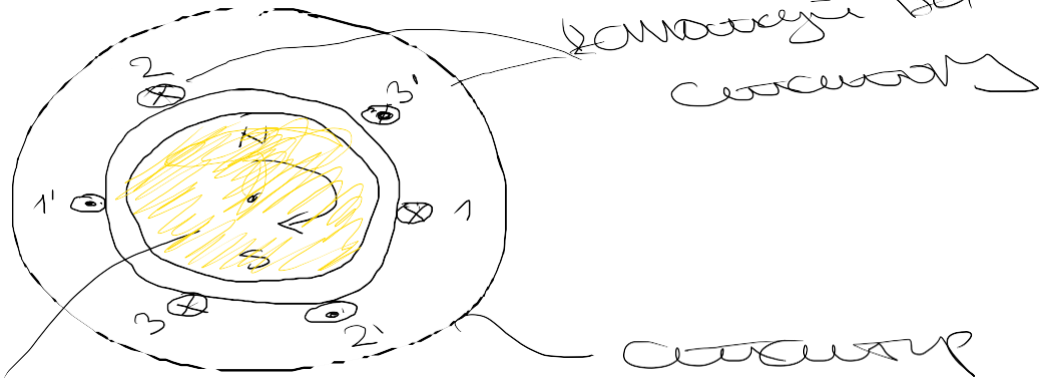
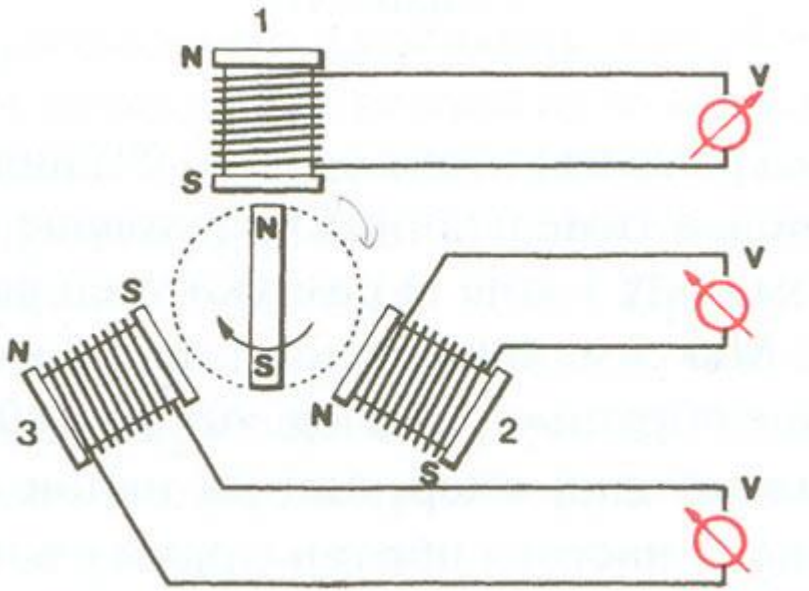
Трофазна кола.

Основи електротехнике 2
Предавање: 12. блок

Трифазни системи

Трифазни генератори

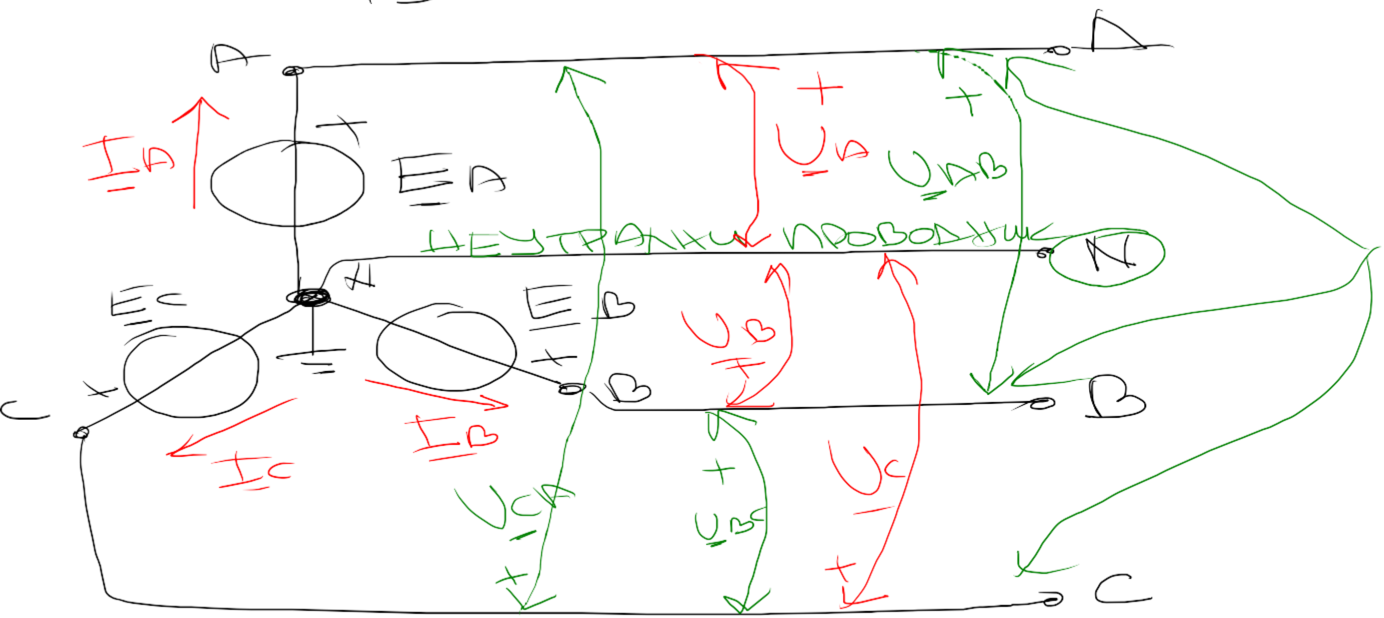




Веза трофазног генератора у звезду

– неутрална тачка или звездиште, означава се са Н и УВЕК се уземљује

директни систем: фаза А (тј. њен напон) фазно предњачи напону фазе В за $2\pi/3$ а фазе С за $4\pi/3$



I_A, I_B, I_C су фазне струје генератора

фазни проводници (фазе)

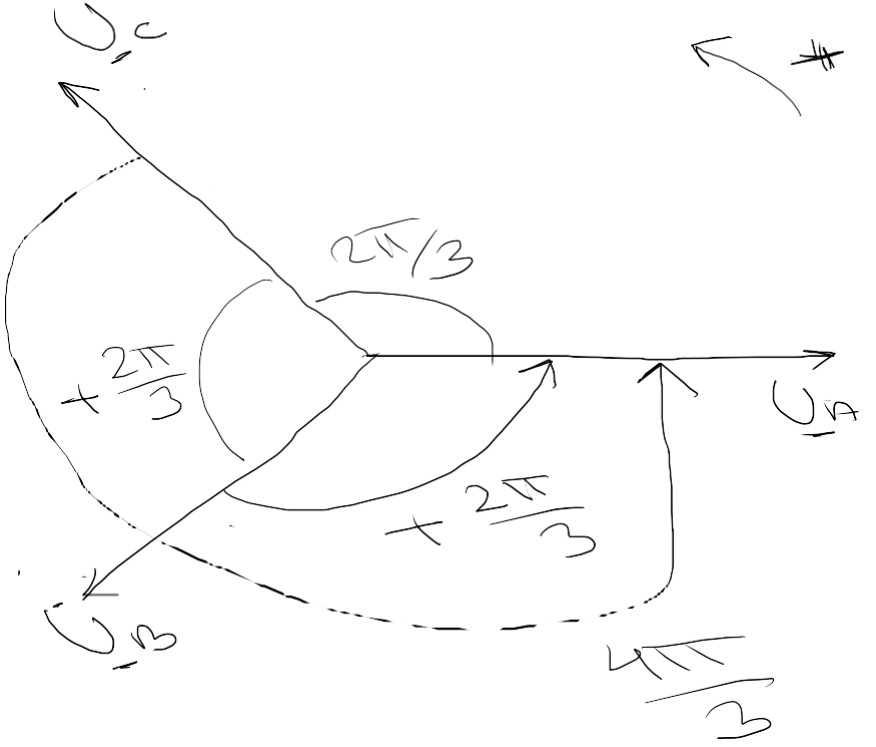
U_A, U_B, U_C фазни напони генератора

U_{AB}, U_{BC}, U_{CA} – међуфазни напони

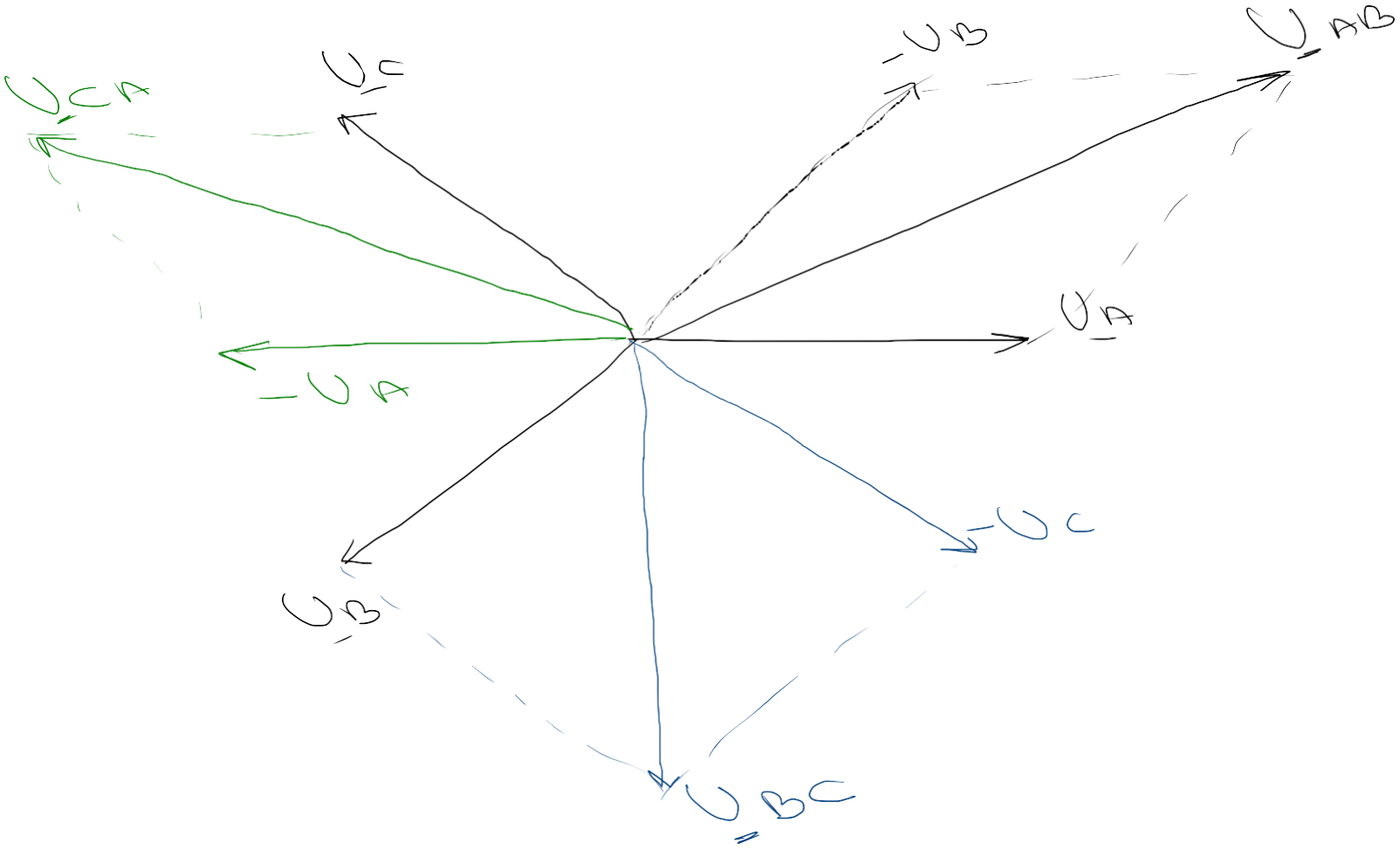
спољашњи

$\underline{U}_A = \underline{E}_A \qquad \underline{U}_B = \underline{E}_B \qquad \underline{U}_C = \underline{E}_C$

$\underline{U}_{AB} = \underline{U}_A - \underline{U}_B \qquad \underline{U}_{BC} = \underline{U}_B - \underline{U}_C \qquad \underline{U}_{CA} = \underline{U}_C - \underline{U}_A$



$$\underline{U}_{AB} = \underline{U}_A - \underline{U}_B$$
$$= \underline{U}_A + (-\underline{U}_B)$$



Симетрични трифазни системи

Симетрично трифазно систем:

$$e_A(t) = \sqrt{2}E\cos(\omega t + \theta_A)$$
$$e_B(t) = \sqrt{2}E\cos(\omega t + \theta_B) = \sqrt{2}E\cos\left(\omega t + \theta_A - \frac{2\pi}{3}\right)$$
$$e_C(t) = \sqrt{2}E\cos(\omega t + \theta_C) = \sqrt{2}E\cos\left(\omega t + \theta_A - \frac{4\pi}{3}\right)$$

$$\underline{E}_A = Ee^{j\theta_A}$$
$$\underline{E}_B = Ee^{j(\theta_A - \frac{2\pi}{3})} = Ee^{j\theta_A}e^{-j\frac{2\pi}{3}} = \underline{E}_A e^{-j\frac{2\pi}{3}}$$
$$\underline{E}_C = \underline{E}_A e^{-j\frac{4\pi}{3}} = \underline{E}_B e^{-j\frac{2\pi}{3}}$$

$$\underline{E}_A + \underline{E}_B + \underline{E}_C = 0$$

$$\underline{U}_{AB} = \underline{E}_A - \underline{E}_B = \underline{E}_A - \underline{E}_A e^{-j\frac{2\pi}{3}} = \underline{E}_A\left(1 - e^{-j\frac{2\pi}{3}}\right) = \underline{E}_A\left(1 - \left(\cos\frac{2\pi}{3} - j\sin\frac{2\pi}{3}\right)\right)$$
$$= \underline{E}_A\left(1 - \left(\cos\frac{2\pi}{3} + j\sin\frac{2\pi}{3}\right)\right) = \underline{E}_A\left(\frac{3}{2} + j\frac{\sqrt{3}}{2}\right) = \sqrt{3}\underline{E}_A\left(\frac{\sqrt{3}}{2} + j\frac{1}{2}\right)$$

$$\underline{U}_{AB} = \sqrt{3}\,\underline{E}_A e^{j\frac{\pi}{6}}$$

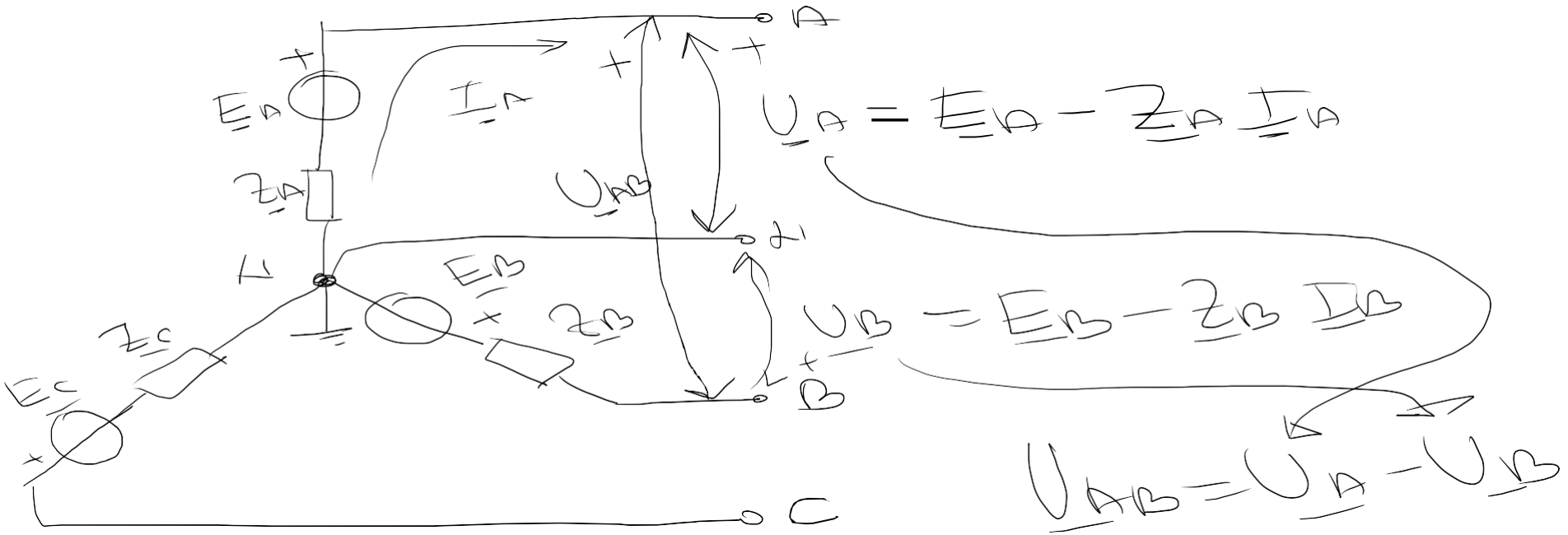
$$\underline{U}_{AB} = \sqrt{3}\,E_A \cdot e^{j\left(\theta_A + \frac{\pi}{6}\right)}$$

Ефективна вредност међуфазног напона је $\sqrt{3}$ пута већа од фазног за исти систем у звезди

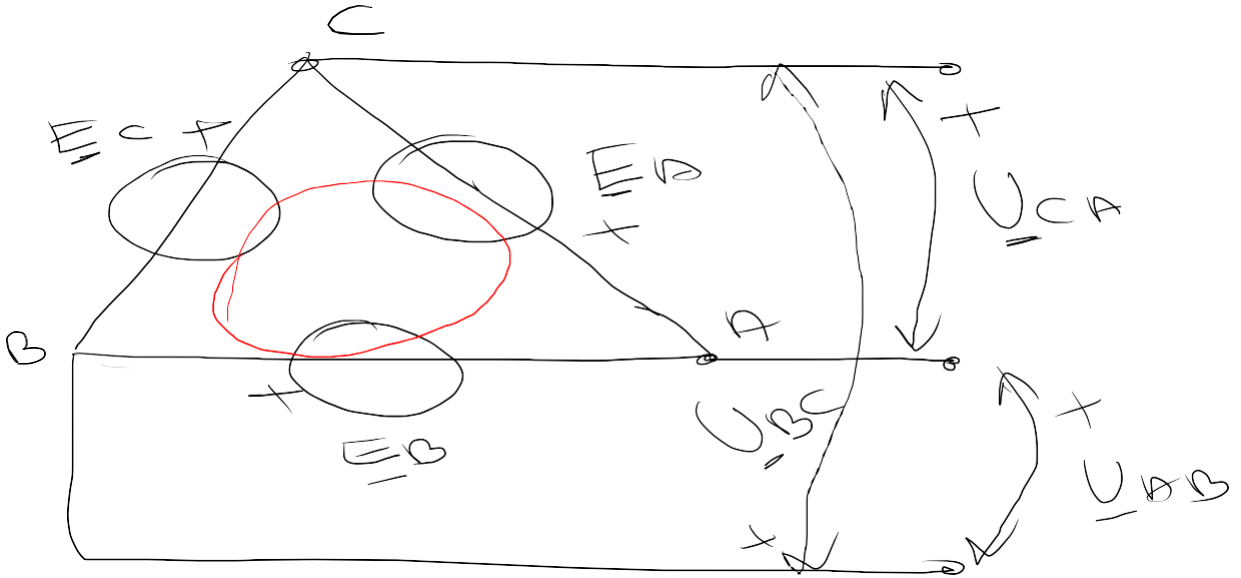
Међуфазни напон претиче фазни за $\frac{\pi}{6}$

$$\underline{U}_{BC} = \sqrt{3}\,\underline{E}_B e^{j\frac{\pi}{6}}$$

$$\underline{U}_{CA} = \sqrt{3}\,\underline{E}_C e^{j\frac{\pi}{6}}$$


A
E_A
I_A
Z_A
U_{AN}
N
E_B
Z_B
Z_C
E_C
B
C
$\underline{U}_A = \underline{E}_A - \underline{Z}_A \underline{I}_A$
$\underline{U}_B = \underline{E}_B - \underline{Z}_B \underline{I}_B$
$\underline{U}_{AB} = \underline{U}_A - \underline{U}_B$

Веза између напона генератора у звезду



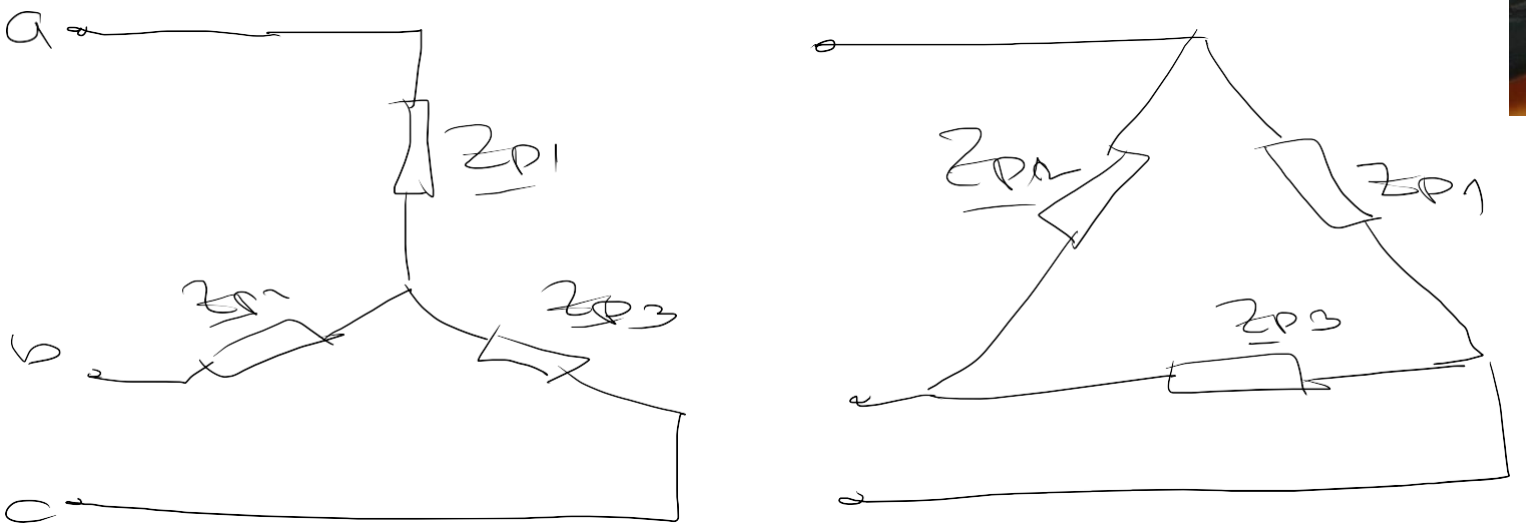
$$\underline{E}_A + \underline{E}_B + \underline{E}_C = 0$$

Veza potrošača na trofazno naizmenično

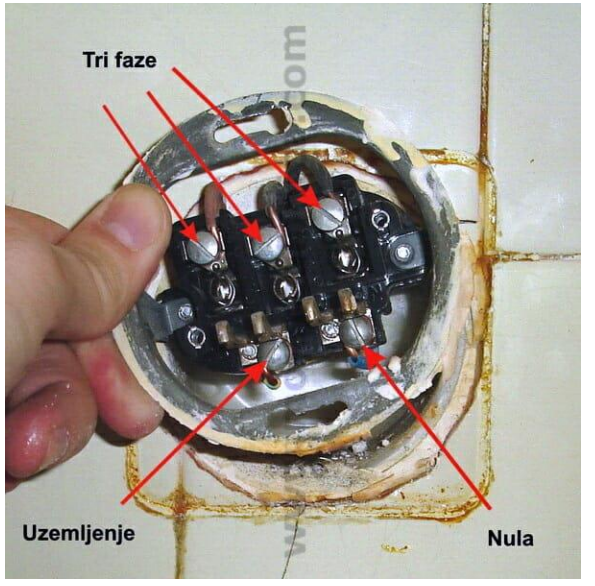
Faze: crna, braon i siva

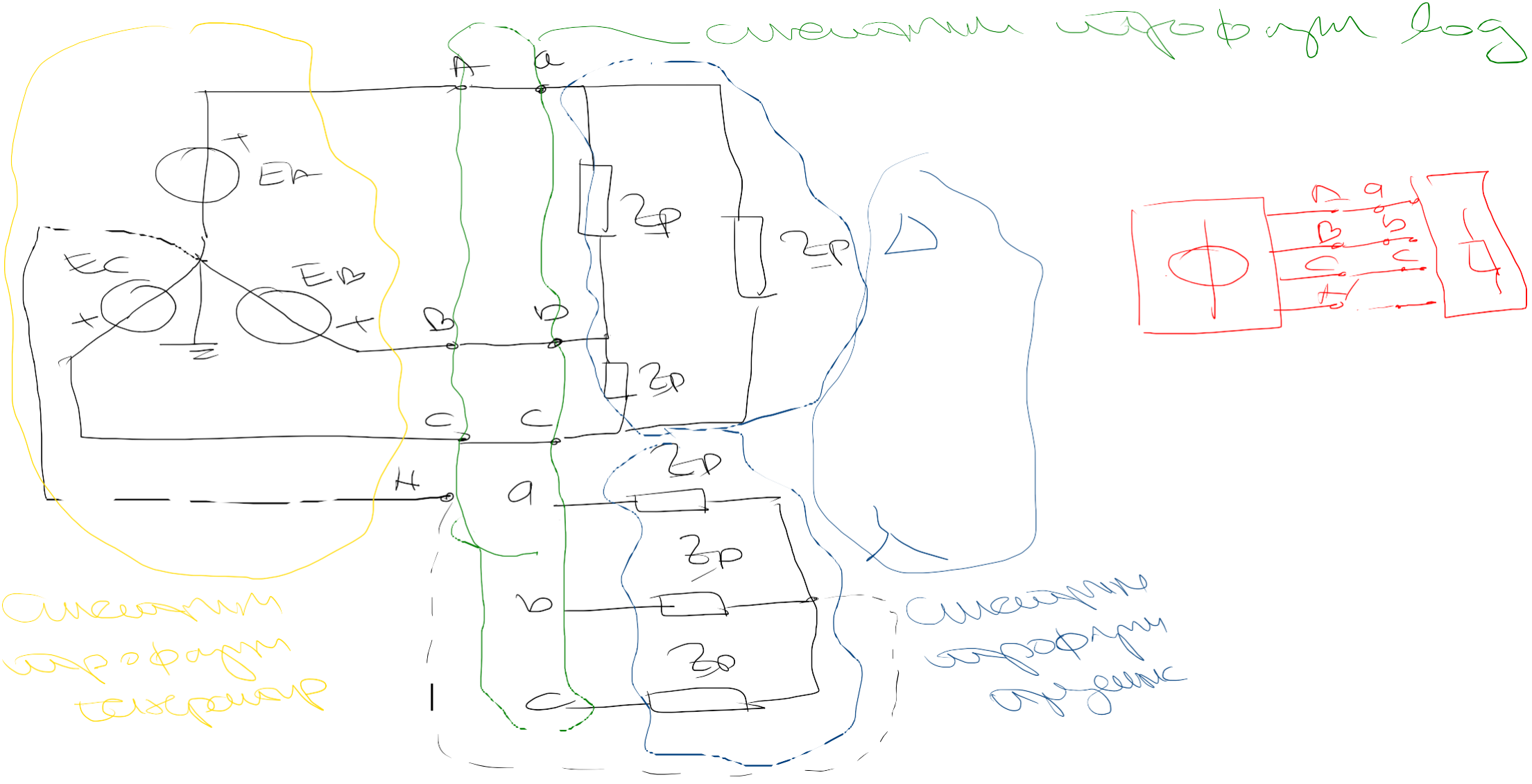
Neutralni: plava boja

Uzemljenje: žuto – zelena



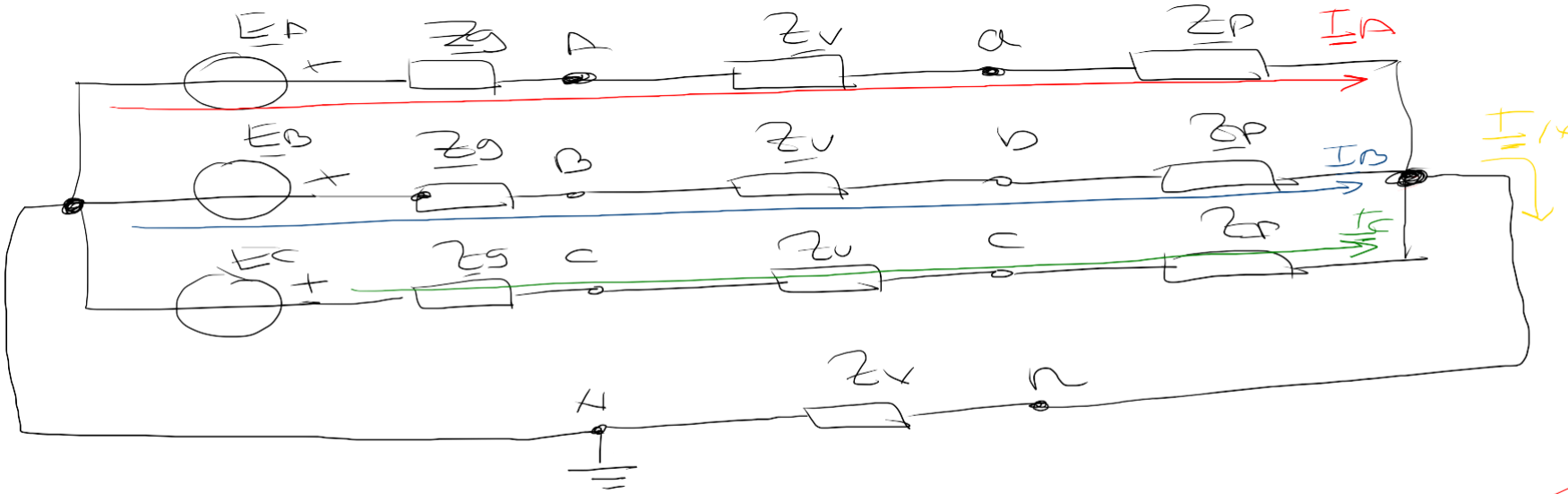
$$Z_{p1} = Z_{p2} = Z_{p3}$$




A
a
B
b
C
c
H
a
b
c
Zp
Zp
Zp
Zp
Zp
Zp
Zp
Zo
Ec
Eb
Ea

Analiza simetričnih trofaznih sistema

1. Veza zvijezda u zvijezdu



$I_N = \phi$

$$\underline{V}_n\left(\frac{3}{\underline{Z}_g+\underline{Z}_v+\underline{Z}_p}+\frac{1}{\underline{Z}_v}\right)=\frac{\underline{E}_A+\underline{E}_B+\underline{E}_C}{\underline{Z}_g+\underline{Z}_v+\underline{Z}_p}=\phi$$

jer je $\underline{E}_A+\underline{E}_B+\underline{E}_C=\phi$

$$\underline{I}_A=\frac{\underline{E}_A}{\underline{Z}_g+\underline{Z}_v+\underline{Z}_p}$$

$$\underline{I}_B=\frac{\underline{E}_B}{\underline{Z}_g+\underline{Z}_v+\underline{Z}_p}$$

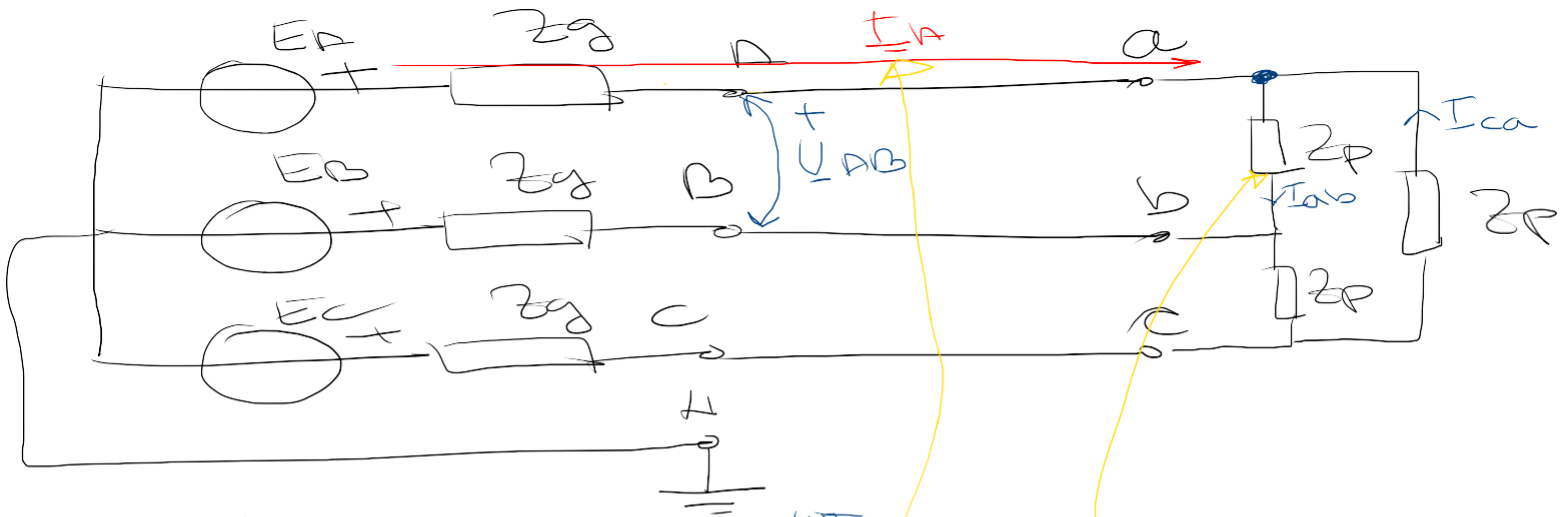
$$\underline{I}_C=\frac{\underline{E}_C}{\underline{Z}_g+\underline{Z}_v+\underline{Z}_p}$$

$$\underline{U}_a = \underline{E}_a - \underline{Z}_g \cdot \underline{I}_a$$

$$\underline{U}_b = \underline{E}_b - \underline{Z}_g \underline{I}_b$$

$$\underline{U}_c = \underline{E}_c - \underline{Z}_g \underline{I}_c$$

2. Веза троугао у троугао



$$\underline{I}_{ab} = \underline{I}_A + \underline{I}_{ca}$$

$$\underline{I}_A = \underline{I}_{ab} - \underline{I}_{ca}$$

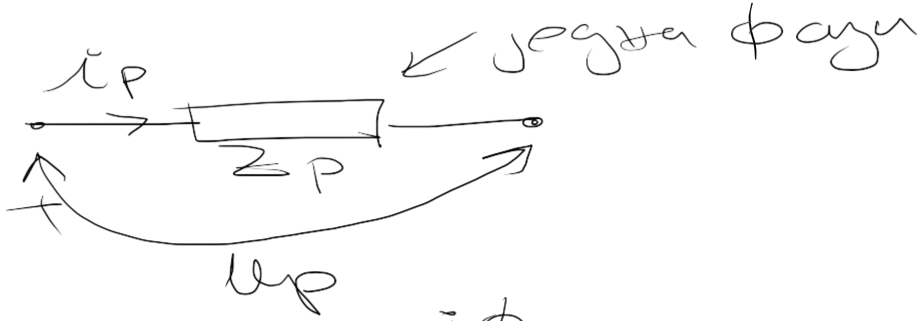
$$= \frac{\underline{U}_{ab}}{\underline{Z}_p} - \frac{\underline{U}_{ca}}{\underline{Z}_p}$$

$$\underline{I}_A = \frac{\underline{U}_{ab}}{\underline{Z}_p} - \frac{\underline{U}_{ab}\, e^{-j\frac{4\pi}{3}}}{\underline{Z}_p\, e^{j\frac{2\pi}{3}}} = \frac{\underline{U}_{ab}}{\underline{Z}_p}\left(1 - e^{-j\frac{2\pi}{3}}\right) = \underline{I}_{ab}\left(1 - e^{-j\frac{2\pi}{3}}\right)$$

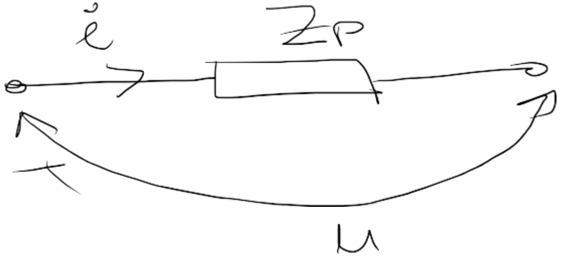
$$\underline{I}_A = \sqrt{3}\, \underline{I}_{ab}\left(\frac{\sqrt{3}}{2} - j\frac{1}{2}\right) = \sqrt{3}\, \underline{I}_{ab} \cdot e^{-j\frac{\pi}{6}}$$

$$\underline{I}_A = \sqrt{3}\, \underline{I}_{ab}\, e^{-j\frac{\pi}{6}}$$

Снаге трофазних генератора и пријемника



$$\underline{Z}_p = Z_p e^{j\phi_p}$$



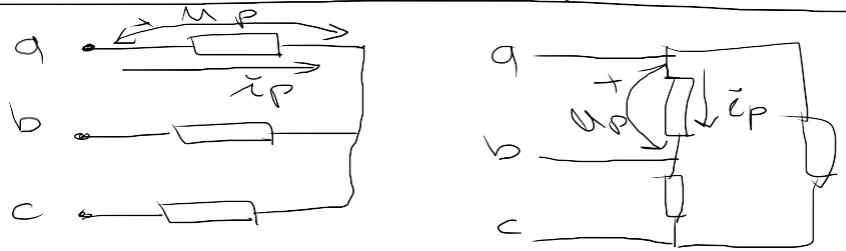
$$\underline{Z}_p = \sqrt{R^2+(\omega L)^2}\, e^{j\,\mathrm{arctg}\frac{\omega L}{R}} = Z_p e^{j\phi_p}$$

$$p(t) = u_{p1}(t)\cdot i_{p1}(t) + u_{p2}(t)\cdot i_{p2}(t) + u_{p3}(t)\cdot i_{p3}(t)$$

$$u_{p1}(t) = \sqrt{2}U_p\cos\omega t \qquad i_{p1}(t) = \sqrt{2}I_p\cos(\omega t - \phi_p)$$

$$u_{p2}(t) = \sqrt{2}U_p\cos\left(\omega t - \frac{2\pi}{3}\right) \qquad i_{p2}(t) = \sqrt{2}I_p\cos\left(\omega t - \frac{2\pi}{3} - \phi_p\right)$$

$$u_{p3}(t) = \sqrt{2}U_p\cos\left(\omega t - \frac{4\pi}{3}\right) \qquad i_{p2}(t) = \sqrt{2}I_p\cos\left(\omega t - \frac{4\pi}{3} - \phi_p\right)$$



$$u_{p1}(t)\cdot i_{p1}(t) = 2U_pI_p\cos\omega t\cdot\cos(\omega t - \phi_p)$$

$$= U_pI_p\cos\phi_p + U_pI_p\cos(2\omega t - \phi_p)$$

$$u_{p2}(t)\cdot i_{p2}(t) = U_pI_p\cos\phi_p + U_pI_p\cos\left(2\omega t - \frac{4\pi}{3} - \phi_p\right)$$

$$u_{p3}(t)\cdot i_{p3}(t) = U_pI_p\cos\phi_p + U_pI_p\cos\left(2\omega t - \frac{8\pi}{3} - \phi_p\right)$$

$$p(t) = 3U_pI_p\cos\phi_p$$

$$P_p = 3 U_p I_p \cos\phi_p$$

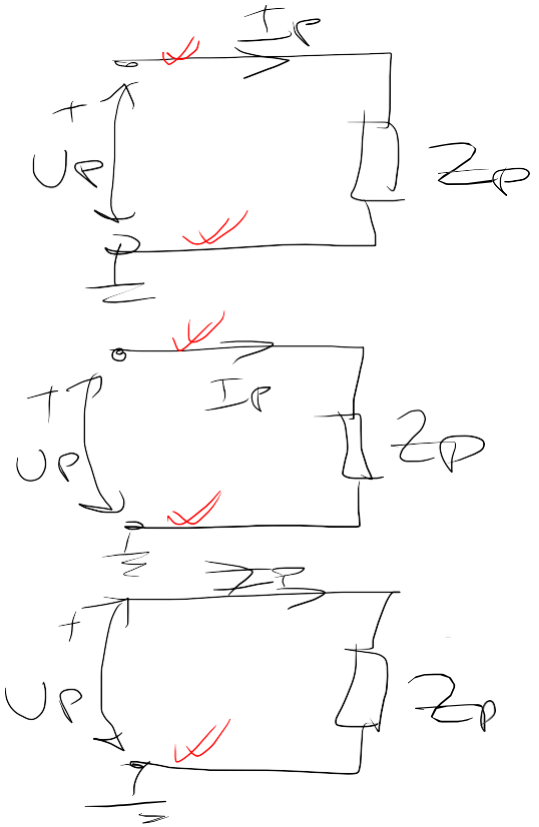
$$Q_p = 3 U_p I_p \sin\phi_p$$

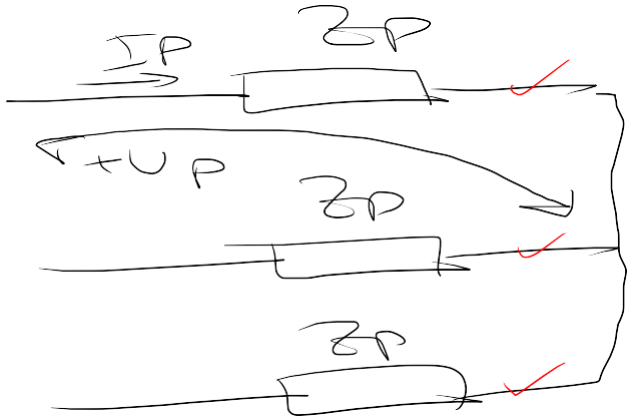
$$\underline{S}_p = 3 \underline{U}_p \underline{I}_p^* = 3 \underline{Z}_p I_p^2 = \frac{3 U_p^2}{\underline{Z}_p^*} = P_p + jQ_p$$

$$\underline{S}_p = 3 \cdot Z_p (\cos\phi_p + j \sin\phi_p) I_p^2$$

$$= 3 U_p I_p (\cos\phi_p + j \sin\phi_p)$$

Предности трофазног система у односу на монофазни





$P_M = 3 U_p I_p \cos\varphi_p$

$P_1 = U_p \cdot I_p \cdot \cos\varphi_p$

$P_M = 3P_1 = 3 U_p I_p \cos\varphi_p$