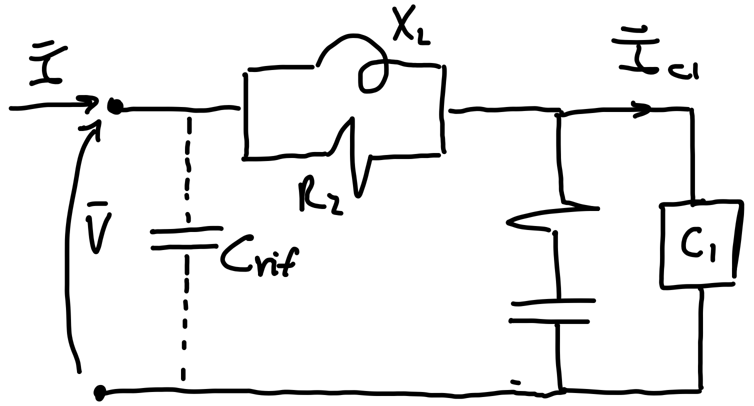
Esercitazione 7 - 1 di Boucherot (& Rifasamento) + Trifase

Esercizio 1



$V = ?$

$I = ?$

$\cos(\varphi) = ?$

$f = 50\,Hz$

$R_1 = 100\,\Omega$

$R_2 = 5\,\Omega$

$X_L = 10\,\Omega$

$X_C = 20\,\Omega$

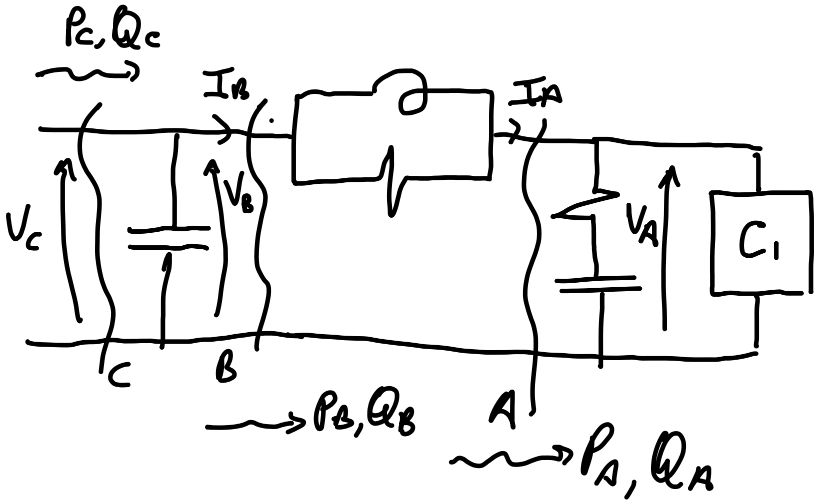
$I_{C1} = 12\,A$

$P_{C1} = 2500\,W$

$\cos(\varphi_{C1}) = 0,7$ in ritardo

C_{rif} ?

$\cos(\varphi_{rif}) = 0,95$



$$P_{C1} = V_A \underbrace{I_{C1} \cos(\varphi_{C1})}_{\bar{I}_{C1}}$$

$$V_A = \frac{P_{C1}}{I_{C1}\cos(\varphi_{C1})} = 297,6\,V$$

$$Q_{C1} = \sqrt{V_A^2 I_{C1}^2 - P_{C1}^2} = P_{C1}\frac{\sqrt{1-\cos^2(\varphi_{C1})}}{\cos(\varphi_{C1})} = V_A I_{C1}\sqrt{1-\cos^2(\varphi_{C1})} =$$

$= 2550{,}2\ VAR$

$$\bar{Z}_{R1XC} = R_1 - jX_c$$

$$\underset{A}{\underset{\shortparallel}{\bar{S}_{R1XC}}} = \frac{V_A^2}{\bar{Z}_{R1XC}} = \frac{V_A^2}{R_1 + jX_c} = \overbrace{851{,}6}^{P_{R1XC}} - j\overbrace{170{,}32}^{-Q_{R1XC}}\ VA$$

negato la parte negativo

$$P_A = P_{C1} + P_{R1XC} = 3351{,}6\ W$$

$$Q_A = Q_{C1} + Q_{R1XC} = 2379{,}9\ VAR$$

$$V_A = 297{,}6\ V$$

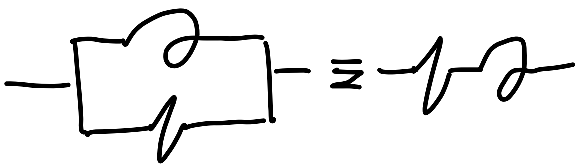
$$I_A^2 = \frac{P_A^2 + Q_A^2}{V_A^2} = 190{,}7\ A^2$$

Sezione B-B

$$\bar{Z}_{R2XL} = \frac{jX_L \cdot R_2}{R_2 + jX_L} = 4 + j2\ \Omega$$

$$P_B = P_A + \mathrm{Re}(\bar{Z}_{R2XL})\, I_A^2 = 4314{,}7\ W$$

$$Q_B = Q_A + \mathrm{Im}(\bar{Z}_{R2XL})\, I_A^2 = 2761{,}5\ VAR$$

Dal punto di vista matematico: 

agli estremi, così succede ai pezzi non ci importa

$$I_B^2 = I_A^2 = 190{,}7\ A^2$$

$$P_B = 4314{,}7\ W$$

$$Q_B - 2761{,}5\ VAR$$

$$V_B^2 = V^2 = \frac{P_B^2 + Q_B^2}{I_B^2} = 137\,539\ V^2$$

$$\boxed{V = 370{,}9\ V} \rightarrow$$ Un dato del problema

Sezione C-C

$$P_c = P_B = 4314{,}7\ W$$

$$Q_c = P_c \frac{\sqrt{1-\cos^2(\varphi_{rif})}}{\cos(\varphi_{rif})} = 1418{,}2\ VAR$$

Perchè vogliamo $\cos(\varphi_{rif}) = 0{,}95$

$$Q_c = Q_B - \frac{V^2}{X_{cril}}$$

$$X_{crif} = \frac{V^2}{Q_B - Q_c} = 102{,}4\ \Omega$$

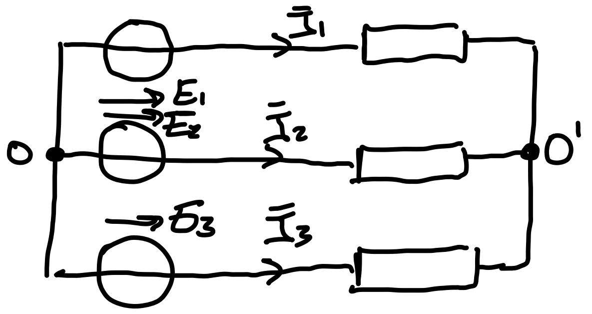
$$X_{crif} = \frac{1}{2\pi f C_{rif}} \Rightarrow C_{rif} = \frac{1}{2\pi f C_{rif}} = 31\ \mu F$$

$$I = \frac{\sqrt{P_B^2 + Q_B^2}}{V} = 13{,}81\ A \qquad I_{rif} = \frac{\sqrt{P_c^2 + Q_c^2}}{V} = 12{,}25\ A$$

Prima di rifasamento

Minimizziamo I per mantenere la potenza a monte

Trifase



$$\bar{I}_1 = \frac{\bar{E}_1 - \bar{V}_{O'O}}{\bar{\bar{Z}}_1}$$

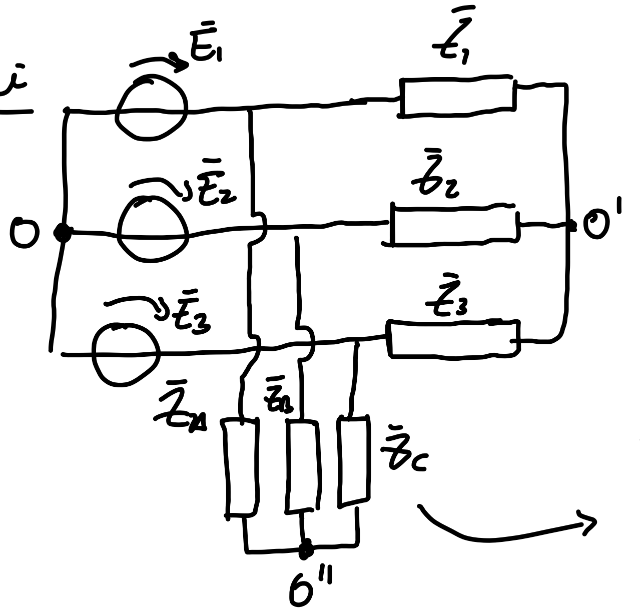
$$\bar{I}_2 = \frac{\bar{E}_2 - \bar{V}_{O'O}}{\bar{\bar{Z}}_2}$$

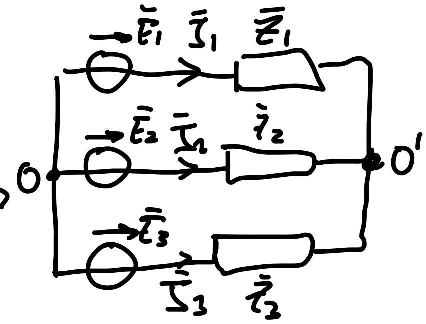
$$\bar{I}_3 = \frac{\bar{E}_3 - \bar{V}_{O'O}}{\bar{\bar{Z}}_3}$$

$$\bar{V}_{O'O} = \frac{\frac{\bar{E}_1}{\bar{\bar{Z}}_1} + \frac{\bar{E}_2}{\bar{\bar{Z}}_2} + \frac{\bar{E}_3}{\bar{\bar{Z}}_3}}{\frac{1}{\bar{\bar{Z}}_1} + \frac{1}{\bar{\bar{Z}}_2} + \frac{1}{\bar{\bar{Z}}_3}}$$

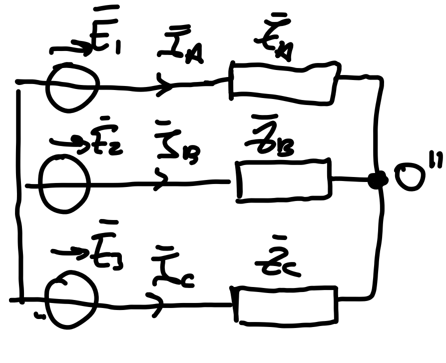
Caso più semplice

Carichi Trasversali

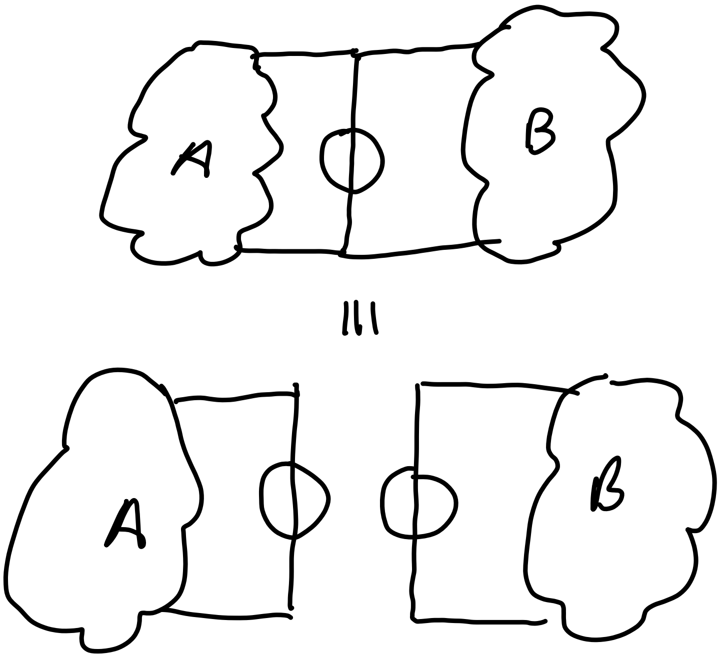




$\bar{V}_{O'O}$
$\bar{I}_1$
$\bar{I}_2$
$\bar{I}_3$



$\bar{V}_{O''O}$
$\bar{I}_A$
$\bar{I}_B$
$\bar{I}_C$

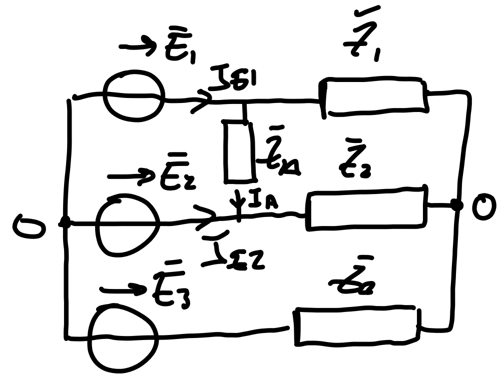


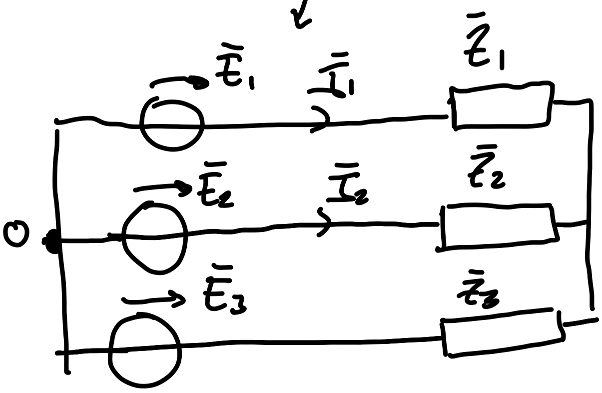
$$\bar{\bar{I}}_{E1} = \bar{\bar{I}}_1 + \bar{\bar{I}}_A$$

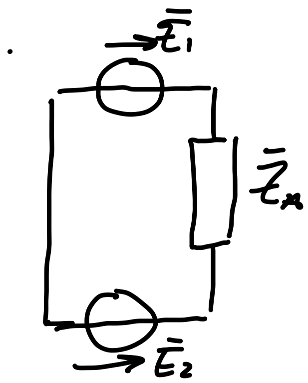
$$\bar{\bar{I}}_{E2} = \bar{\bar{I}}_2 + \bar{\bar{I}}_B$$

$$\bar{\bar{I}}_{E3} = \bar{\bar{I}}_3 + \bar{\bar{I}}_C$$

Perdita di Simmetria



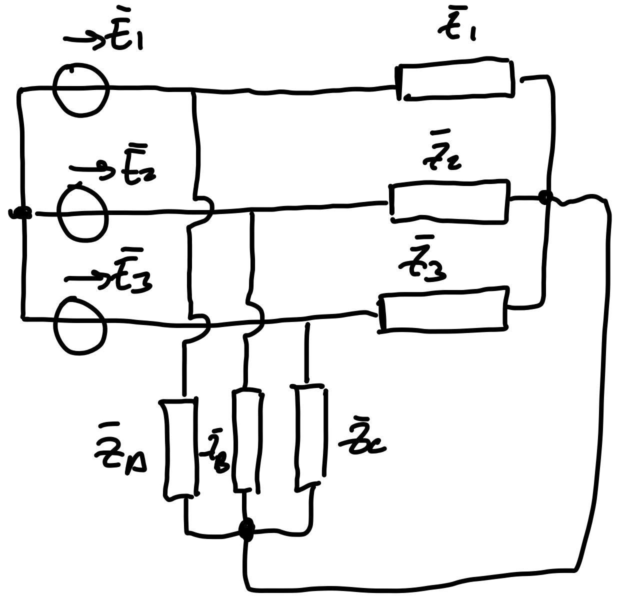




$$\bar{I}_{E1} = \bar{I}_1 + \bar{I}_A$$

$$\bar{I}_{E2} = \bar{I}_2 - \bar{I}_A$$

Caso con nettente



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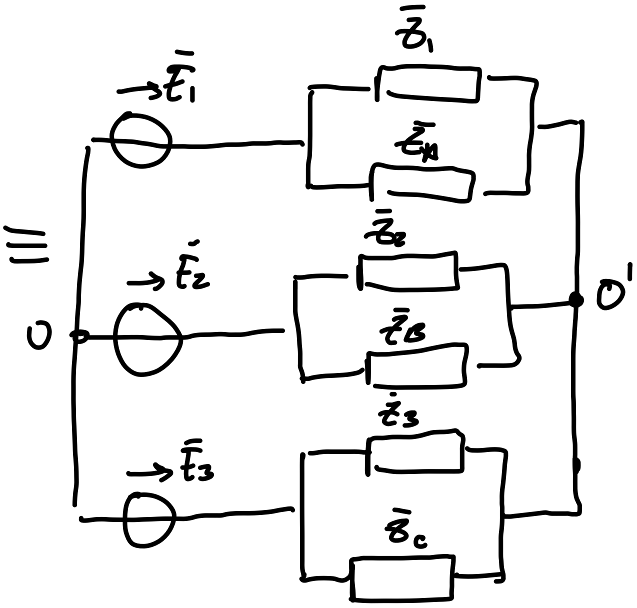
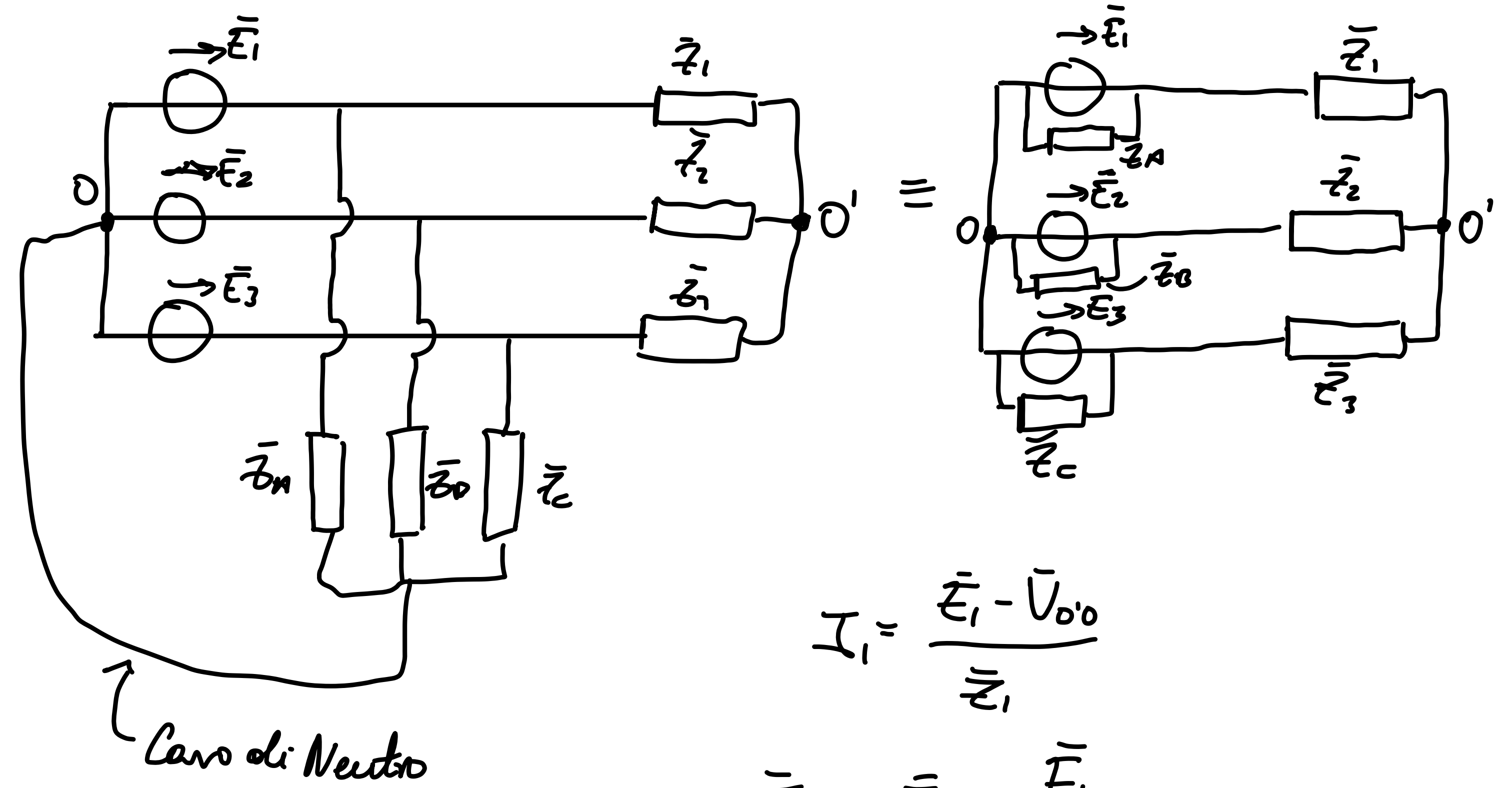


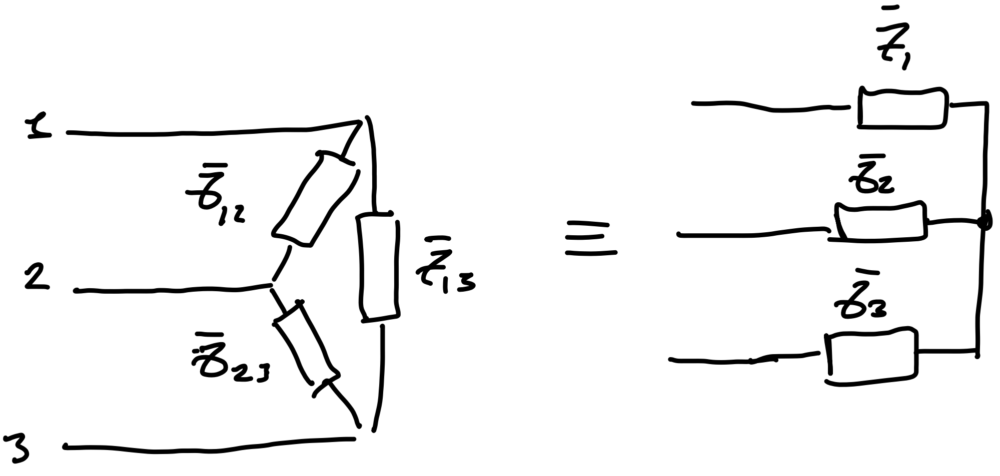
Conduttore di Neutro



$$\bar{I}_1 = \frac{\bar{E}_1 - \bar{V}_{O'O}}{\bar{Z}_1}$$

$$\bar{I}_{E1} = \bar{I}_1 + \frac{\bar{E}_1}{\bar{Z}_A}$$

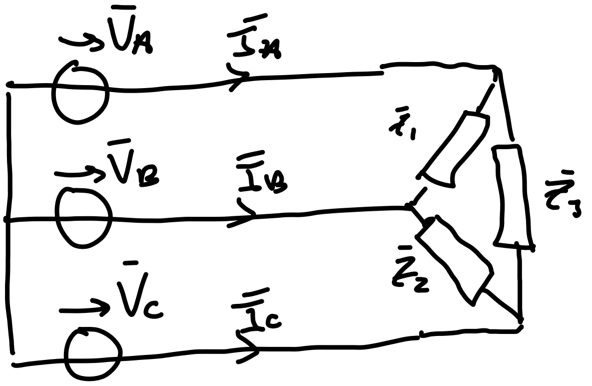
Carichi a Triangolo



$$\bar{Z}_1 = \frac{\bar{Z}_{12} + \bar{Z}_{13}}{\bar{Z}_{12} + \bar{Z}_{23} + \bar{Z}_{13}} \qquad \bar{Z}_2 = \frac{\bar{Z}_{23} + \bar{Z}_{12}}{\bar{Z}_{12} + \bar{Z}_{23} + \bar{Z}_{13}}$$

$$\bar{Z}_3 = \frac{\bar{Z}_{13} + \bar{Z}_{23}}{\bar{Z}_{12} + \bar{Z}_{23} + \bar{Z}_{13}}$$

Esercizio 1



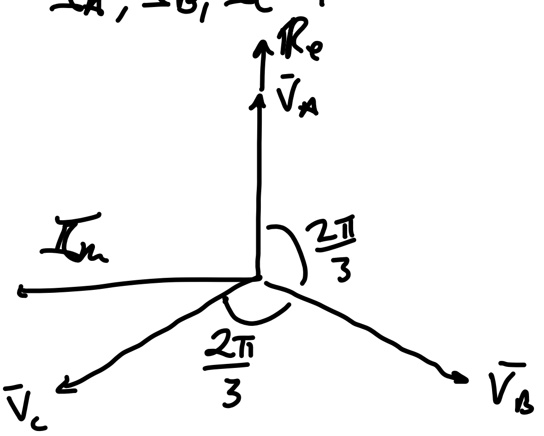
$V_A = V_B = V_C = 220V$

$\bar Z_1 = 3\Omega$

$\bar Z_2 = 4 - j1$

$\bar Z_3 = 3 + j2\Omega$

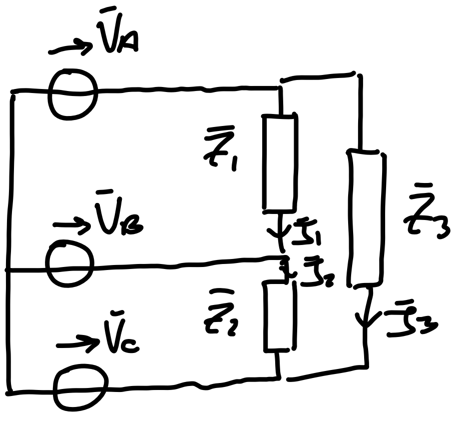
$\bar I_A, \bar I_B, \bar I_C$?



$\bar V_A = 220V$

$\bar V_B = 220e^{-j\frac{2\pi}{3}} = -110V - j190{,}5V$

$\bar V_C = 220\,e^{j\frac{2\pi}{3}} = -110 + j190{,}5V$



$\bar I_1 = \dfrac{\bar V_A - \bar V_B}{\bar Z_1} = 110 + j63{,}5A$ $\quad \bar I_3 = \dfrac{\bar V_A - \bar V_C}{\bar Z_3} = 46{,}85 - j94{,}73A$

$\bar I_2 = \dfrac{\bar V_B - \bar V_C}{\bar Z_2} = 22{,}41 - j89{,}65A$

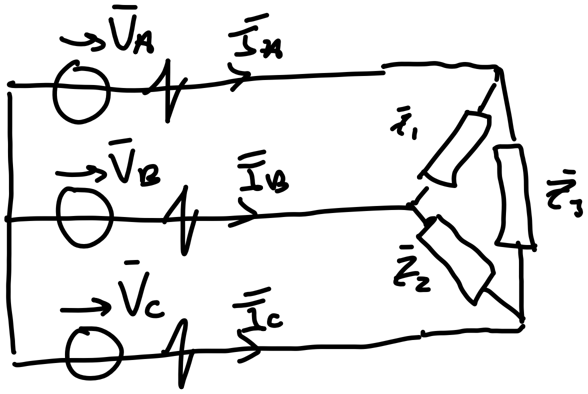
$\bar{I}_A = \bar{I}_1 + \bar{I}_3 = 15685 - j31,23 A$

$\bar{I}_B = -\bar{I}_1 + \bar{I}_2 = -87,59 - j153,15 A$

$\bar{I}_C = -\bar{I}_2 - \bar{I}_3 = -69,26 + j184,38 A$

Ci sono casi dove non è possibile usare la formula che abbiamo visto prima

Esercizio 3: Stesso ma con resistenze



$V_A = V_B = V_C = 220V$

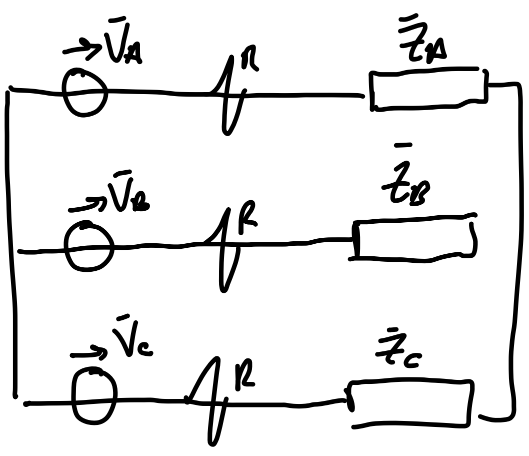
$\bar{Z}_1 = 3\Omega$

$\bar{Z}_2 = 4 - j1$

$\bar{Z}_3 = 3 + j2\Omega$

$\bar{I}_A, \bar{I}_B, \bar{I}_C$?

Non possiamo fare come prima quindi convertiamo a stella come visto nelle equazioni



$$\bar{Z}_A = \frac{\bar{Z}_1 + \bar{Z}_3}{\bar{Z}_1 + \bar{Z}_2 + \bar{Z}_3} = 0,95 + j0,50\Omega$$

$$\bar{Z}_B = \frac{\bar{Z}_1 + \bar{Z}_2}{\bar{Z}_1 + \bar{Z}_2 + \bar{Z}_3} = 1,16 - j0,42\Omega$$

$$\bar{Z}_C = \frac{\bar{Z}_2 + \bar{Z}_3}{\bar{Z}_1 + \bar{Z}_2 + \bar{Z}_3} = 1,44 + j0,36\Omega$$

$$\bar{Z}_{AR} = R + \bar{Z}_A = 1,95 + j0,5\ \Omega$$

$$\bar{Z}_{BR} = R + \bar{Z}_B = 2,16 + j0,42\ \Omega$$

$$\bar{Z}_{CR} = R + \bar{Z}_C = 3,44 + j0,36\ \Omega$$

$$\bar{V}_{O'O} = \frac{\frac{\bar{V}_A}{\bar{Z}_{AR}} + \frac{\bar{V}_B}{\bar{Z}_{BR}} + \frac{\bar{V}_C}{\bar{Z}_{CR}}}{\frac{1}{\bar{Z}_{AR}} + \frac{1}{\bar{Z}_{BR}} + \frac{1}{\bar{Z}_{CR}}} = \underbrace{32,29 - j\,26,53\,V}_{}$$

Un circuito ben progettato ha tensioni basse < 220V

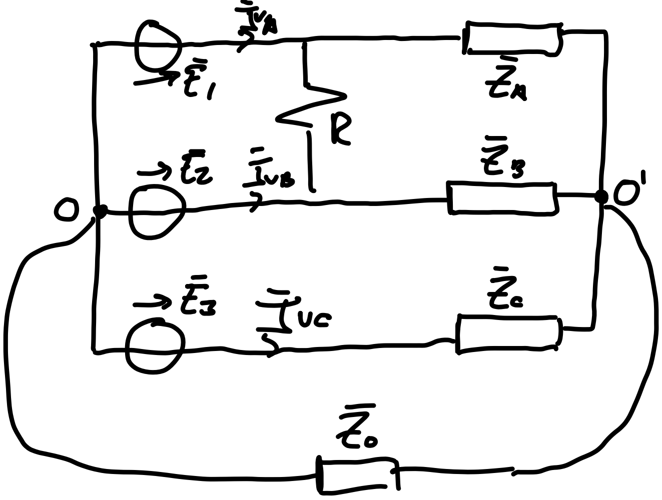
$$\bar{I}_A = \frac{\bar{E}_A - \bar{V}_{O'O}}{\bar{Z}_{AR}} = 93,59 - j10,39\,A$$

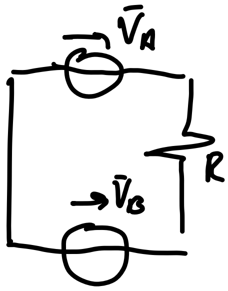
$$\bar{I}_B = \frac{\bar{E}_B - \bar{V}_{O'O}}{\bar{Z}_{BR}} = -49,25 - j85,5\,A$$

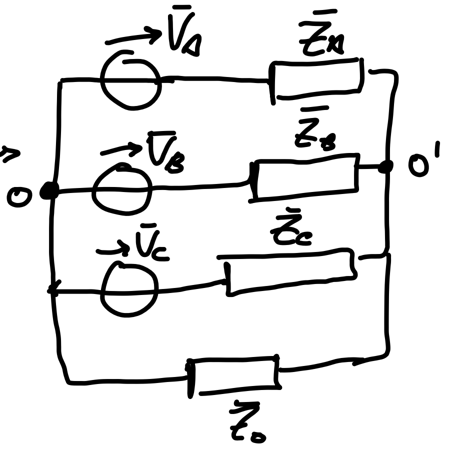
$$\bar{I}_C = \frac{\bar{E}_C - \bar{V}_{O'O}}{\bar{Z}_{CR}} = -44,35 + j\,95,89\,A$$

In questo caso non si può evitare l'equivalenza, nell'altro caso si poteva evitare quindi è quello che abbiamo fatto

Esercizio 4 – Stesse tensioni







$V_A = V_B = V_C = 220\,V$

$\bar{Z}_0 = 4 + j7\,\Omega$

$R = 5\,\Omega$

$\bar{Z}_B = 7 - j5\,\Omega$

$Z_C = j5\,\Omega$

$\bar{Z}_A = 3\,\Omega$

$\bar{S}_{gen} = ?$

$$V_{O'O} = \frac{\frac{\bar{V}_A}{\bar{Z}_A} + \frac{\bar{V}_B}{\bar{Z}_B} + \frac{\bar{V}_C}{\bar{Z}_C}}{\frac{1}{\bar{Z}_A} + \frac{1}{\bar{Z}_B} + \frac{1}{\bar{Z}_C} + \frac{1}{\bar{Z}_0}} = 190 + j86{,}33\,V$$

$$\bar{I}_R = \frac{\bar{V}_A - \bar{V}_B}{R} = 66 + j38{,}1\,A$$

$$\bar{I}_A = \frac{\bar{V}_A - \bar{V}_{OO'}}{\bar{Z}_A} = 9{,}88 - j28{,}78\,A$$

$$\bar{I}_B = \frac{\bar{V}_B - \bar{V}_{O'O}}{\bar{Z}_B} = -9{,}71 - j46{,}48\,A$$

$$\bar{I}_C = \frac{\bar{V}_C - \bar{V}_{O'O}}{\bar{Z}_C} = 20{,}83 + j60{,}07\,A$$

$\bar{I}_{VC} = \bar{I}_C$

$\bar{I}_{VA} = \bar{I}_A + \bar{I}_R = 75{,}88 + j9{,}37\,A$

$\bar{I}_{VB} = \bar{I}_B - \bar{I}_R = -75{,}71 - j84{,}58\,A$

$$\bar{S}_{gen} = \bar{V}_A \underline{I}_{VA} + \bar{V}_B \underline{I}_{VB} + \bar{V}_C \underline{I}_{VC}$$

$$= 5029 + j\,13645 \text{ VA}$$