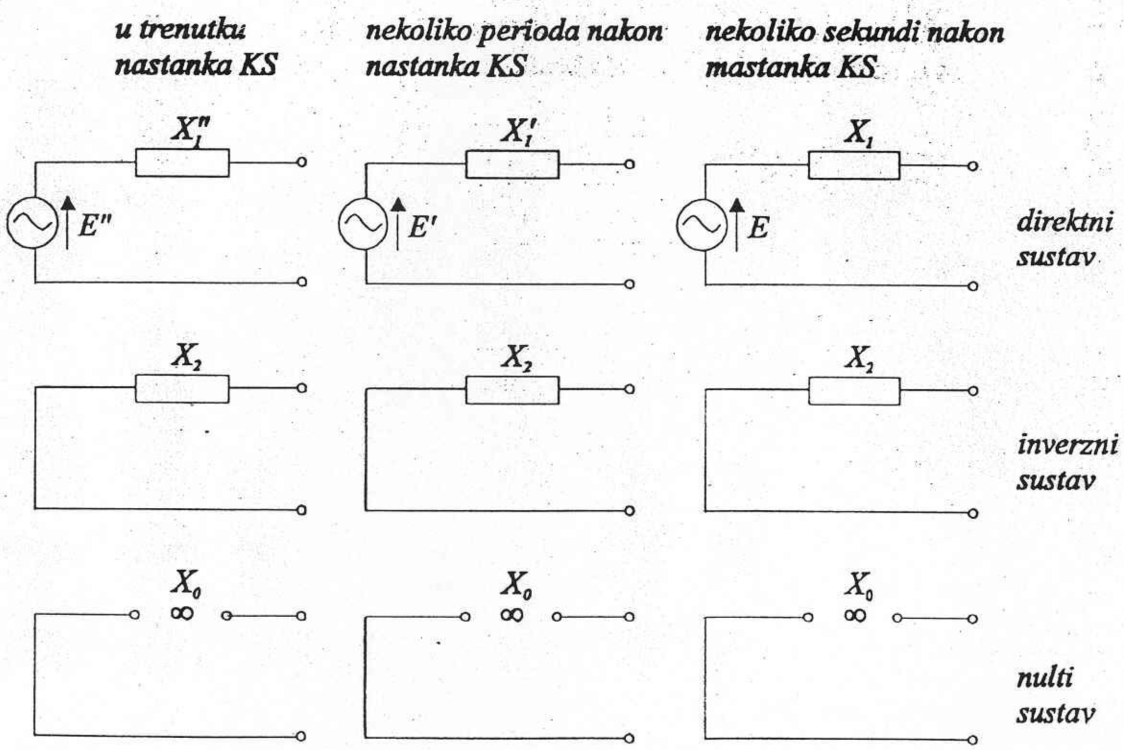
$\left.\begin{matrix} X_G \\ E_G \end{matrix}\right\}$ RAZLIČITE VRIJEDNOSTI ZA
- RAZLIČITE STRUJE PRIJELAZNE POJAVE
- RAZLIČITE VRSTE ANALIZA

ZA SVAKU VRSTU ANALIZE POTREBNO JE ODREDITI REAKTANCIJU GENERATORA, TE ONDA IZ VEKTORSKOG DIJAGRAMA NAPONA ODREDITI ELEKTROMOTORNU SILU GENERATORA $\vec{E}_G$.

NADOMJESNE SHEME SINKRONOG GENERATORA



a) trofazna shema *b) jednopolna shema*



c) jednofazne sheme

ELEKTROMOTORNA SILA	REAKTANCIJA	POGONSKI SLUČAJ
DIREKTNI SUSTAV $\vec{E}''$ $\vec{E}'$ $\vec{E}$	X_d'', X_q'' $X_d', X_q' = X_q$ X_d, X_q	I_k'' POČETAK KS I_k' DINAMIČKA STABILNOST I SKLOP I_k TRAJNA STRUJA KS
INVERZNI SUSTAV $\vec{E}_2 = 0$	$X_2 = \frac{X_d'' + X_q''}{2}$	NESIMETRIČNO OPTEREĆENJE
NULTI SUSTAV $\vec{E}_0 = 0$	$X_0 = \frac{1}{3} \ldots\ldots \frac{1}{6} X_d''$	

- TRI KARAKTERISTIČNA STANJA PRIJELAZNE POJAVE:
  - POČETNI (SUBTRANZIJENTNI) TRENUTAK

    X_d'', X_q'' POČETNA (SUBTRANZIJENTNA) REAKTANCIJA

    $\vec{E}''$ ELEKTROMOTORNA SILA IZA POČETNE REAKTANCIJE (SUBTRANZIJENTNA EMS)
  - PRIJELAZNO (TRANZIJENTNO) RAZDOBLJE

    X_d', X_q' PRIJELAZNA (TRANZIJENTNA) REAKTANCIJA

    $\vec{E}'$ ELEKTROMOTORNA SILA IZA PRIJELAZNE REAKTANCIJE (TRANZIJENTNA EMS)
  - TRAJNO RAZDOBLJE

    X_d, X_q SINKRONA REAKTANCIJA

    $\vec{E}$ ELEKTROMOTORNA SILA IZA SINKRONE REAKTANCIJE (SINKRONA EMS)

- BROJČANE VRIJEDNOSTI REAKTANCIJA

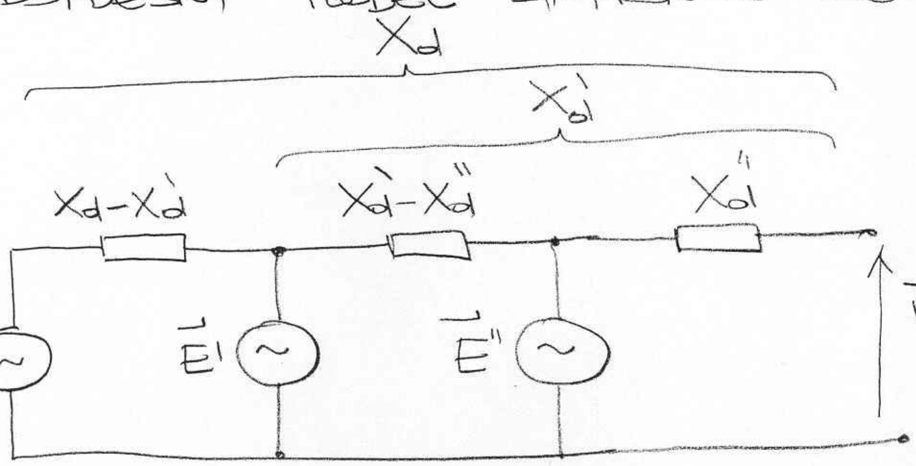
  APSOLUTNE $X\ (\Omega)$

  RELATIVNE $x = X \dfrac{S_n}{U_n^2}$

  $$X = \frac{x\%}{100} \frac{U_n^2}{S_n}$$

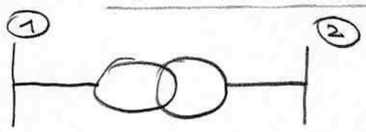
  $$X_d > X_d' > X_d''$$

- NADOMJESNI MODEL SINKRONOG GENERATORA



6.7 NADOMJESNI MODELI ENERGETSKIH TRANSFORMATORA

1. DVONAMOTNI TROFAZNI ENERGETSKI TRANSFORMATORI

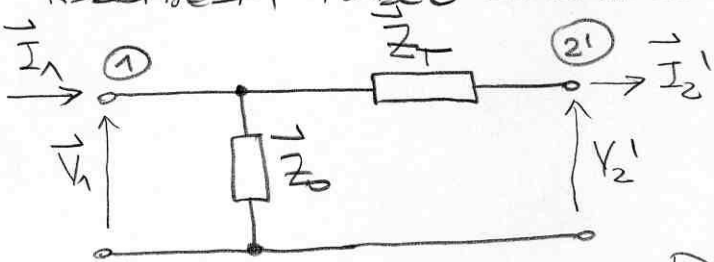


U_{n1} (kV) U_{n2} (kV) S_n (MVA)

I_{n1} (A) I_{n2} (A) $t_n = \frac{U_{n1}}{U_{n2}}$

$u_k\%$, P_{Cun} (kW) $i_0\%$ P_{Fen} (kW)

NADOMJESNI MODEL DIREKTNOG SUSTAVA:

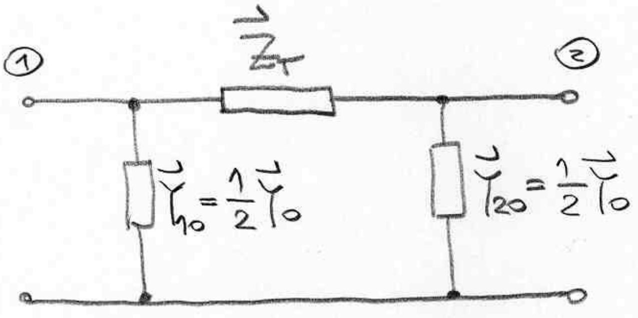


Γ NADOMJESNI MODEL

$$\vec{Z}_T = R_T + jX_T \qquad R_T = \frac{P_{Cu} U_{n1}^2}{S_n^2} \qquad X_T = \frac{U_{n1}^2}{S_n}\sqrt{u_k^2 - \left(\frac{P_{Cu}}{S_n}\right)^2}$$

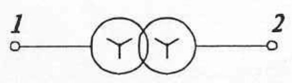
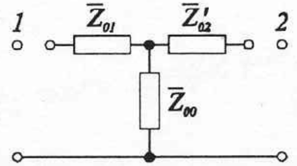
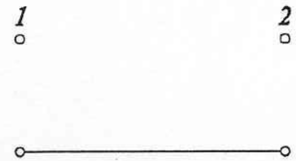
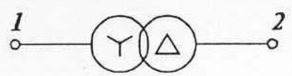
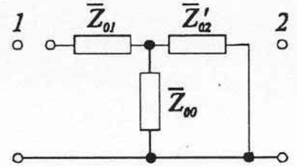
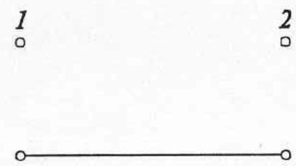
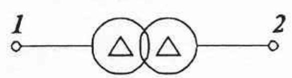
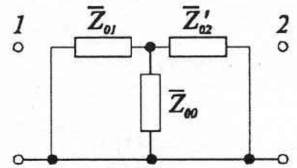
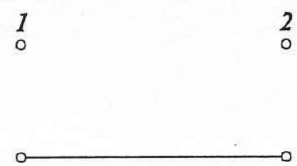
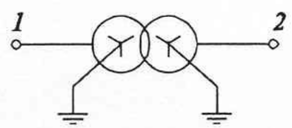
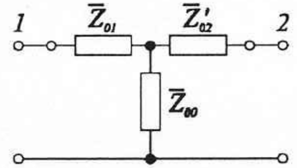
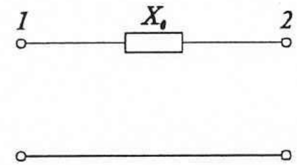
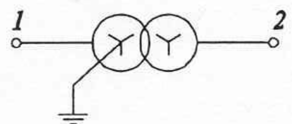
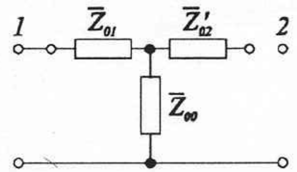
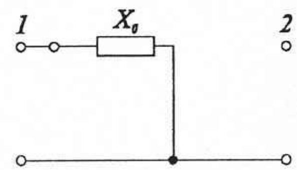
$$\vec{Z}_0 = R_0 + jX_0$$

$$\vec{Y}_0 = \frac{1}{\vec{Z}_0} = G_0 - jB_0 \qquad G_0 = \frac{P_{Fe}}{U_{n1}^2} \qquad B_0 = \frac{S_n}{U_{n1}^2}\sqrt{i_0^2 - \left(\frac{P_{Fe}}{S_n}\right)^2}$$

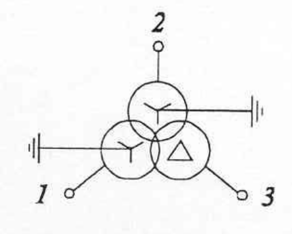
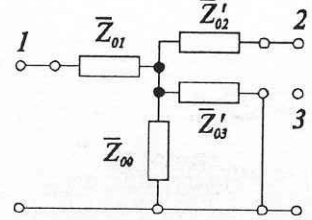
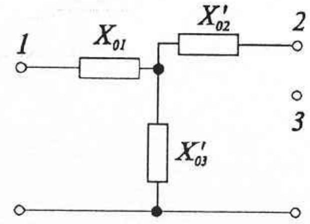
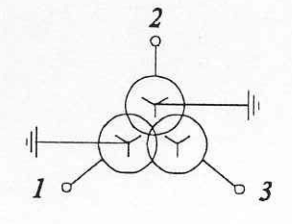
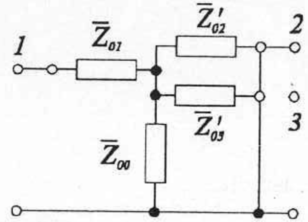
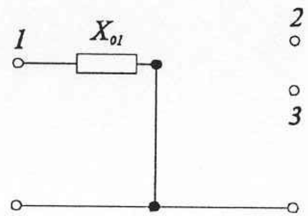
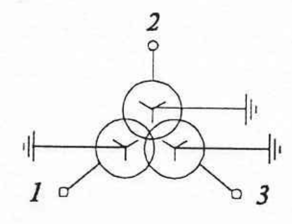
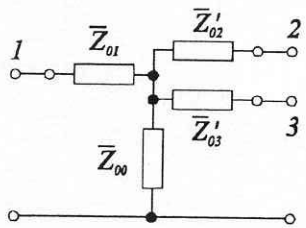
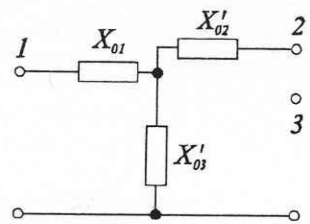


Π NADOMJESNI MODEL

NADOMJESNI MODEL NULTOG SUSTAVA

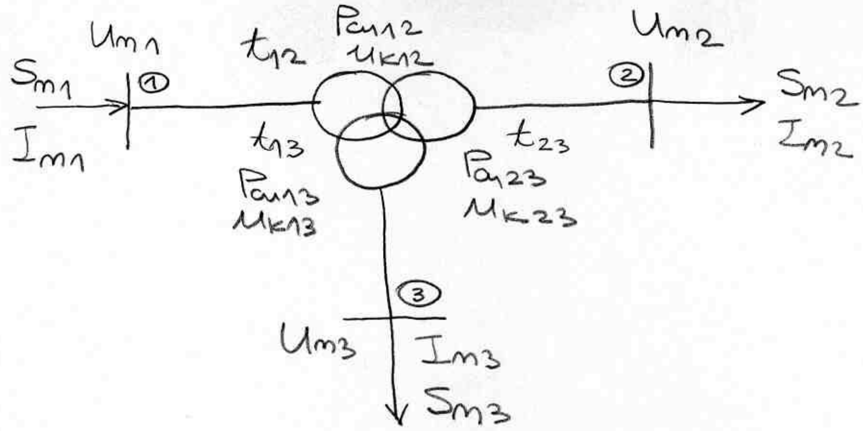
	Spoj	Kompletna nadomjesna shema	Nulte impedancije	Shema transformatora u mreži (sa zanemarenjima)	Nulta reaktancija
a			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}'_{02}=\overline{Z}'_2$ $\overline{Z}_{00}$ VELIKO		$X_0=\infty$
b			—||—		—||—
c			—||—		—||—
d			—||—		$X_0=X1+X2=X\doteq\|\overline{Z}\|$
e	Trofazni transf. 		$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}'_{02}=\overline{Z}'_2$ $\overline{Z}_{00}=8\ldots15\,\overline{Z}_1$		$X_0\doteq10\,X\doteq10\|\overline{Z}\|$

Sl. 7.6a-e - Nadomjesne sheme nultog sustava dvonamotnog transformatora

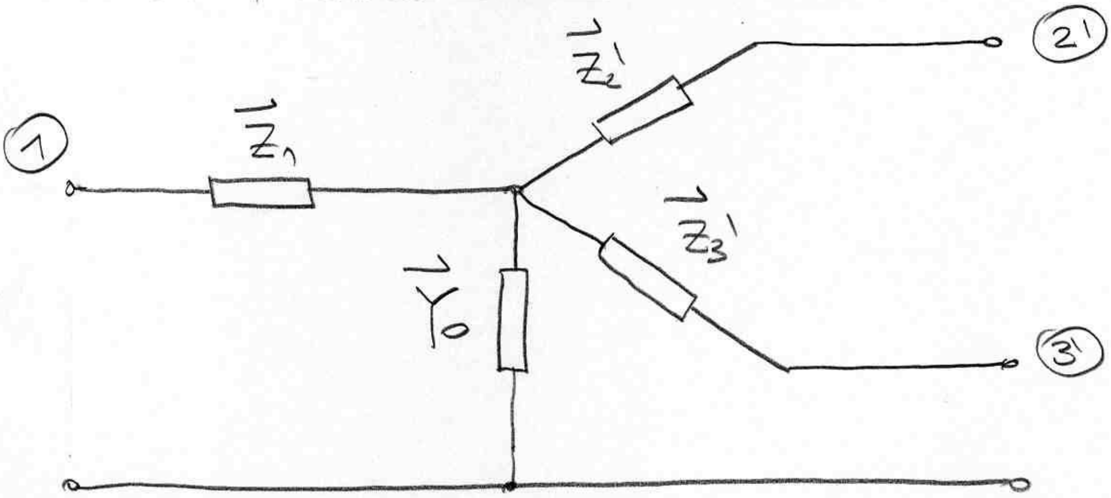
	Spoj	Kompletna nadomjesna shema	Nulte impedancije	Shema transformatora u mreži (sa zanemarenjima)	Nulta reaktancija
e			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}'_{02}=\overline{Z}'_2$ $\overline{Z}'_{03}=\overline{Z}'_3$ $\overline{Z}_{00}$ VELIKO		$X_0=X_1\doteq\lvert\overline{Z}_1\rvert$ $X'_{02}=X'_2\doteq\lvert\overline{Z}'_2\rvert$ $X'_{03}=X'_3\doteq\lvert\overline{Z}'_3\rvert$
f			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}'_{02}=\overline{Z}'_2$ $\overline{Z}'_{03}=\overline{Z}'_3$ $\overline{Z}_{00}$ VELIKO		$X_0=X_1+\frac{X'_2X'_3}{X'_2+X'_3}=$ $\doteq\overline{Z}_1+\frac{\lvert\overline{Z}'_2\rvert\,\lvert\overline{Z}'_3\rvert}{\lvert\overline{Z}'_2\rvert+\lvert\overline{Z}'_3\rvert}$
g			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}'_{02}=\overline{Z}'_2$ $\overline{Z}'_3=\overline{Z}'_3$ $\overline{Z}_{00}$ VELIKO		$X_{01}=X_1\doteq\lvert\overline{Z}_1\rvert$ $X'_{02}=X'_2\doteq\lvert\overline{Z}'_2\rvert$ $X'_{03}=X'_3\doteq\lvert\overline{Z}'_3\rvert$

Nadomjesne sheme nultog sustava tronamotnog transformatora

2. TRONAMOTNI TROFAZNI ENERGETSKI TRANSFORMATORI



NADOMJESNI MODEL DIREKTNOG SUSTAVA :



- PARAMETRI UZDUŽNIH GRANA SE ODREĐUJU IZ POKUSA KS IZMEĐU PAROVA NAMOTA UZ ZANEMARENJE, $P_{cu}=P_K$ U ODNOSU NA S_M (PRERAČUNAVANJE NA U_{m1} ①)

$$R_{12}=\frac{P_{cu12}\,U_{m1}^2}{S_{12}^2}\ (\Omega) \qquad \vec{Z}_{12}=R_{12}+jX_{12}\ (\Omega)$$

$$X_{12}=\frac{u_{k12}\,U_{m1}^2}{S_{12}}\ (\Omega)$$

$$R_{13}=\frac{P_{cu13}\,U_{m1}^2}{S_{13}^2}\ (\Omega) \qquad \vec{Z}_{13}=R_{13}+jX_{13}\ (\Omega)$$

$$X_{13}=\frac{u_{k13}\,U_{m1}^2}{S_{13}}\ (\Omega)$$

$$R_{23}=\frac{P_{cu23}\,U_{m1}^2}{S_{23}^2}\ (\Omega) \qquad \vec{Z}_{23}=R_{23}+jX_{23}\ (\Omega)$$

$$X_{23}=\frac{u_{k23}\,U_{m1}^2}{S_{23}}\ (\Omega)$$

S_{12} = MANJA VRIJEDNOST OD (S_{m1}, S_{m2})
S_{13} = —II— (S_{m1}, S_{m3})
S_{23} = —II— (S_{m2}, S_{m3})

PREMA JEDNOFAZNOM NADOMJESNOM MODELU:

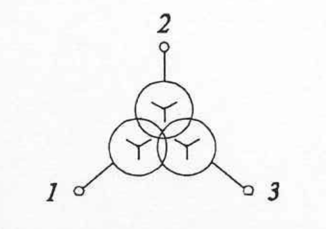
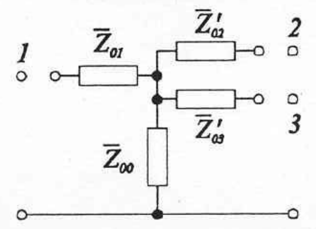
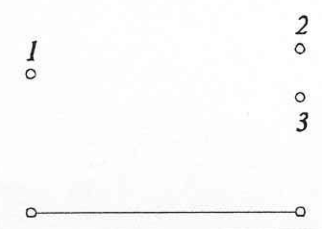
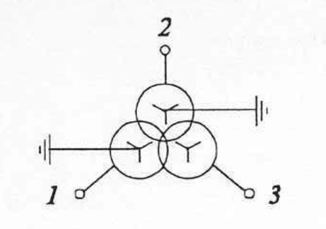
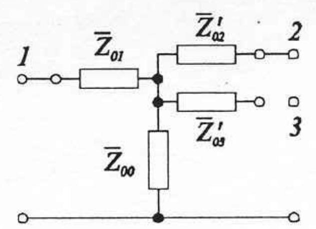
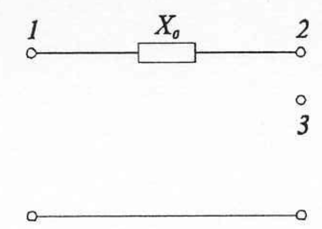
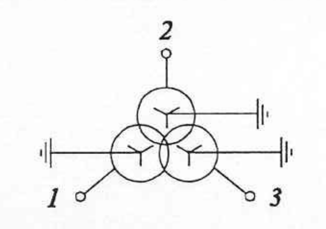
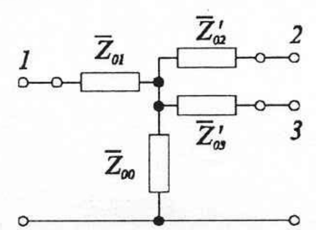
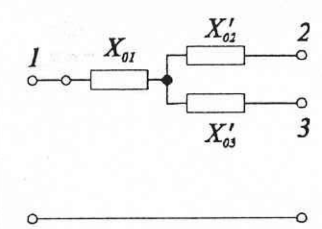
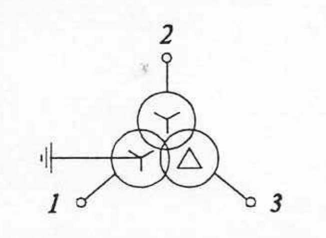
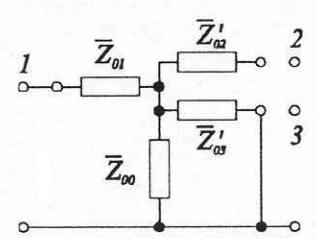
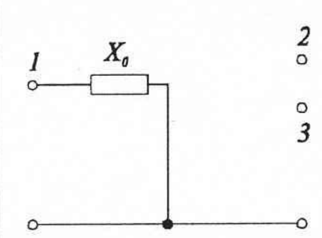
$$\left.\begin{aligned}\vec{Z}_{12}&=\vec{Z}_1+\vec{Z}_2'\\ \vec{Z}_{13}&=\vec{Z}_1+\vec{Z}_3'\\ \vec{Z}_{23}&=\vec{Z}_2'+\vec{Z}_3'\end{aligned}\right\} \qquad \boxed{\begin{aligned}\vec{Z}_1&=\frac{1}{2}\left(\vec{Z}_{12}+\vec{Z}_{13}-\vec{Z}_{23}\right)\\ \vec{Z}_2'&=\frac{1}{2}\left(\vec{Z}_{12}+\vec{Z}_{23}-\vec{Z}_{13}\right)\\ \vec{Z}_3'&=\frac{1}{2}\left(\vec{Z}_{13}+\vec{Z}_{23}-\vec{Z}_{12}\right)\end{aligned}}$$

$$\boxed{\vec{Y}_0=G_0+jB_0}$$

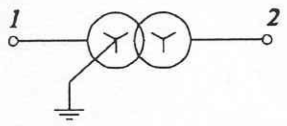
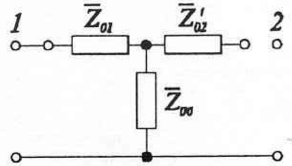
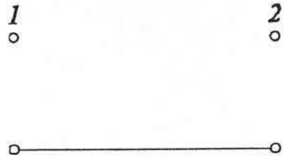
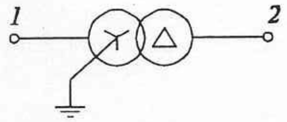
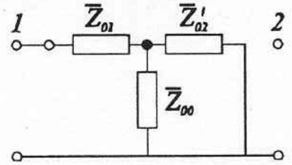
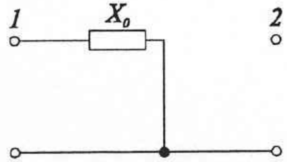
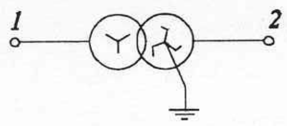
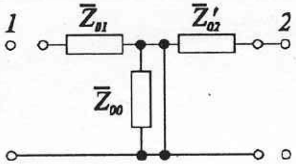
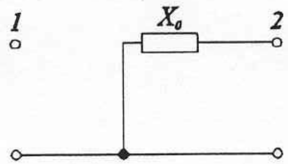
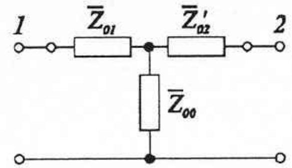
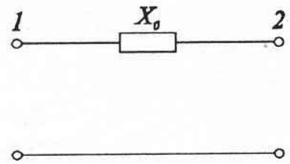
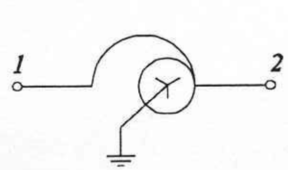
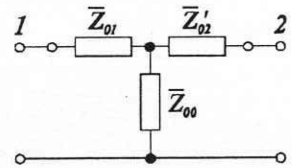
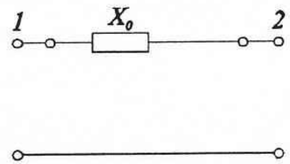
ADMITANCIJA POPREČNE GRANE (POKUS PH) ISTE RELACIJE KAO I ZA DVONAMOTNI EN. TR.

NADOMJESNI MODELI TRONAMOTNIH ENERGETSKIH TRANSFORMATORA U NULTOM SUSTAVU

- NADOMJESNI MODEL TRONAMOTNOG EN. TR. U NULTOM SUSTAVU – JEDNAKI KAO U DIREKTNOM SUSTAVU AKO SE MOGU RAZVITI NULTE STRUJE, A ŠTO OVISI O
  - VRSTI SPOJA FAZNIH NAMOTA
  - NAČINU UZEMLJENJA ZVJEZDIŠTA

	Spoj	Kompletna nadomjesna shema	Nulte impedancije	Shema transformatora u mreži (sa zanemarenjima)	Nulta reaktancija
a			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}_{02}'=\overline{Z}_2'$ $\overline{Z}_3'=\overline{Z}_3'$ $\overline{Z}_{00}$ VELIKO		$X_0=\infty$
b			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}_{02}'=\overline{Z}_2'$ $\overline{Z}_3'=\overline{Z}_3'$ $\overline{Z}_{00}$ VELIKO		$X_0=X_1+X_2'=X_{12}=$ $\doteq\lvert\overline{Z}_{12}\rvert$
c			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}_{02}'=\overline{Z}_2$ $\overline{Z}_3'=\overline{Z}_3'$ $\overline{Z}_{00}$ VELIKO		$X_{01}=X_1\doteq\lvert\overline{Z}_1\rvert$ $X_{02}'=X_2'\doteq\lvert\overline{Z}_2'\rvert$ $X_{03}'=X_3'\doteq\lvert\overline{Z}_3'\rvert$
d			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}_{02}'=\overline{Z}_2'$ $\overline{Z}_{03}'=\overline{Z}_3'$ $\overline{Z}_{00}$ VELIKO		$X_0=X_1+X_3'=X_{13}=$ $\doteq\lvert\overline{Z}_{13}\rvert$

Nadomjesne sheme nultog sustava tronamotnog transformatora

	Spoj	Kompletna nadomjesna shema	Nulte impedancije	Shema transformatora u mreži (sa zanemarenjima)	Nulta reaktancija
f	*3 jednofazna transformatora* 		$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}'_{02}=\overline{Z}'_2$ $\overline{Z}_{00}$ *VELIKO*		$X_0=\infty$
g			—//—		$X_0=X\doteq\lvert\overline{Z}\rvert$
h			$\overline{Z}_{01}\doteq\overline{Z}_1$ $\overline{Z}'_{02}=0{,}1\,\overline{Z}$ $\overline{Z}_{00}$ *VELIKO*		$X_0\doteq 0{,}1\,X\doteq 0{,}1\,\lvert\overline{Z}\rvert$
i			*za trofazni* $\overline{Z}_{01}+\overline{Z}'_{02}=10\,\overline{Z}$ *za 3 jedno fazna* $\overline{Z}_{01}+\overline{Z}'_{02}=\infty$ $\overline{Z}_{00}$ *VELIKO*		*za trofazni* $X_0\doteq 10\,X$ *za 3 jednofazna* $X_0=\infty$
j			$\overline{Z}_{01}=\overline{Z}_1$ $\overline{Z}'_{02}=\overline{Z}'_2$ $\overline{Z}_{00}$ *VELIKO*		$X_0=X\doteq\lvert\overline{Z}\rvert$

Nadomjesne sheme nultog sustava dvonamotnog transformatora (nastavak) i autotransformatora

LITERATURA:

1. MARIJA I KARLO OŽEGOVIĆ: ELEKTRIČNE ENERGETSKE MREŽE I, II FESB Split