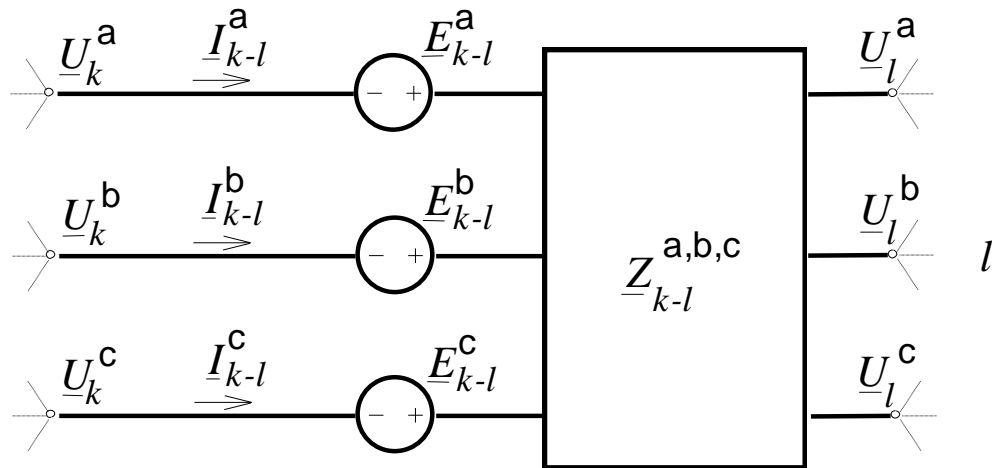


ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

Импеданциска форма



$$\underline{U}_{k-l}^a = \underline{U}_k^a - \underline{U}_l^a; \quad \underline{U}_{k-l}^b = \underline{U}_k^b - \underline{U}_l^b; \quad \underline{U}_{k-l}^c = \underline{U}_k^c - \underline{U}_l^c$$

$$\underline{U}_{k-l}^a = \underline{U}_k^a - \underline{U}_l^a$$

$$\underline{U}_{k-l}^b = \underline{U}_k^b - \underline{U}_l^b$$

$$\underline{U}_{k-l}^c = \underline{U}_k^c - \underline{U}_l^c$$

$$\underline{Z}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{Z}_{k-l}^{aa} & \underline{Z}_{k-l}^{ab} & \underline{Z}_{k-l}^{ac} \\ \underline{Z}_{k-l}^{ba} & \underline{Z}_{k-l}^{bb} & \underline{Z}_{k-l}^{bc} \\ \underline{Z}_{k-l}^{ca} & \underline{Z}_{k-l}^{cb} & \underline{Z}_{k-l}^{cc} \end{bmatrix}$$

$$\underline{U}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{U}_{k-l}^a \\ \underline{U}_{k-l}^b \\ \underline{U}_{k-l}^c \end{bmatrix}$$

$$\underline{E}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{E}_{k-l}^a \\ \underline{E}_{k-l}^b \\ \underline{E}_{k-l}^c \end{bmatrix}$$

$$\underline{U}_{k-l}^a + \underline{E}_{k-l}^a = \underline{Z}_{k-l}^{aa} \cdot \underline{I}_{k-l}^a + \underline{Z}_{k-l}^{ab} \cdot \underline{I}_{k-l}^b + \underline{Z}_{k-l}^{ac} \cdot \underline{I}_{k-l}^c$$

$$\underline{U}_{k-l}^b + \underline{E}_{k-l}^b = \underline{Z}_{k-l}^{ba} \cdot \underline{I}_{k-l}^a + \underline{Z}_{k-l}^{bb} \cdot \underline{I}_{k-l}^b + \underline{Z}_{k-l}^{bc} \cdot \underline{I}_{k-l}^c$$

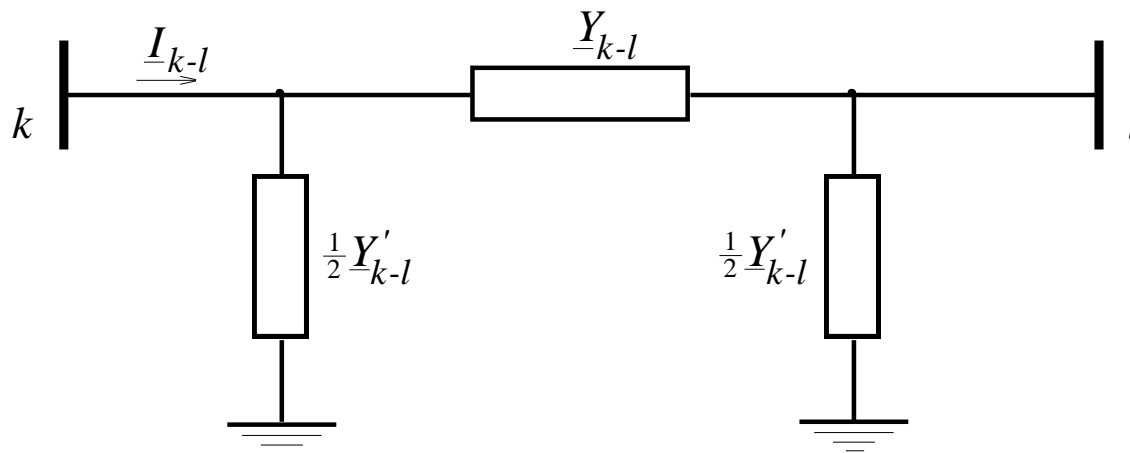
$$\underline{U}_{k-l}^c + \underline{E}_{k-l}^c = \underline{Z}_{k-l}^{ca} \cdot \underline{I}_{k-l}^a + \underline{Z}_{k-l}^{cb} \cdot \underline{I}_{k-l}^b + \underline{Z}_{k-l}^{cc} \cdot \underline{I}_{k-l}^c$$

$$\underline{I}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{I}_{k-l}^a \\ \underline{I}_{k-l}^b \\ \underline{I}_{k-l}^c \end{bmatrix}$$

$$\underline{U}_{k-l}^{a,b,c} + \underline{E}_{k-l}^{a,b,c} = \underline{Z}_{k-l}^{a,b,c} \cdot \underline{I}_{k-l}^{a,b,c}$$

ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

Претставување на водови



\underline{Y}_{k-l} вкупна надолжна адмитанција на водот за директен редослед

\underline{Y}'_{k-l} вкупна напречна адмитанција на водот за директен редослед

ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

Импеданциска форма

Трифазната гранка $k-l$ е индуктивно спрегната со трифазната гранка $g-h$

$$\underline{Z}_{k-l,g-h}^{a,b,c} = \begin{bmatrix} \underline{Z}_{k-l,g-h}^{aa} & \underline{Z}_{k-l,g-h}^{ab} & \underline{Z}_{k-l,g-h}^{ac} \\ \underline{Z}_{k-l,g-h}^{ba} & \underline{Z}_{k-l,g-h}^{bb} & \underline{Z}_{k-l,g-h}^{bc} \\ \underline{Z}_{k-l,g-h}^{ca} & \underline{Z}_{k-l,g-h}^{cb} & \underline{Z}_{k-l,g-h}^{cc} \end{bmatrix} \quad \underline{U}_{k-l}^{a,b,c} + \underline{E}_{k-l}^{a,b,c} = \underline{Z}_{k-l}^{a,b,c} \cdot \underline{I}_{k-l}^{a,b,c} + \underline{Z}_{k-l,g-h}^{a,b,c} \cdot \underline{I}_{g-h}^{a,b,c}$$

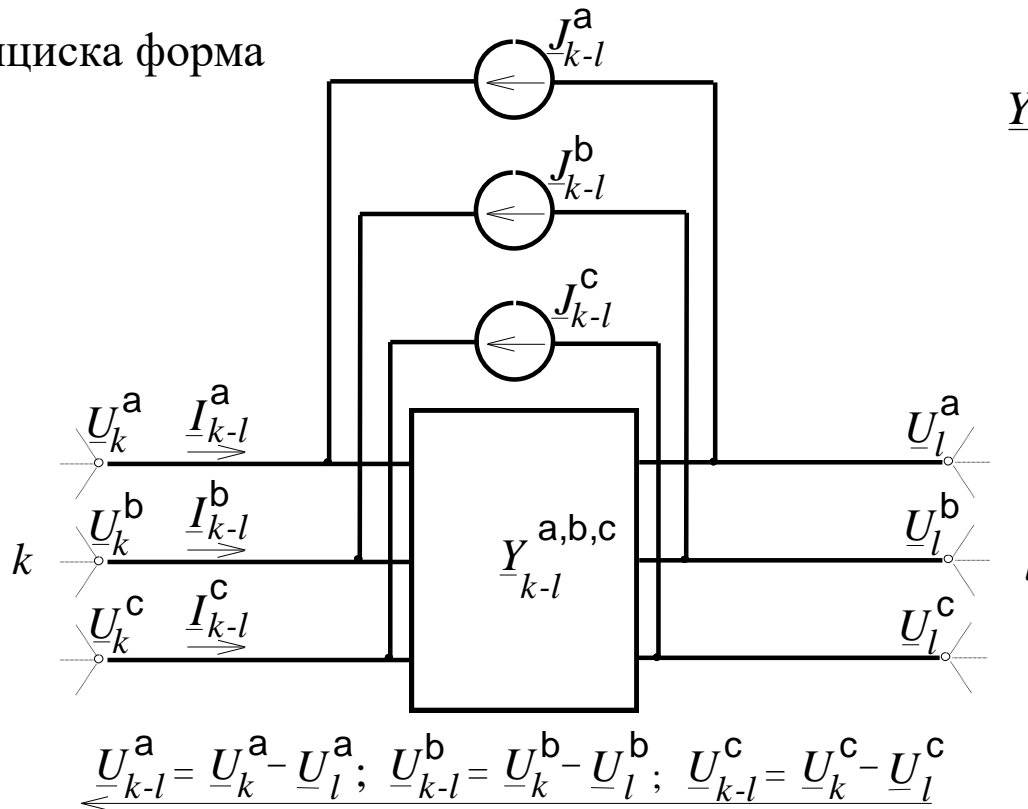
$$\left[\underline{U}_{k-l}^{a,b,c} \right] + \left[\underline{E}_{k-l}^{a,b,c} \right] = \left[\underline{Z}_{k-l}^{a,b,c} \right] \cdot \left[\underline{I}_{k-l}^{a,b,c} \right]$$

$\left[\underline{Z}_{k-l}^{a,b,c} \right]$ Матрица на импеданции на гранката

- дијагонални елементи (субматрици 3×3) $\underline{Z}_{k-l}^{a,b,c}$
- вондијагонални елементи (субматрици 3×3) $\underline{Z}_{k-l,g-h}^{a,b,c}$
- во систем со ng гранки, бројот на равенки е $3 \times ng$

ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

Адмитанциска форма



$$\underline{Y}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{Y}_{k-l}^{aa} & \underline{Y}_{k-l}^{ab} & \underline{Y}_{k-l}^{ac} \\ \underline{Y}_{k-l}^{ba} & \underline{Y}_{k-l}^{bb} & \underline{Y}_{k-l}^{bc} \\ \underline{Y}_{k-l}^{ca} & \underline{Y}_{k-l}^{cb} & \underline{Y}_{k-l}^{cc} \end{bmatrix}$$

$$\underline{J}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{J}_{k-l}^a \\ \underline{J}_{k-l}^b \\ \underline{J}_{k-l}^c \end{bmatrix}$$

$$\underline{I}_{k-l}^a + \underline{J}_{k-l}^a = \underline{Y}_{k-l}^{aa} \cdot \underline{U}_{k-l}^a + \underline{Y}_{k-l}^{ab} \cdot \underline{U}_{k-l}^b + \underline{Y}_{k-l}^{ac} \cdot \underline{U}_{k-l}^c$$

$$\underline{I}_{k-l}^b + \underline{J}_{k-l}^b = \underline{Y}_{k-l}^{ba} \cdot \underline{U}_{k-l}^a + \underline{Y}_{k-l}^{bb} \cdot \underline{U}_{k-l}^b + \underline{Y}_{k-l}^{bc} \cdot \underline{U}_{k-l}^c$$

$$\underline{I}_{k-l}^c + \underline{J}_{k-l}^c = \underline{Y}_{k-l}^{ca} \cdot \underline{U}_{k-l}^a + \underline{Y}_{k-l}^{cb} \cdot \underline{U}_{k-l}^b + \underline{Y}_{k-l}^{cc} \cdot \underline{U}_{k-l}^c$$

$$\underline{Y}_{k-l}^{a,b,c} = \left(\underline{Z}_{k-l}^{a,b,c} \right)^{-1}$$

$$\underline{J}_{k-l}^{a,b,c} = -\underline{Y}_{k-l}^{a,b,c} \cdot \underline{E}_{k-l}^{a,b,c}$$

$$\underline{I}_{k-l}^{a,b,c} + \underline{J}_{k-l}^{a,b,c} = \underline{Y}_{k-l}^{a,b,c} \cdot \underline{U}_{k-l}^{a,b,c}$$

ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

Адмитанциска форма

Трифазната гранка $k-l$ е индуктивно спрегната со трифазната гранка $g-h$

$$\underline{Y}_{k-l,g-h}^{a,b,c} = \begin{bmatrix} \underline{Y}_{k-l,g-h}^{aa} & \underline{Y}_{k-l,g-h}^{ab} & \underline{Y}_{k-l,g-h}^{ac} \\ \underline{Y}_{k-l,g-h}^{ba} & \underline{Y}_{k-l,g-h}^{bb} & \underline{Y}_{k-l,g-h}^{bc} \\ \underline{Y}_{k-l,g-h}^{ca} & \underline{Y}_{k-l,g-h}^{cb} & \underline{Y}_{k-l,g-h}^{cc} \end{bmatrix}$$
$$\underline{I}_{k-l}^{a,b,c} + \underline{J}_{k-l}^{a,b,c} = \underline{Y}_{k-l}^{a,b,c} \cdot \underline{U}_{k-l}^{a,b,c} + \underline{Y}_{k-l,g-h}^{a,b,c} \cdot \underline{U}_{g-h}^{a,b,c}$$

$$\left[\underline{I}_{k-l}^{a,b,c} \right] + \left[\underline{J}_{k-l}^{a,b,c} \right] = \left[\underline{Y}_{k-l}^{a,b,c} \right] \cdot \left[\underline{U}_{k-l}^{a,b,c} \right]$$

$\left[\underline{Y}_{k-l}^{a,b,c} \right]$ Матрица на адмитанција на гранката

- дијагонални елементи (субматрици 3×3) $\underline{Y}_{k-l}^{a,b,c}$

- вондијагонални елементи (субматрици 3×3) $\underline{Y}_{k-l,g-h}^{a,b,c}$

- во систем со ng гранки, бројот на равенки е $3 \times ng$

$$\left[\underline{Y}_{k-l}^{a,b,c} \right] = \left(\left[\underline{Z}_{k-l}^{a,b,c} \right] \right)^{-1}$$

$$\left[\underline{J}_{k-l}^{a,b,c} \right] = - \left[\underline{Y}_{k-l}^{a,b,c} \right] \cdot \left[\underline{E}_{k-l}^{a,b,c} \right]$$

ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

Равенки на урамнотежени гранки и системи

Водови и трансформатори

$$\underline{Z}_{k-l}^{aa} = \underline{Z}_{k-l}^{bb} = \underline{Z}_{k-l}^{cc} = \underline{Z}_{k-l}^s$$

$$\underline{Z}_{k-l}^{ab} = \underline{Z}_{k-l}^{bc} = \underline{Z}_{k-l}^{ca} = \underline{Z}_{k-l}^{ac} = \underline{Z}_{k-l}^{cb} = \underline{Z}_{k-l}^{ba} = \underline{Z}_{k-l}^m$$

$$\underline{Z}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{Z}_{k-l}^s & \underline{Z}_{k-l}^m & \underline{Z}_{k-l}^m \\ \underline{Z}_{k-l}^m & \underline{Z}_{k-l}^s & \underline{Z}_{k-l}^m \\ \underline{Z}_{k-l}^m & \underline{Z}_{k-l}^m & \underline{Z}_{k-l}^s \end{bmatrix}$$

$$\underline{E}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{E}_{k-l}^a \\ \underline{E}_{k-l}^b \\ \underline{E}_{k-l}^c \end{bmatrix} = \begin{bmatrix} \underline{E}_{k-l}^a \\ \underline{a}^2 \cdot \underline{E}_{k-l}^a \\ \underline{a} \cdot \underline{E}_{k-l}^a \end{bmatrix} = \begin{bmatrix} 1 \\ \underline{a}^2 \\ \underline{a} \end{bmatrix} \cdot \underline{E}_{k-l}^a$$

$$\underline{J}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{J}_{k-l}^a \\ \underline{J}_{k-l}^b \\ \underline{J}_{k-l}^c \end{bmatrix} = \begin{bmatrix} \underline{J}_{k-l}^a \\ \underline{a}^2 \cdot \underline{J}_{k-l}^a \\ \underline{a} \cdot \underline{J}_{k-l}^a \end{bmatrix} = \begin{bmatrix} 1 \\ \underline{a}^2 \\ \underline{a} \end{bmatrix} \cdot \underline{J}_{k-l}^a$$

$$\underline{a} = e^{j \frac{2\pi}{3}}$$

Генератори

$$\underline{Z}_{k-l}^{aa} = \underline{Z}_{k-l}^{bb} = \underline{Z}_{k-l}^{cc} = \underline{Z}_{k-l}^s$$

$$\underline{Z}_{k-l}^{ac} = \underline{Z}_{k-l}^{cb} = \underline{Z}_{k-l}^{ba} = \underline{Z}_{k-l}^{m2}$$

$$\underline{Z}_{k-l}^{ab} = \underline{Z}_{k-l}^{bc} = \underline{Z}_{k-l}^{ca} = \underline{Z}_{k-l}^{m1}$$

$$\underline{Z}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{Z}_{k-l}^s & \underline{Z}_{k-l}^{m1} & \underline{Z}_{k-l}^{m2} \\ \underline{Z}_{k-l}^{m2} & \underline{Z}_{k-l}^s & \underline{Z}_{k-l}^{m1} \\ \underline{Z}_{k-l}^{m1} & \underline{Z}_{k-l}^{m2} & \underline{Z}_{k-l}^s \end{bmatrix}$$

$$\underline{U}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{U}_{k-l}^a \\ \underline{U}_{k-l}^b \\ \underline{U}_{k-l}^c \end{bmatrix} = \begin{bmatrix} \underline{U}_{k-l}^a \\ \underline{a}^2 \cdot \underline{U}_{k-l}^a \\ \underline{a} \cdot \underline{U}_{k-l}^a \end{bmatrix} = \begin{bmatrix} 1 \\ \underline{a}^2 \\ \underline{a} \end{bmatrix} \cdot \underline{U}_{k-l}^a$$

$$\underline{I}_{k-l}^{a,b,c} = \begin{bmatrix} \underline{I}_{k-l}^a \\ \underline{I}_{k-l}^b \\ \underline{I}_{k-l}^c \end{bmatrix} = \begin{bmatrix} \underline{I}_{k-l}^a \\ \underline{a}^2 \cdot \underline{I}_{k-l}^a \\ \underline{a} \cdot \underline{I}_{k-l}^a \end{bmatrix} = \begin{bmatrix} 1 \\ \underline{a}^2 \\ \underline{a} \end{bmatrix} \cdot \underline{I}_{k-l}^a$$

ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

Равенки на урамнотежени гранки и системи

Генератори

$$\underline{U}_{k-l}^a + \underline{E}_{k-l}^a = \underline{Z}_{k-l}^s \cdot \underline{I}_{k-l}^a + \underline{Z}_{k-l}^{m1} \cdot \underline{a}^2 \cdot \underline{I}_{k-l}^a + \underline{Z}_{k-l}^{m2} \cdot \underline{a} \cdot \underline{I}_{k-l}^a$$

$$\underline{U}_{k-l}^b + \underline{E}_{k-l}^b = \underline{Z}_{k-l}^{m2} \cdot \underline{a} \cdot \underline{I}_{k-l}^b + \underline{Z}_{k-l}^s \cdot \underline{I}_{k-l}^b + \underline{Z}_{k-l}^{m1} \cdot \underline{a}^2 \cdot \underline{I}_{k-l}^b$$

$$\underline{U}_{k-l}^c + \underline{E}_{k-l}^c = \underline{Z}_{k-l}^{m1} \cdot \underline{a}^2 \cdot \underline{I}_{k-l}^c + \underline{Z}_{k-l}^{m2} \cdot \underline{a} \cdot \underline{I}_{k-l}^c + \underline{Z}_{k-l}^s \cdot \underline{I}_{k-l}^c$$

$$\underline{U}_{k-l}^a + \underline{E}_{k-l}^a = \left(\underline{Z}_{k-l}^s + \underline{a}^2 \cdot \underline{Z}_{k-l}^{m1} + \underline{a} \cdot \underline{Z}_{k-l}^{m2} \right) \cdot \underline{I}_{k-l}^a$$

$$\underline{U}_{k-l}^a + \underline{E}_{k-l}^a = \underline{Z}_{k-l}^{(1)} \cdot \underline{I}_{k-l}^a$$

$$\underline{U}_{k-l}^b + \underline{E}_{k-l}^b = \left(\underline{Z}_{k-l}^s + \underline{a}^2 \cdot \underline{Z}_{k-l}^{m1} + \underline{a} \cdot \underline{Z}_{k-l}^{m2} \right) \cdot \underline{I}_{k-l}^b$$

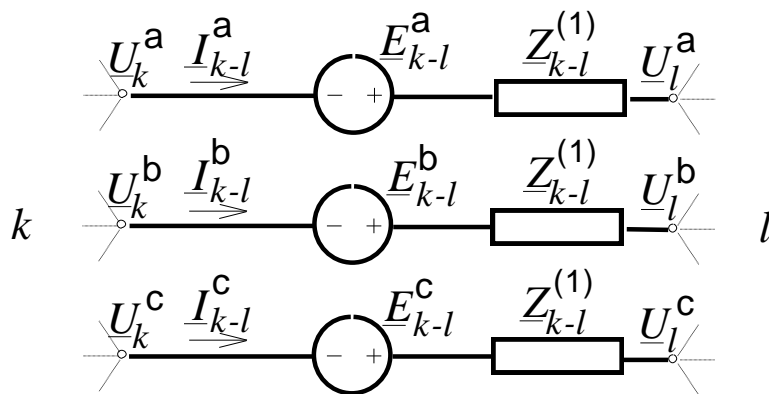
$$\underline{U}_{k-l}^b + \underline{E}_{k-l}^b = \underline{Z}_{k-l}^{(1)} \cdot \underline{I}_{k-l}^b$$

$$\underline{U}_{k-l}^c + \underline{E}_{k-l}^c = \left(\underline{Z}_{k-l}^s + \underline{a}^2 \cdot \underline{Z}_{k-l}^{m1} + \underline{a} \cdot \underline{Z}_{k-l}^{m2} \right) \cdot \underline{I}_{k-l}^c$$

$$\underline{U}_{k-l}^c + \underline{E}_{k-l}^c = \underline{Z}_{k-l}^{(1)} \cdot \underline{I}_{k-l}^c$$

$$\underline{Z}_{k-l}^{(1)} = \underline{Z}_{k-l}^s + \underline{a}^2 \cdot \underline{Z}_{k-l}^{m1} + \underline{a} \cdot \underline{Z}_{k-l}^{m2}$$

$\underline{Z}_{k-l}^{(1)}$ Импеданција на трифазна урамнотежена гранка за директен редослед



Трифазната гранка се разделува на три монофазни гранки помеѓу кои не постои меѓусебна спрега

Во систем со ng гранки треба да се решат три независни системи со ng равенки, што е многу побрзо

ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

Равенки на урамнотежени гранки и системи

Водови и трансформатори

$$\underline{U}_{k-l}^a + \underline{E}_{k-l}^a = \left(\underline{Z}_{k-l}^s + \underline{a}^2 \cdot \underline{Z}_{k-l}^{m1} + \underline{a} \cdot \underline{Z}_{k-l}^{m2} \right) \cdot \underline{I}_{k-l}^a$$

$$\underline{U}_{k-l}^b + \underline{E}_{k-l}^b = \left(\underline{Z}_{k-l}^s + \underline{a}^2 \cdot \underline{Z}_{k-l}^{m1} + \underline{a} \cdot \underline{Z}_{k-l}^{m2} \right) \cdot \underline{I}_{k-l}^b$$

$$\underline{U}_{k-l}^c + \underline{E}_{k-l}^c = \left(\underline{Z}_{k-l}^s + \underline{a}^2 \cdot \underline{Z}_{k-l}^{m1} + \underline{a} \cdot \underline{Z}_{k-l}^{m2} \right) \cdot \underline{I}_{k-l}^c$$

$$\underline{Z}_{k-l}^{m1} = \underline{Z}_{k-l}^{m2} = \underline{Z}_{k-l}^m$$

$$\underline{E}_{k-l}^{a,b,c} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix} \quad \underline{a} + \underline{a}^2 = -1$$

$$\underline{U}_{k-l}^a = \left(\underline{Z}_{k-l}^s - \underline{Z}_{k-l}^m \right) \cdot \underline{I}_{k-l}^a$$

$$\underline{U}_{k-l}^b = \left(\underline{Z}_{k-l}^s - \underline{Z}_{k-l}^m \right) \cdot \underline{I}_{k-l}^b$$

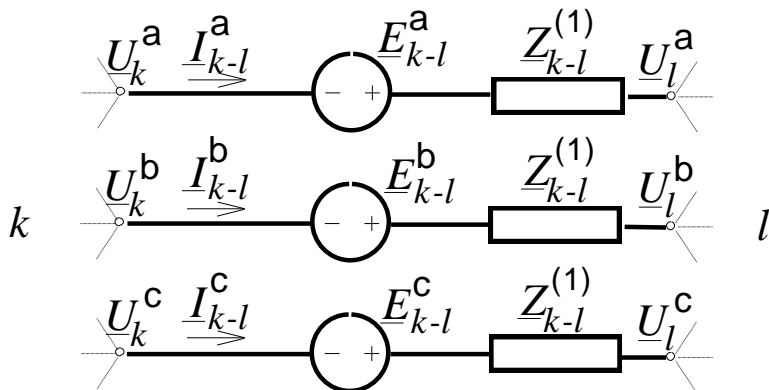
$$\underline{U}_{k-l}^c = \left(\underline{Z}_{k-l}^s - \underline{Z}_{k-l}^m \right) \cdot \underline{I}_{k-l}^c$$

$$\underline{Z}_{k-l}^{(1)} = \underline{Z}_{k-l}^s - \underline{Z}_{k-l}^m$$

$$\underline{U}_{k-l}^a = \underline{Z}_{k-l}^{(1)} \cdot \underline{I}_{k-l}^a$$

$$\underline{U}_{k-l}^b = \underline{Z}_{k-l}^{(1)} \cdot \underline{I}_{k-l}^b$$

$$\underline{U}_{k-l}^c = \underline{Z}_{k-l}^{(1)} \cdot \underline{I}_{k-l}^c$$



Трифазната гранка се разделува на три монофазни гранки помеѓу кои не постои меѓусебна спрега

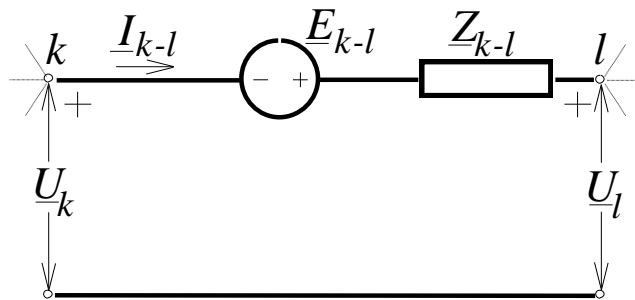
Во систем со ng гранки треба да се решат три независни системи со ng равенки, што е многу побрзо

ОСНОВНИ РАВЕНКИ ЗА ТРИФАЗНИ ГРАНКИ И СИСТЕМИ

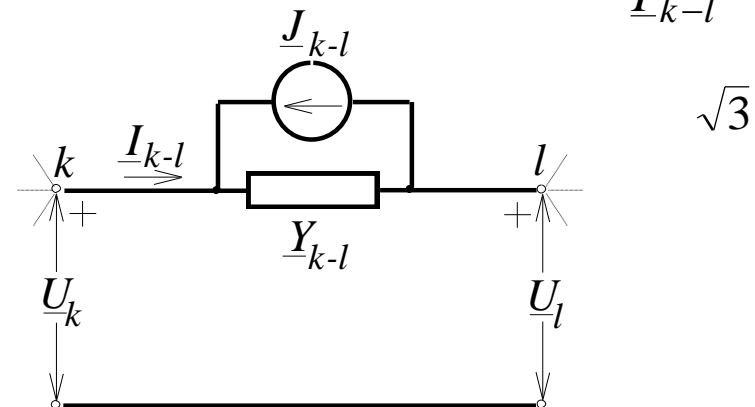
Монофазен модел на трифазни урамнотежени гранки и системи

- моќноста на гранката во монофазниот модел треба да бидат еднаква со моќноста на моќноста на трифазната гранка што моделот ја заменува
 - напоните на јазлите во монофазниот модел треба да бидат еднакви на меѓуфазните напони на соодветните јазли од трифазниот систем
 - струите низ гранката во монофазниот модел ќе бидат со $\sqrt{3}$ пати поголема ефективна вредност

$$|\underline{U}_k| = \sqrt{3} \cdot |\underline{U}_k^a| \quad |\underline{E}_{k-l}| = \sqrt{3} \cdot |\underline{E}_{k-l}^a| \quad |\underline{I}_{k-l}| = \sqrt{3} \cdot |\underline{I}_{k-l}^a| \quad |\underline{J}_{k-l}| = \sqrt{3} \cdot |\underline{J}_{k-l}^a| \quad \underline{Z}_{k-l} = \frac{1}{\underline{Y}_{k-l}} = \underline{Z}_{k-l}^{(1)}$$



Импеданциска форма



Адмитанциска форма

$$\underline{U}_{k-l} + \underline{E}_{k-l} = \underline{Z}_{k-l} \cdot \underline{I}_{k-l}$$

$$\underline{I}_{k-l} + \underline{J}_{k-l} = \underline{Y}_{k-l} \cdot \underline{U}_{k-l}$$

$$[\underline{U}_{k-l}] + [\underline{E}_{k-l}] = [\underline{Z}_{k-l}] \cdot [\underline{I}_{k-l}] \quad [\underline{Z}_{k-l}]_{ng \times ng}$$

$$[\underline{I}_{k-l}] + [\underline{J}_{k-l}] = [\underline{Y}_{k-l}] \cdot [\underline{U}_{k-l}] \quad [\underline{Y}_{k-l}]_{ng \times ng}$$