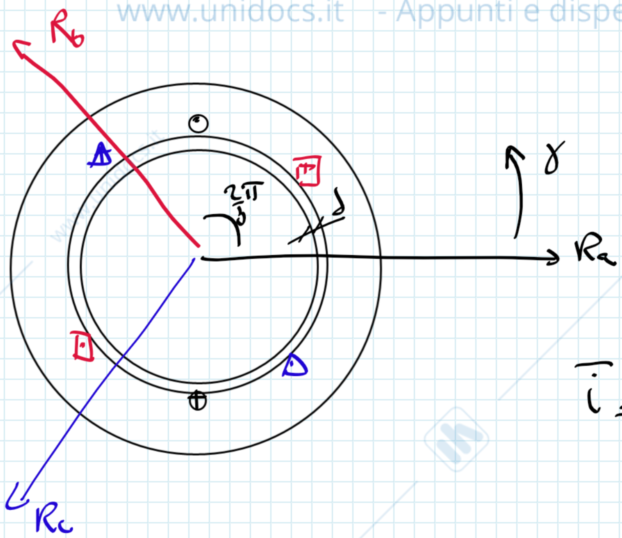


$$B(t,\gamma) = B_1(t,\gamma) + B_2(t,\gamma) + B_3(t,\gamma)$$

$$= \mathrm{Re}\left(\frac{4}{\pi}\cdot\frac{N}{2\delta}\,\mu_0 \underbrace{\tfrac{3}{2} I_M\, e^{j\omega t}}_{\bar{i}}\, e^{-j\gamma}\right)$$

FASORE SPAZ. CORR (NATURALE)

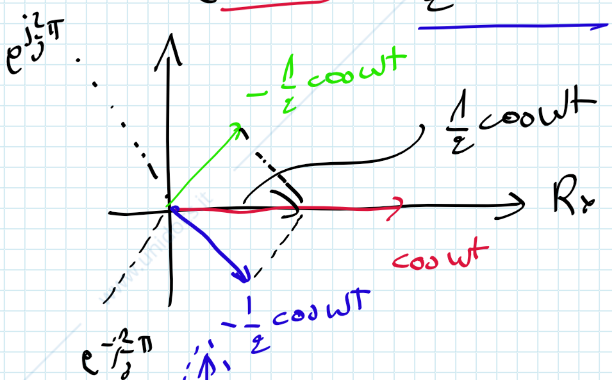
$$\bar{i} = (i_1 + \alpha i_2 + \alpha^2 i_3) \qquad \alpha = e^{j\frac{2}{3}\pi}$$

$$\bar{i} = \Big(I_M\cos\omega t + I_M\cos\left(\omega t - \tfrac{2}{3}\pi\right)\overbrace{e^{j\frac{2}{3}\pi}}^{\alpha} + I_M\cos\left(\omega t + \tfrac{2}{3}\pi\right)\overbrace{e^{-j\frac{2}{3}\pi}}^{\alpha^2}\Big)$$

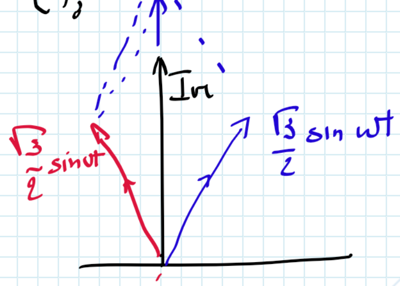
$$= I_M\cos\omega t + I_M\Big(\cos\omega t\,\overbrace{\cos\tfrac{2}{3}\pi}^{-1/2} + \sin\omega t\,\overbrace{\sin\tfrac{2}{3}\pi}^{\sqrt{3}/2}\Big)e^{j\frac{2}{3}\pi} + I_M\Big(\cos\omega t\cos\tfrac{2}{3}\pi -$$
$$- \sin\omega t\sin\tfrac{2}{3}\pi\Big)e^{-j\frac{2}{3}\pi} =$$

$$= I_M\Big(\cos\omega t - \tfrac{1}{2}\cos\omega t\,\overbrace{e^{j\frac{2}{3}\pi}}^{\alpha} - \tfrac{1}{2}\cos\omega t\,\overbrace{e^{j\frac{4}{3}\pi}}^{\alpha^2}\Big) + I_M\Big(\tfrac{\sqrt{3}}{2}\sin\omega t\, e^{j\frac{2}{3}\pi} -$$
$$- \tfrac{\sqrt{3}}{2}\sin\omega t\, e^{-j\frac{2}{3}\pi}\Big)$$

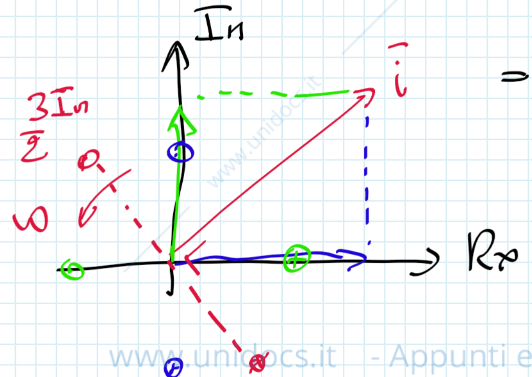
$$= I_M\Big(\cos\omega t - \tfrac{1}{2}\cos\omega t\,\alpha - \tfrac{1}{2}\cos\omega t\,\alpha^2\Big) + I_M\Big(\tfrac{\sqrt{3}}{2}\sin\omega t\,\alpha - \tfrac{\sqrt{3}}{2}\sin\omega t\,\alpha^2\Big)$$

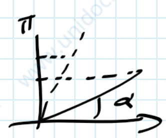


$$\bar{i} = I_M\left(\tfrac{3}{2}\cos\omega t + \tfrac{3}{2} j\sin\omega t\right)$$
$$= \tfrac{3}{2} I_M(\cos\omega t + j\sin\omega t)$$
$$= \tfrac{3}{2} I_M\, e^{j\omega t}$$



$$B(t,\gamma) = \mathrm{Re}\Big(\overbrace{\tfrac{4}{\pi}\tfrac{N}{2\delta}\mu_0\tfrac{3}{2}}^{K} I_M(\cos\omega t + j\sin\omega t)\,e^{-j\gamma}\Big)$$
$$= \mathrm{Re}\left(K I_M\cos\omega t\, e^{-j\gamma}\right) + \mathrm{Re}\left(K j I_M\sin\omega t\, e^{-j\gamma}\right)$$
$$= \mathrm{Re}\left(K I_M\cos\omega t\, e^{-j\gamma}\right) + \mathrm{Re}\left(K I_M\sin\omega t\, e^{-j\gamma} e^{j\frac{\pi}{2}}\right)$$





$$\sin\omega t = \cos\left(\omega t - \tfrac{\pi}{2}\right)$$

$$B(t,\gamma) = B_1 + B_2$$

R_a $\leftarrow I_M$

$$\boxed{\bar{i}_N = (i_a + i_b\alpha + i_c\alpha^2)} \rightarrow \bar{i} = \sqrt{\frac{2}{3}}(i_a + i_b\alpha + i_c\alpha^2)$$

NATURALE — RAZIONALE

MANTIENE INALT LE POT.

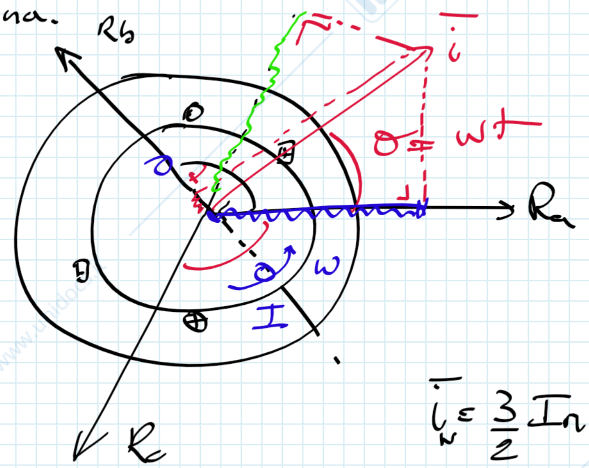
$$B(t,\gamma) = Re\left(\frac{4}{\pi}\frac{N}{2\delta}\mu_0\sqrt{\frac{3}{2}}\,\bar{i}\,e^{-j\gamma}\right)$$

$$p = \bar{v}\cdot\bar{i}$$

$\bar{i}$ ↓

La sua proiezione sull'asse della bobina ≡ al valore istantaneo della corrente che passa nella bobina.

$$i_a = I_M\cos\omega t$$
$$i_b = I_M\cos\left(\omega t - \frac{2\pi}{3}\right)$$
$$i_c = I_M\cos\left(\omega t + \frac{2\pi}{3}\right)$$



$$i_A = \sqrt{\frac{2}{3}}Re(\bar{i})$$
$$i_B = \sqrt{\frac{2}{3}}Re\left(\bar{i}\,e^{-j\frac{2}{3}\pi}\right)$$

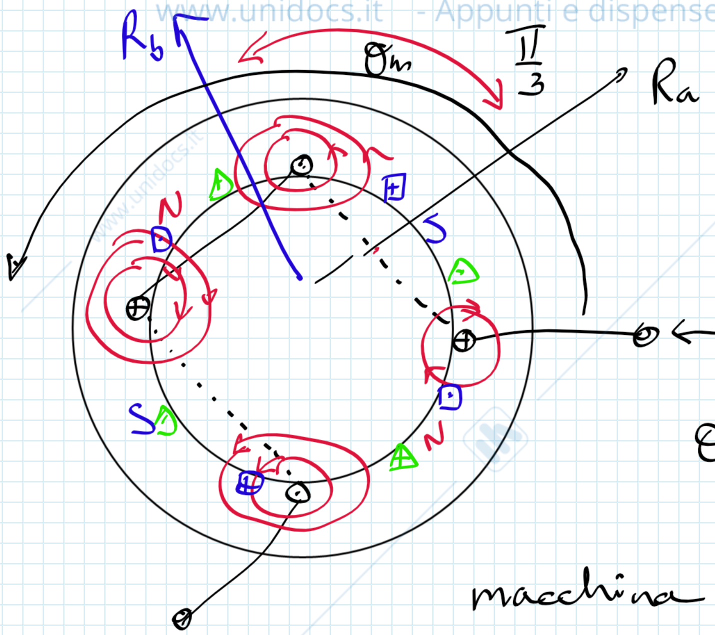
$$\bar{i}_N = \frac{3}{2}I_M e^{j\omega t}$$
$$\bar{i} = \sqrt{\frac{3}{2}}I_M e^{j\omega t}$$

$$\boxed{\text{SFAS. SPAZ} \leftrightarrows \text{SF. TEMP.}}$$

$$i_A = \sqrt{\frac{2}{3}}Re\left(\sqrt{\frac{3}{2}}I_M e^{j\omega t}\right) = I_M\cos\omega t$$
$$i_b = \sqrt{\frac{2}{3}}Re\left(\sqrt{\frac{3}{2}}I_M e^{j\omega t}e^{-j\frac{2}{3}\pi}\right) = I_M\cos\left(\omega t - \frac{2}{3}\pi\right)$$
$$i_c = \sqrt{\frac{2}{3}}Re\left(\sqrt{\frac{3}{2}}I_M e^{j\omega t}e^{j\frac{2}{3}\pi}\right) = I_M\cos\left(\omega t + \frac{2}{3}\pi\right)$$

$$I = \sqrt{\frac{2}{3}}Re\left(\sqrt{\frac{3}{2}}I_M \cancel{e^{j\omega t}}\,\cancel{e^{-j\omega t}}\right) = I_M$$

T.



4 poli

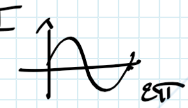
angolo in rad. mecc.

$\theta_m = \frac{\pi}{3}$

n poli

$p =$ coppie polari $= \frac{4}{2}$

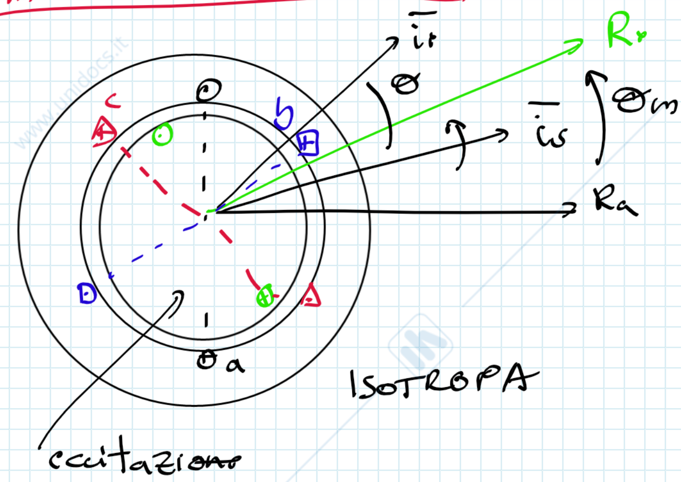
$i_a = I_M \cos(\omega t)$



$$\theta_m = \frac{\theta_e}{p} \Rightarrow \boxed{\omega_m = \frac{\omega}{p}}$$

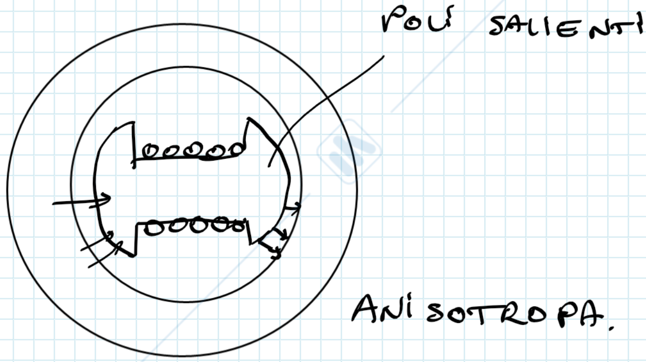
macchina eq. a 2 poli.

Macchina Sincrona



MACCHINA SINCRONA ISOTROPA

ISOTROPA = stesso traferro in tutte le direzioni.



$$\begin{cases} v_a = L_{aa}\dfrac{di_a}{dt} + L_{ab}\dfrac{di_b}{dt} + L_{ac}\dfrac{di_c}{dt} + \dfrac{d\psi_{ae}}{dt} \\ v_b = L_{bb}\dfrac{di_b}{dt} + L_{ab}\dfrac{di_a}{dt} + L_{bc}\dfrac{di_c}{dt} + \dfrac{d\psi_{be}}{dt} \\ v_c = L_{cc}\dfrac{di_c}{dt} + L_{ac}\dfrac{di_a}{dt} + L_{bc}\dfrac{di_b}{dt} + \dfrac{d\psi_{ce}}{dt} \end{cases}$$

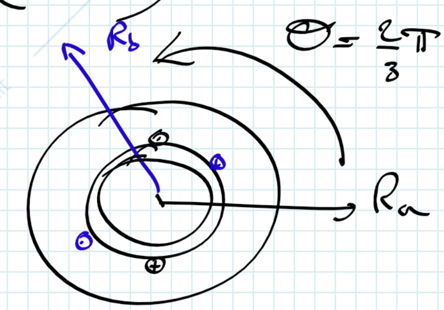
TRASF DI CLARK ←
(TRASF. DI PARK)

$$\bar{i} = \sqrt{\frac{2}{3}}\left(i_a + \alpha i_b + \alpha^2 i_c\right)$$

$$\bar{v} = \sqrt{\frac{2}{3}}\left(v_a + v_b\alpha + v_c\alpha^2\right) \Rightarrow$$

$$v_a = \sqrt{\frac{2}{3}}\,R_e(\bar{v}) \qquad v_b = \sqrt{\frac{2}{3}}\,R_e\left(\bar{v}\,e^{-j\frac{2}{3}\pi}\right)$$

$$v_c = \sqrt{\frac{2}{3}}\left(\bar{v}\,e^{+j\frac{2}{3}\pi}\right)$$



$$v_a = L_{aa}\frac{di_a}{dt} + L_{ab}\frac{di_b}{dt} + L_{ac}\frac{di_c}{dt} + \dots$$

$$= L\frac{di_a}{dt} - \frac{L}{2}\frac{di_b}{dt} - \frac{L}{2}\frac{di_c}{dt} + \dots$$

$$= L\frac{di_a}{dt} + \frac{L}{2}\frac{d}{dt}\left(-i_b - i_c\right) + \dots$$

$$= L\frac{di_a}{dt} + \frac{L}{2}\frac{di_a}{dt} + \dots$$

$$L = L_{aa} = L_{bb} = L_{cc}$$

$$L_{ab} = L_{ba} = L\cdot\cos\theta$$
$$= L\cdot\left(-\frac{1}{2}\right)$$

$$i_a + i_b + i_c = 0$$

$$i_a = -i_b - i_c$$

$$\sqrt{\frac{2}{3}}\left(\begin{array}{l} v_a = \dfrac{3}{2}L\dfrac{di_a}{dt} + \dots \\ + \\ \alpha\, v_b = \dfrac{3}{2}L\dfrac{di_b}{dt} + \dots \\ + \\ \alpha^2 v_c = \dfrac{3}{2}L\dfrac{di_c}{dt} + \dots \end{array}\right) \Rightarrow \overbrace{\sqrt{\frac{2}{3}}\left(v_a + \alpha v_b + \alpha^2 v_c\right)}^{\bar{v}_s} = \frac{3}{2}L\frac{d}{dt}\overbrace{\left(i_a + \alpha i_b + \alpha^2 i_c\right)}^{\bar{i}_s}$$

$$\boxed{\bar{v}_s = \frac{3}{2}L\frac{d}{dt}\left(\bar{i}_s\right) +}$$

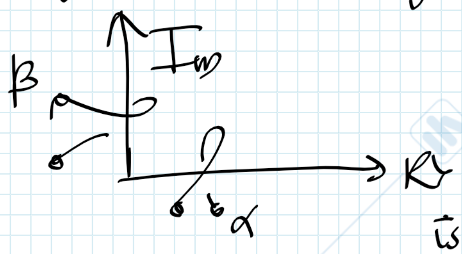
$$\bar{v}_s = \frac{3}{2} L \frac{d\bar{i}_s}{dt} + \dots$$

$v_s = v_\alpha + j v_\beta$ $\qquad$ $\bar{i}_s = i_\alpha + j i_\beta$

$$v_\alpha = \frac{3}{2} L \frac{di_\alpha}{dt} \qquad \text{STATORE}$$

$$v_\beta = \frac{3}{2} L \frac{di_\beta}{dt}$$

L_s = INDUTTANZA SINCRONA

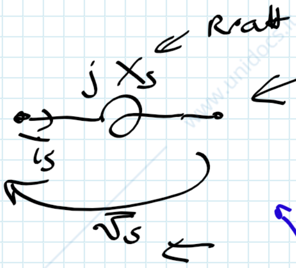


$$\bar{v}_s = v_\alpha + j v_\beta \Rightarrow v_a = \sqrt{\frac{2}{3}} \, Re(\bar{v}_s)$$

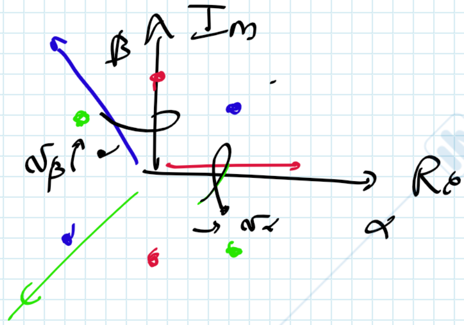
X_s = REATT. SINC

$$\bar{v}_s = L_s \frac{d}{dt}\Big(\underbrace{\sqrt{\tfrac{3}{2}} I_n e^{j\omega t}}_{\bar{i}_s}\Big) = j\omega L_s \underbrace{\sqrt{\tfrac{3}{2}} I_n e^{j\omega t}}_{\bar{i}_s} = j\underbrace{\omega L_s}_{X_s} \bar{i}_s \quad \text{A REGIME}$$

$$\boxed{\bar{v}_s = j X_s \bar{i}_s}$$

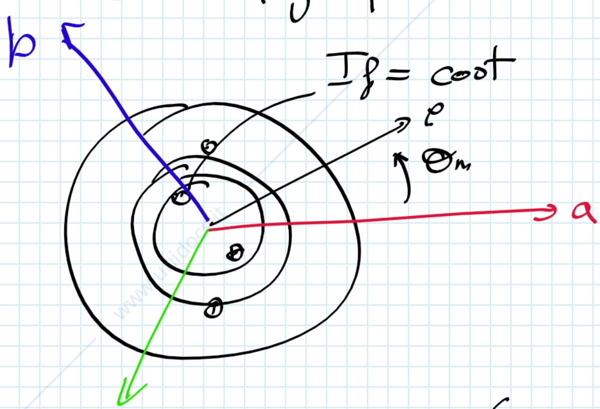


DI TUTTA LA MACCHINA (NON DI UNA FASE!)



$$\bar{v}_s = \sqrt{\frac{2}{3}}\left(v_a + v_b \alpha + v_c \alpha^2\right)$$

$$= v_\alpha + j v_\beta$$

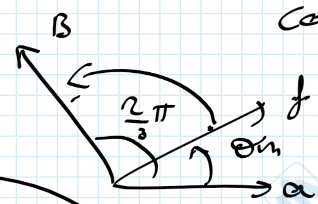


L_f = ind. L_{ar} $\theta_m = 0$

L_{ar}

$$+ \frac{d\psi_{ar}}{dt} \qquad \frac{d\psi_{br}}{dt} \qquad \frac{d\psi_{cr}}{dt}$$

$\cos(x) = \cos(-x)$



$$\sqrt{\frac{2}{3}}\left(\begin{aligned} & v_a = \frac{3}{2} L \frac{di_a}{dt} + \frac{d}{dt}\left(L_f \cos\theta_m \, I_f\right) \\ & + \alpha \\ & v_b = \frac{3}{2} L \frac{di_b}{dt} + \frac{d}{dt}\left(L_f \cos\left(\theta_m - \frac{2}{3}\pi\right) I_f\right) \\ & + \alpha^2 \\ & v_c = \frac{3}{2} L \frac{di_c}{dt} + \frac{d}{dt}\left(L_f \cos\left(\theta_m + \frac{2}{3}\right) I_f\right) \end{aligned}\right)$$

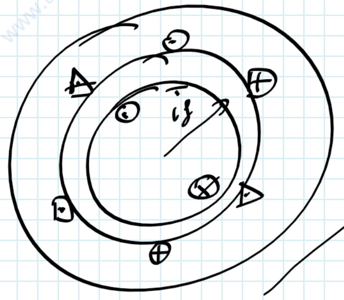
$$\cos\left(\frac{2}{3}\pi - \theta_m\right)$$
$$\cos\left(\theta_m - \frac{2}{3}\pi\right)$$

somma - sott

$$\dots + L_f I_f \frac{d}{dt}\Big(\underbrace{\cos\theta_m + \alpha\cos\left(\theta_m - \frac{2}{3}\pi\right) + \alpha^2\cos\left(\theta_m + \frac{2}{3}\pi\right)}_{\frac{3}{2}(\cos\theta_m + j\sin\theta_m)}\Big)$$

$$\bar{v}_s = \frac{3}{2} L_s \frac{d\bar{i}_s}{dt} + L_f I_f \frac{d}{dt}\left(\frac{3}{2}\cos\vartheta_m + j\sin\vartheta_m\right)\sqrt{\frac{2}{3}}$$

$\bar{i}_s = 0$ (statore aperto)



$$\bar{v}_s = \sqrt{\frac{2}{3}} L_f \bar{I}_f \frac{d}{dt}\left(\frac{3}{2}\cos\vartheta_m + j\sin\vartheta_m\right) =$$

$$= \sqrt{\frac{2}{3}} L_f I_f \frac{d}{dt}\left(\frac{3}{2} e^{j\vartheta_m}\right)$$

$$\boxed{\vartheta_m = \omega t}$$

$$= j\omega L_f \underbrace{\sqrt{\frac{2}{3}}\,\frac{3}{2} I_f e^{j\omega t}}$$

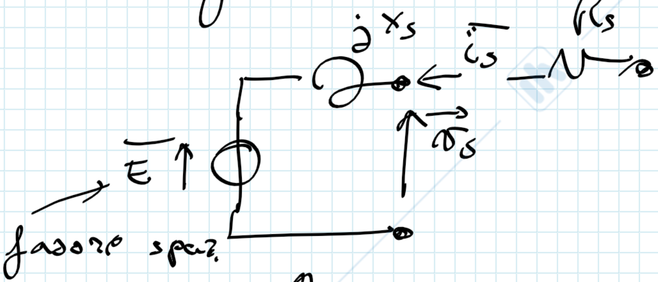
cost.

$$\boxed{\bar{i}_f = \sqrt{\frac{3}{2}} I_f e^{j\omega t}}$$

$$= j\omega L_f \bar{i}_f$$

$$\sqrt{\frac{2}{3}}\,\mathrm{Re}\left(\bar{v}_s\right) = v_a$$

$$\bar{v}_s = jX_s\bar{i}_s + \underbrace{j\underbrace{\omega L_f}_{X_f} \cdot \bar{i}_f}_{\bar{E}} \Rightarrow \bar{v}_s = jX_s\bar{i}_s + \bar{E}$$



$$\boxed{\text{Costruzione di Behn-Eschenburg}}$$