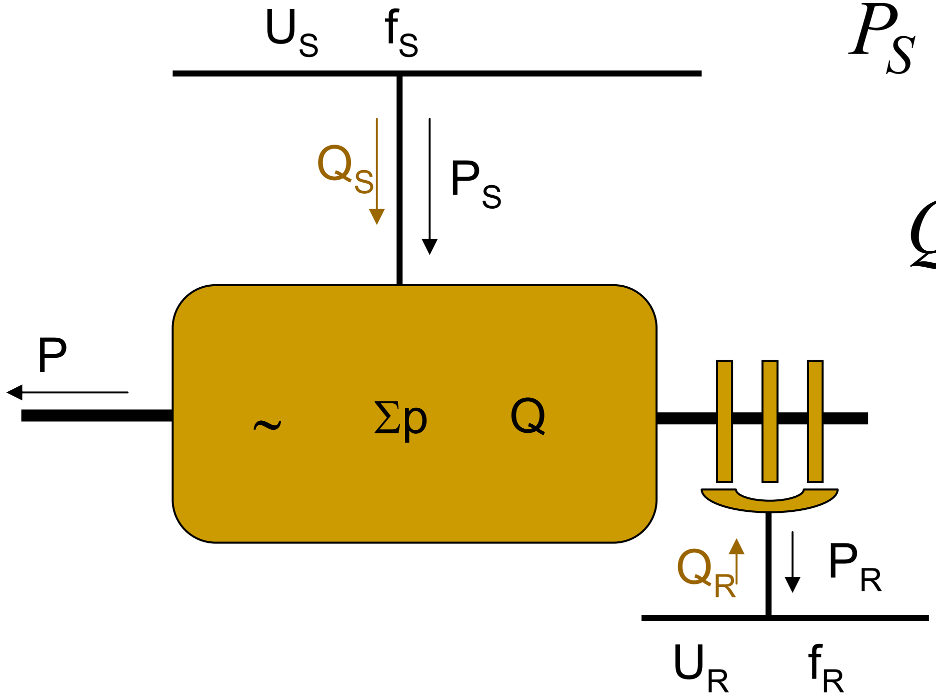
Regimuri speciale ale maşinii de inducţie

Regimul de dublă alimentare

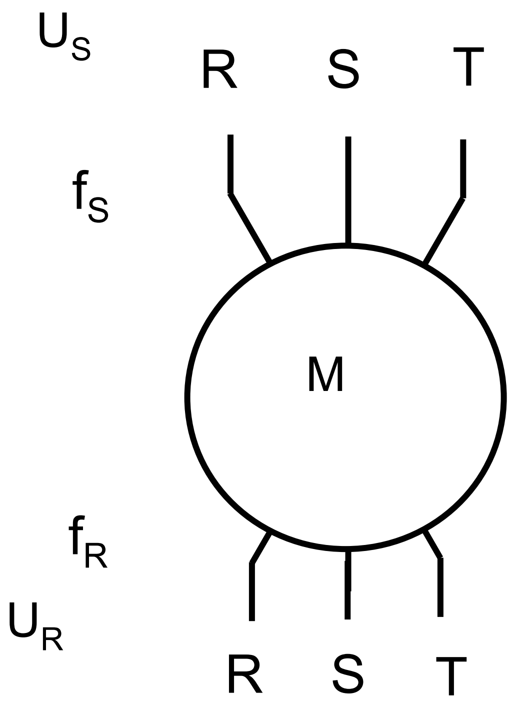
Dubla alimentare



$$P_S + P_R + P + \sum p = 0$$

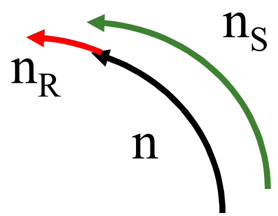
$$Q_S + Q_R + Q = 0$$

Conditii de dublă alimentare



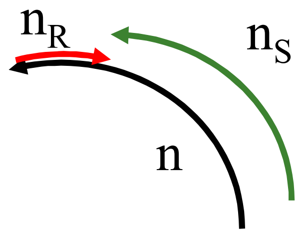
$$n_S = n \pm n_R$$

Aceeasi succesiune



$$n < n_S$$

Succesiune diferită



$$n > n_S$$

Cazuri limită

$$f_S = f_R$$

Aceeasi succesiune

$$n = 0$$

Succesiune diferită

$$n = 2 \cdot n_S$$

$$f_R = 0$$

$$n = n_S$$

Maşina sincronă

Studiul analitic

Cazul general

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

$$\underline{U}_R = \underline{Z}_R \cdot \underline{I}_R - s \cdot \underline{E}_S$$

$$\underline{E}_S = -\underline{Z}_m \cdot \underline{I}_m$$

$$\underline{I}_m = \underline{I}_S + \underline{I}_R$$

$$\underline{I}_S = \frac{\underline{U}_S \cdot \left(\underline{Z}_{Rs} + \underline{Z}_m\right) - \frac{\underline{U}_R}{s}\underline{Z}_m}{\underline{Z}_S \cdot \underline{Z}_{Rs} + \underline{Z}_m \cdot \left(\underline{Z}_S + \underline{Z}_{Rs}\right)}$$

$$\underline{I}_R = \frac{\frac{\underline{U}_R}{s} \cdot \left(\underline{Z}_S + \underline{Z}_m\right) - \underline{U}_S \cdot \underline{Z}_m}{\underline{Z}_S \cdot \underline{Z}_{Rs} + \underline{Z}_m \cdot \left(\underline{Z}_S + \underline{Z}_{Rs}\right)}$$

Studiul analitic

$$\underline{U}_R = \frac{1}{k}\underline{U}_S \cdot e^{-j\upsilon}$$

$$\underline{I}_S = \frac{\left(\underline{Z}_{Rs} + \underline{Z}_m\right) - \frac{e^{-j\upsilon}}{k \cdot s}\underline{Z}_m}{\underline{Z}_S \cdot \underline{Z}_{Rs} + \underline{Z}_m \cdot \left(\underline{Z}_S + \underline{Z}_{Rs}\right)}\underline{U}_S$$

$$\underline{Z}_{Rs} = \frac{R_R}{s} + jX_{R\sigma}$$

$$\underline{I}_R = \frac{\frac{e^{-j\upsilon}}{k \cdot s} \cdot \left(\underline{Z}_S + \underline{Z}_m\right) - \underline{Z}_m}{\underline{Z}_S \cdot \underline{Z}_{Rs} + \underline{Z}_m \cdot \left(\underline{Z}_S + \underline{Z}_{Rs}\right)}\underline{U}_S$$

$$e^{-j\upsilon} = \cos\upsilon - j\sin\upsilon$$

Curenții variază cu amplitudinea şi faza tensiunii rotorice

Studiul analitic

$$\underline{I}_R = \frac{\frac{e^{-j\upsilon}}{k}\cdot\left(\underline{Z}_S + \underline{Z}_m\right) - s\cdot\underline{Z}_m}{s\cdot\underline{Z}_S\cdot\underline{Z}_m + s\cdot\underline{Z}_{Rs}\cdot\left(\underline{Z}_S + \underline{Z}_m\right)}\underline{U}_S$$

$$s \rightarrow 0$$

$$\underline{I}_R = \frac{\frac{e^{-j\upsilon}}{k}}{R_R}\underline{U}_S \neq 0$$

Există curent, cuplu la viteza de sincronism (maşina sincronă)

Cuplul devine nul atunci când curentul rotoric este nul

$$\underline{I}_R = 0 = \frac{e^{-j\upsilon}}{k}\cdot\left(\underline{Z}_S + \underline{Z}_m\right) - s\cdot\underline{Z}_m$$

$$s_0 = \frac{\underline{C}_S}{k}e^{-j\upsilon}$$

Alunecarea la cuplu, curent rotoric nul

Studiul analitic

$$\underline{C}_S = C_S \cdot e^{j\delta}$$

$$s_0 = \frac{C_S}{k}\cos(\delta - \upsilon)$$

$$0 = \sin(\delta - \upsilon)$$

$$\delta - \upsilon = k \cdot \pi \qquad \delta \cong 0 \qquad \Rightarrow \qquad \upsilon \cong 0, \pi$$

Deci $\underline{U}_S$ si $\underline{U}_R$ sunt în fază sau în opoziție de fază

Alunecarea la cuplu zero

$$s_0 \cong \frac{C_S}{k}$$

Deci se modifică turația

Dacă $\upsilon \cong \frac{\pi}{2}$

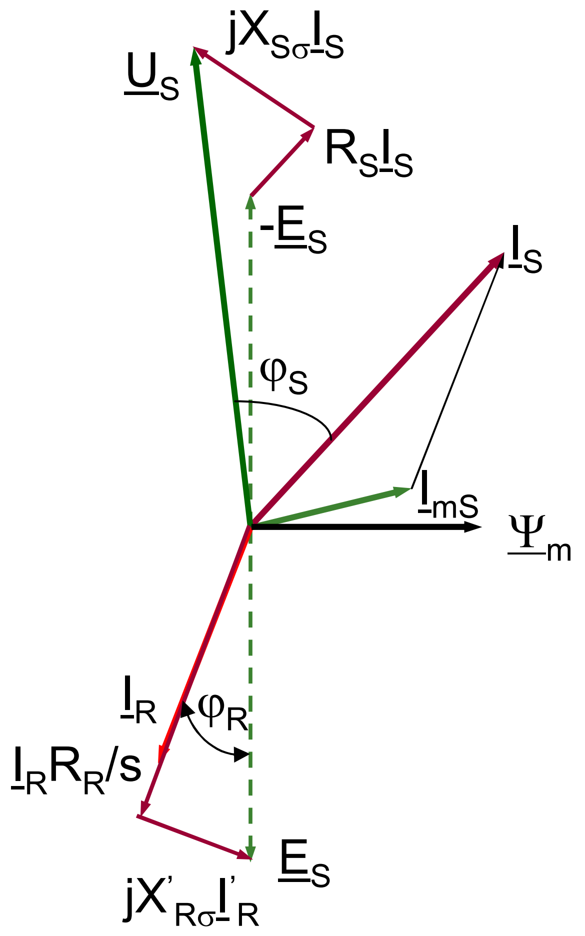
$$s_0 \cong 0$$

Nu se modifică turația

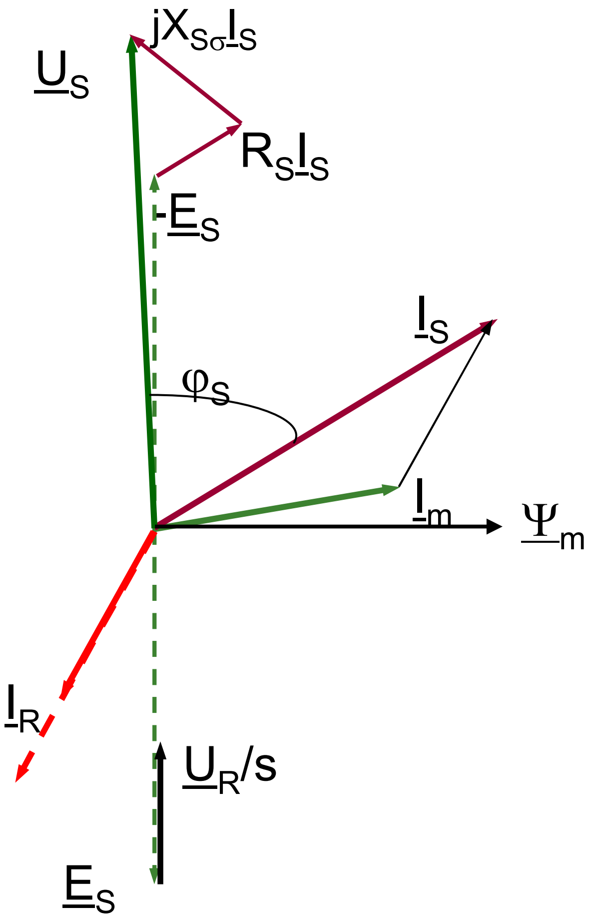
Diagrama vectoriala

$$\underline{I}_R = \frac{\underline{E}_S}{\underline{Z}_{Rs}} + \frac{\frac{\underline{U}_R}{s}}{\underline{Z}_{Rs}}$$

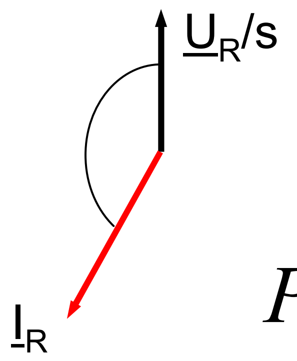
$$\underline{I}_R = \frac{\underline{E}_S}{\underline{Z}_{Rs}} e^{-j\varphi_R} + \frac{\underline{U}_R}{s \cdot \underline{Z}_{Rs}}$$



Studiul analitic.Tensiune în fază cu cea statorică



$$\underline{I}_R = \frac{\underline{E}_S + \underline{U}_R}{Z_{Rs}} e^{-j\varphi_R}$$



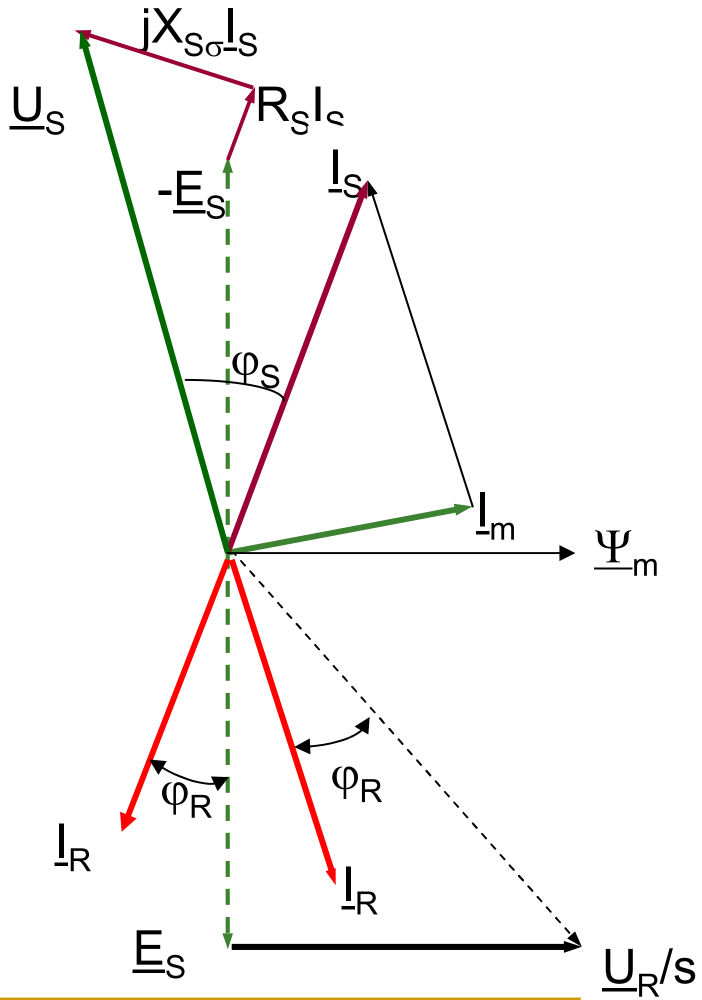
$P_R < 0$

$Q_R < 0$

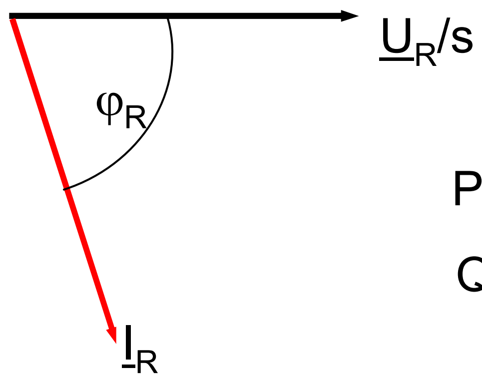
$$P = P_S + P_R - \sum p$$

$$Q = Q_S + Q_R$$

Studiul analitic.Tensiune defazată față de cea statorică



$$\underline{I}_R = \frac{\underline{E}_S + \underline{U}_R}{Z_{Rs}} e^{-j\varphi_R}$$



$P_R > 0$

$Q_R > 0$

$$P = P_S + P_R - \sum p$$

$$Q = Q_S + Q_R$$

Rezistenta in rotor

$$\underline{U}_R = -R \cdot \underline{I}_R$$

$$\underline{I}_R = \frac{-\underline{Z}_m}{\underline{Z}_S \cdot \underline{Z}_{Rms} + \underline{Z}_m \cdot \left(\underline{Z}_S + \underline{Z}_{Rms}\right)} \underline{U}_S$$

$$\underline{Z}_{Rms} = \frac{R_R + R}{s} + j(X_{R\sigma} + X)$$

Se modifică parametrii rotorului

Identificarea parametrilor k, υ $\Rightarrow$ R, X

$$\frac{1}{k} e^{-j\upsilon} = \frac{\underline{Z}_m \cdot (R + jX)}{\underline{Z}_S \cdot \underline{Z}_{Rms} + \underline{Z}_m \cdot \left(\underline{Z}_S + \underline{Z}_{Rms}\right)}$$

Caracteristici

Alunecarea critică

$$s_k = \frac{c_S \cdot (R_R' + R')}{\pm\sqrt{R_S^2 + \left(X_{S\sigma} + c_S \cdot (X_{R\sigma}' + X')\right)^2}} \qquad \varepsilon = \frac{s_k \cdot R_S}{c_S \cdot R_R'} = \frac{R_S}{\pm\sqrt{R_S^2 + \left(X_{S\sigma} + c_S \cdot (X_{R\sigma}' + X')\right)^2}}$$

Cuplul maxim

$$T_k = \frac{p \cdot m_S}{\omega_S} \frac{U_S^2}{2 \cdot c_S} \frac{1}{R_S \pm \sqrt{R_S^2 + \left(X_{S\sigma} + c_S \cdot (X_{R\sigma}' + X')\right)^2}}$$

Caracteristica mecanica

$$\frac{T}{T_k} = \frac{2 \cdot (1 + \varepsilon)}{\frac{s}{s_k} + \frac{s_k}{s} + 2 \cdot \varepsilon}$$

Exemplu

Parametrii maşinii de inducție:

$rs := 1.1 \quad \Omega$ $\qquad$ $rr := 1.4 \quad \Omega$ $\qquad$ $rm := 2.8 \quad \Omega$

$xs\sigma := 2.4 \quad \Omega$ $\qquad$ $xr\sigma := 3 \quad \Omega$ $\qquad$ $xm := 39.8 \quad \Omega$

$U_S = 220$ V $\qquad$ K = 15 $\qquad$ $\upsilon = 45^{0}$

Impedantele motorului $\qquad$ $Zs := Rs + Xs\sigma \cdot i$ $\qquad$ $Zm := Rm + Xm \cdot i$

$$cs := \frac{(Zs + Zm)}{Zm} \qquad cs = 1.062 - 0.023i$$

$$\delta := \arg(cs) \qquad \delta = -0.022$$

Exemplu

Tensiunea rotorică

$$Ur := \frac{Us \cdot \exp(-i \cdot \upsilon)}{k}$$

$$Ur = 6.223 - 6.223i$$

Alunecarea de mers în gol

$$s := |cs| \cdot \frac{(\cos(\delta - \upsilon))}{k}$$

$$s = 0.029$$

alunecarea

$$s := 0.06$$

Impedanța rotorică

$$Zrd := Xr\sigma \cdot i + \frac{Rr}{s}$$

$$Zrd = 23.333 + 3i$$

Exemplu

$$Ze := \frac{\exp(-i \cdot \upsilon) \cdot (Zrd \cdot cs + Zs)}{k}$$

$$Ze = 0.877 - 0.591i$$

$$a := 1 - \frac{\cos(\upsilon)}{s \cdot k}$$

$$a = 0.529$$

$$b := \frac{-\sin(\upsilon)}{s \cdot k}$$

$$b = -0.471$$

$$c := 1 - \frac{\cos(\upsilon)}{k}$$

$$c = 0.972$$

$$d := \frac{-\sin(\upsilon)}{k}$$

$$d = -0.028$$

Exemplu

Parametrii echivalenți dependenți de sarcină

$$X := \frac{\left(\mathrm{Re}(Ze) + a \cdot \frac{\mathrm{Im}(Ze)}{b}\right)}{d + a \cdot \frac{c}{b}} \qquad X = -1.377$$

$$R := \frac{\mathrm{Re}(Ze) - d \cdot X}{a} \qquad R = 1.585$$

Exemplu

Cuplul electromagnetic

$$Te := \frac{\dfrac{\left[3 \cdot p \cdot Us^2 \cdot \dfrac{(R+Rr)}{s}\right]}{100 \cdot \pi}}{\left[Rs + \dfrac{(Rr + R) \cdot |cs|}{s}\right]^2 + \left[Xs\sigma + (X + Xr\sigma) \cdot |cs|\right]^2}$$

Curentul

$Te = 23.57$ Nm

$$Is := \frac{\left[(Zrd + Zm) \cdot Us - Ur \cdot \dfrac{Zm}{s}\right]}{Zs \cdot Zrd + Zm \cdot (Zs + Zrd)}$$

$Is = 5.097 - 1.895i$

Factorul de putere

$$\cos\phi := \frac{Re(Is)}{|Is|}$$

$\cos\phi = 0.937$

Exemplu

Tensiunea rotorică

$k := 25$ $\upsilon := \pi$ $Ur = -8.8$

Alunecarea de mers în gol

$s0 = -0.042$

Cuplul electromagnetic

$Te = 52.119$ Nm

Curentul statoric

$|Is| = 9.346$ A

Factorul de putere

$\cos\phi = 0.827$

Exemplu

Tensiunea rotorică

$k := 25$

$\upsilon := \frac{-\pi}{2}$ $Ur = 8.8i$ V

$\upsilon := \frac{\pi}{2}$ $Ur = -8.8i$ V

Alunecarea de mers în gol

$s0 = 9.312 \times 10^{-4}$ $s0 = -9.312 \times 10^{-4}$

Cuplul electromagnetic

$Te = 20.405$ Nm

$Te = 16.633$ Nm

Curentul statoric

$|Is| = 11.441$ A

$|Is| = 3.564$ A

Factorul de putere

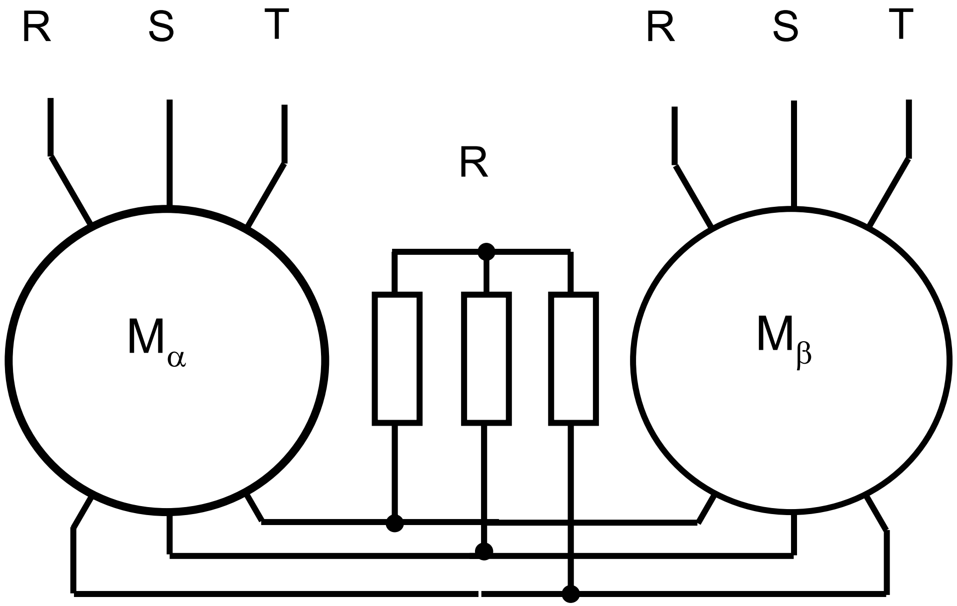
$\cos\phi = 0.254$

$\cos\phi = 0.988$

Regimuri speciale ale maşinii de inducţie

Arbore electric

Arbore electric simplu

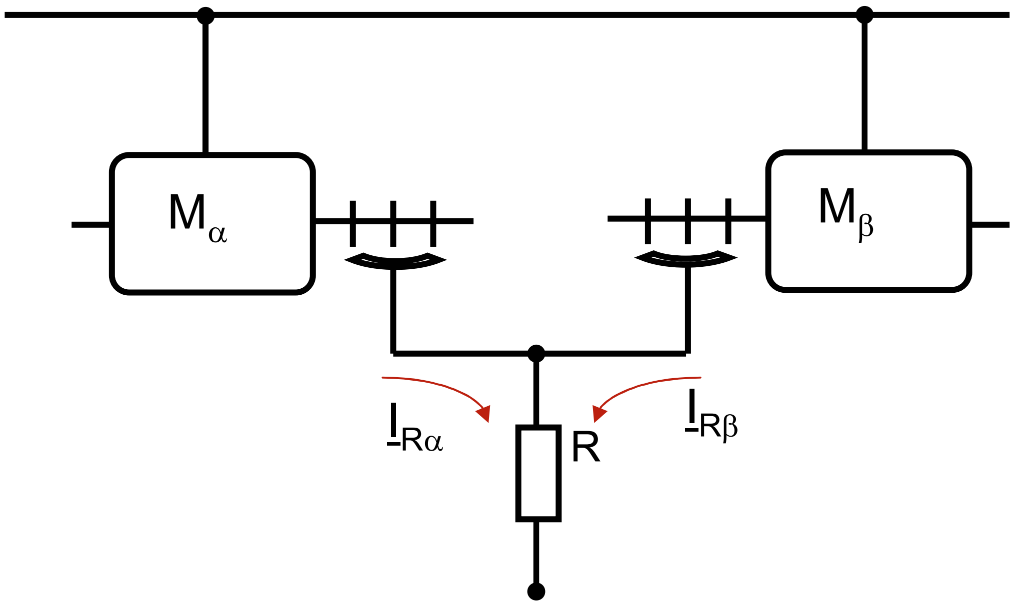


Schema electrică

Două maşini identice

Pot fi şi mai multe maşini, în acest caz unul este de putere = ΣP,

Arbore electric



Schema electrică monofilară

Ecuații în regim permanent sinusoidal

Ecuații în regim permanent sinusoidal

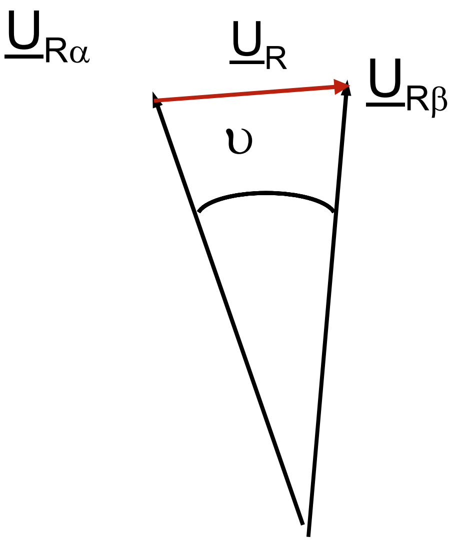
$$\underline{U}_S = \underline{Z}_{S\alpha}\underline{I}_{S\alpha} + \underline{Z}_{m\alpha}\left(\underline{I}_{S\alpha} + \underline{I}_{R\alpha}\right)$$

$$\frac{\underline{U}_{R\alpha}}{s} = \underline{Z}_{Rs\alpha}\underline{I}_{R\alpha} + \underline{Z}_{m\alpha}\left(\underline{I}_{S\alpha} + \underline{I}_{R\alpha}\right)$$

$$\underline{U}_S = \underline{Z}_{S\beta}\underline{I}_{S\beta} + \underline{Z}_{m\beta}\left(\underline{I}_{S\beta} + \underline{I}_{R\beta}\right)$$

$$\frac{\underline{U}_{R\beta}}{s} = \underline{Z}_{Rs\beta}\underline{I}_{R\beta} + \underline{Z}_{m\beta}\left(\underline{I}_{S\beta} + \underline{I}_{R\beta}\right)$$

Tensiunea rotorică



$$\frac{\underline{U}_{R\alpha}}{\underline{U}_{R\beta}} = e^{j\upsilon}$$

$$\underline{U}_R = \underline{U}_{R\beta} - \underline{U}_{R\alpha} = \underline{U}_{R\beta}\left(1 - e^{j\upsilon}\right)$$

$$\underline{U}_{R\alpha} = \frac{\underline{U}_R}{1 - e^{j\upsilon}} e^{j\upsilon}$$

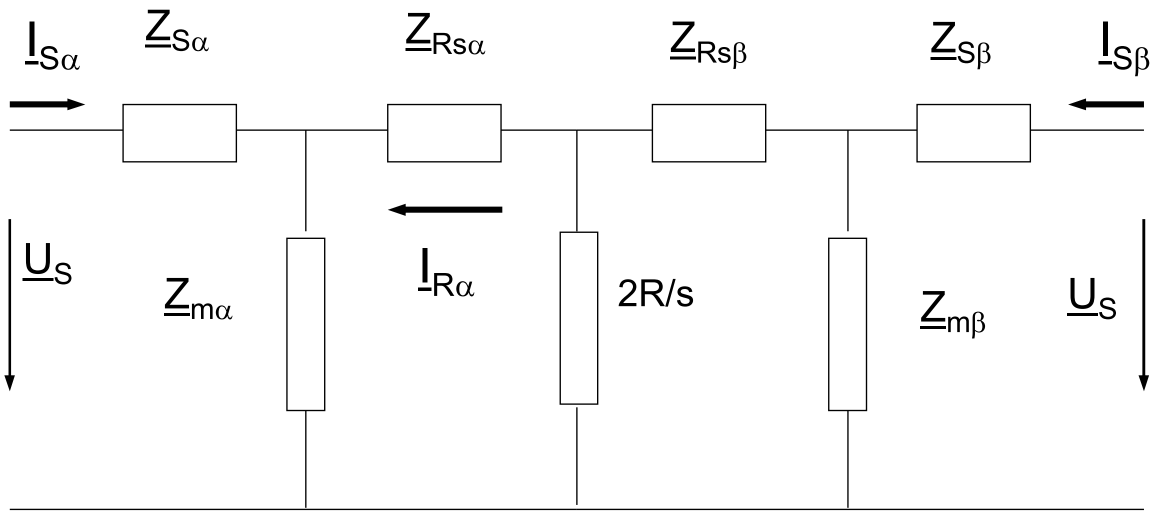
$$\underline{U}_{R\beta} = \frac{\underline{U}_R}{1 - e^{j\upsilon}}$$

Rezistența în circuitul rotoric

$$\underline{U}_R = -R \cdot \left(\underline{I}_{R\alpha} + \underline{I}_{R\beta}\right)$$

Schema echivalentă

$$\underline{U}_R = -R \cdot \left(\underline{I}_{R\alpha} + \underline{I}_{R\beta}\right)$$



$$\underline{I}_S = \frac{\underline{U}_S}{\underline{Z}_S + \underline{Z}_m} - \frac{\underline{Z}_m}{\underline{Z}_S + \underline{Z}_m}\underline{I}_R = \underline{I}_{S0} - \frac{\underline{I}_R}{\underline{C}_S}$$

Expresiile curenților rotorici

Ținând seama de expresia $\underline{U}_R$

$$\frac{-\frac{R}{s}\left(\underline{I}_{R\alpha}+\underline{I}_{R\beta}\right)}{1-e^{j\upsilon}}e^{j\upsilon}=\underline{Z}_{Rs\alpha}\underline{I}_{R\alpha}+\underline{Z}_{m\alpha}\left(\underline{I}_{S\alpha}+\underline{I}_{R\alpha}\right)$$

$$\frac{-\frac{R}{s}\left(\underline{I}_{R\alpha}+\underline{I}_{R\beta}\right)}{1-e^{j\upsilon}}=\underline{Z}_{Rs\beta}\underline{I}_{R\beta}+\underline{Z}_{m\beta}\left(\underline{I}_{S\beta}+\underline{I}_{R\beta}\right)$$

Ținând seama de expresia $\underline{I}_S$

$$-\left(1-e^{j\upsilon}\right)\frac{\underline{U}_S}{\underline{C}_{S\alpha}}=\left(\frac{R}{s}e^{j\upsilon}+\left(\underline{Z}_{Rs\alpha}+\underline{Z}_{m\alpha}\left(1-\frac{1}{\underline{C}_{S\alpha}}\right)\right)\cdot\left(1-e^{j\upsilon}\right)\right)\cdot\underline{I}_{R\alpha}+\frac{R}{s}\underline{I}_{R\beta}e^{j\upsilon}$$

$$-\left(1-e^{j\upsilon}\right)\frac{\underline{U}_S}{\underline{C}_{S\beta}}=\frac{R}{s}\underline{I}_{R\alpha}+\left(\frac{R}{s}+\left(\underline{Z}_{Rs\beta}+\underline{Z}_{m\beta}\left(1-\frac{1}{\underline{C}_{S\beta}}\right)\right)\cdot\left(1-e^{j\upsilon}\right)\right)\cdot\underline{I}_{R\beta}$$

Expresia curentului rotoric

Considerând maşinile identice şi notând

$$\underline{Z}_{Rs\alpha}+\underline{Z}_{m\alpha}\left(1-\frac{1}{\underline{C}_{S\alpha}}\right)=\underline{Z}_{scR\alpha}=\frac{R_R}{s}+jX_{R\sigma}+\frac{\underline{Z}_S\cdot\underline{Z}_m}{\underline{Z}_S+\underline{Z}_m}$$

Rezultă sistemul de ecuaţii:

$$-\left(1-e^{j\upsilon}\right)\frac{\underline{U}_S}{\underline{C}_S}=\left(\frac{R}{s}e^{j\upsilon}+\underline{Z}_{scR}\cdot\left(1-e^{j\upsilon}\right)\right)\cdot\underline{I}_{R\alpha}+\frac{R}{s}\underline{I}_{R\beta}e^{j\upsilon}$$

$$-\left(1-e^{j\upsilon}\right)\frac{\underline{U}_S}{\underline{C}_S}=\frac{R}{s}\underline{I}_{R\alpha}+\left(\frac{R}{s}+\underline{Z}_{scR}\cdot\left(1-e^{j\upsilon}\right)\right)\cdot\underline{I}_{R\beta}$$

Determinantul sistemului de ecuaţii

$$\Delta=\left(\frac{R}{s}e^{j\upsilon}+\underline{Z}_{scR}\cdot\left(1-e^{j\upsilon}\right)\right)\cdot\left(\frac{R}{s}+\underline{Z}_{scR}\cdot\left(1-e^{j\upsilon}\right)\right)-\left(\frac{R}{s}\right)^2\cdot e^{j\upsilon}$$

$$\Delta=\left(\frac{R}{s}\cdot\underline{Z}_{scR}\cdot\left(1+e^{j\upsilon}\right)+\left(\underline{Z}_{scR}\cdot\left(1-e^{j\upsilon}\right)\right)^2\right)\cdot\left(1-e^{j\upsilon}\right)$$

Cuplul electromagnetic

$$\Delta_{I_R} = -\left(1-e^{j\upsilon}\right)\frac{\underline{U}_S}{\underline{C}_S}\cdot\left[\left(\frac{R}{s}+\underline{Z}_{scR}\cdot\left(1-e^{j\upsilon}\right)\right)-\frac{R}{s}e^{j\upsilon}\right]$$

Curentul din rotor

$$\underline{I}_{R\alpha} = \frac{\underline{U}_S}{\underline{C}_S}\frac{\frac{R}{s}+\underline{Z}_{scR}}{\frac{R}{s}\underline{Z}_{scR}\frac{1+e^{j\upsilon}}{1-e^{j\upsilon}}+\underline{Z}_{scR}^2} = \frac{\underline{U}_S}{\underline{C}_S}\frac{\frac{R}{s\cdot\underline{Z}_{scR}}+1}{j\frac{\sin\upsilon}{1-\cos\upsilon}\frac{R}{s}+\underline{Z}_{scR}}$$

Cuplul electromagnetic

$$T_\alpha = \frac{3\cdot p}{\omega}X_m\cdot\Im_m\left\{\underline{I}_R^*\cdot\underline{I}_S\right\} = \frac{3\cdot p}{\omega}X_m\cdot\Im_m\left\{\underline{I}_R^*\cdot\underline{I}_{S0}\right\}$$

$$T_\alpha = \frac{\Im_m\left\{\frac{R}{s\cdot\underline{Z}_{scR}}\right\}\cdot\Re_e\left\{\underline{Z}_{scR}\right\}-\left(1+\Re_e\left\{\frac{R}{s\cdot\underline{Z}_{scR}}\right\}\right)\cdot\left(\Im_m\left\{\underline{Z}_{scR}\right\}+\frac{\sin\upsilon}{1-\cos\upsilon}\frac{R}{s}\right)}{\left(\Im_m\left\{\underline{Z}_{scR}\right\}+\frac{\sin\upsilon}{1-\cos\upsilon}\frac{R}{s}\right)^2+\left(\Re_e\left\{\underline{Z}_{scR}\right\}\right)^2}\frac{U_S^2}{C_S^2}$$

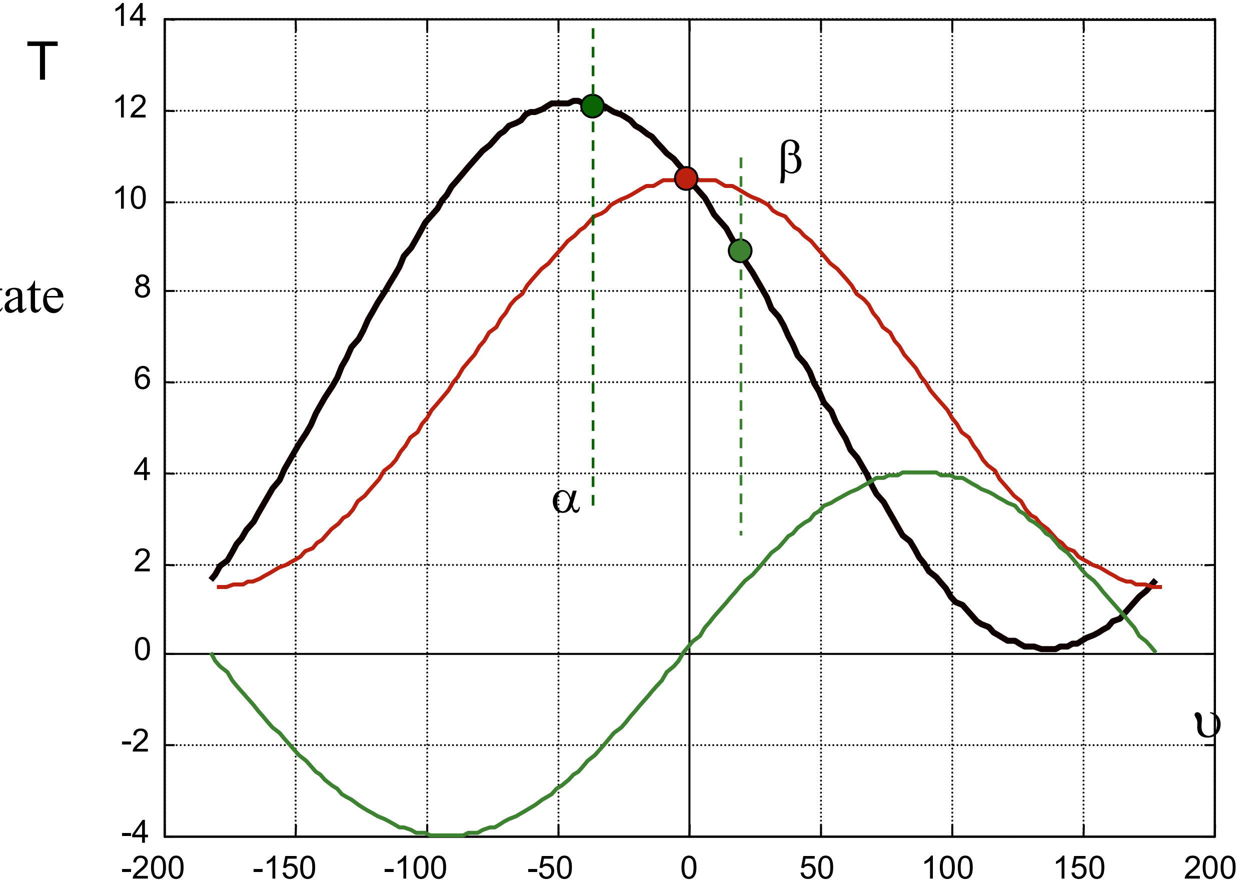
Variația cuplului electromagnetic

$$T = T_k \frac{\underline{A} + \underline{B}\cos\upsilon}{\underline{C}} - T_k \frac{\underline{D}}{\underline{C}}\sin\upsilon$$

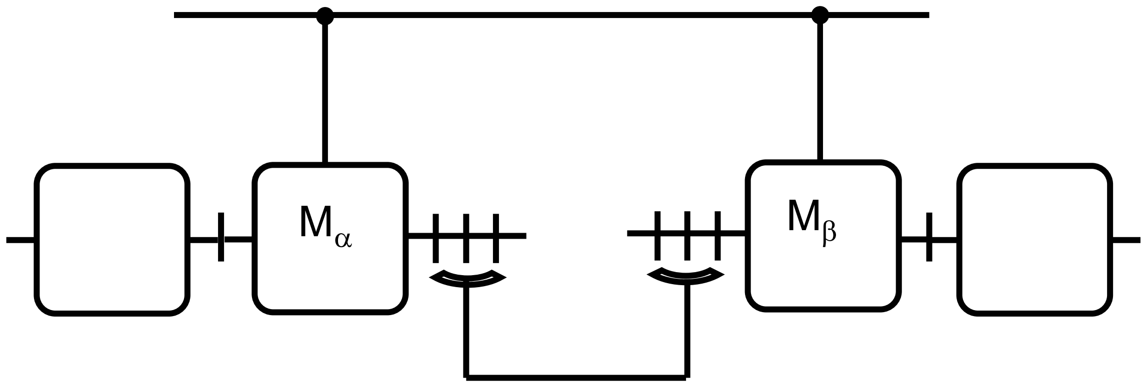
Grad de neuniformitate

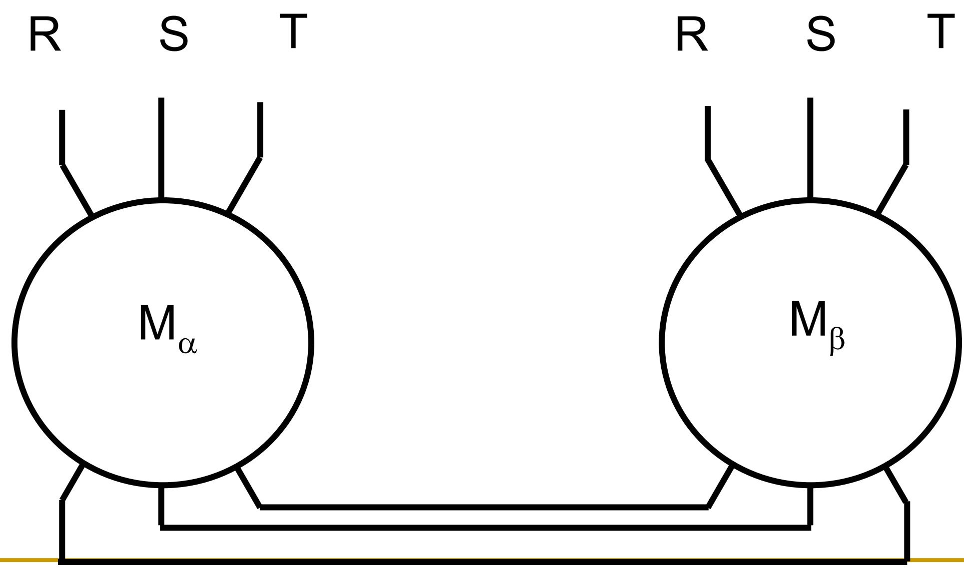
$$\Delta = \frac{T_\alpha - T_\beta}{T_\alpha + T_\beta}$$

$$\Delta \cong 10 \div 15\%$$

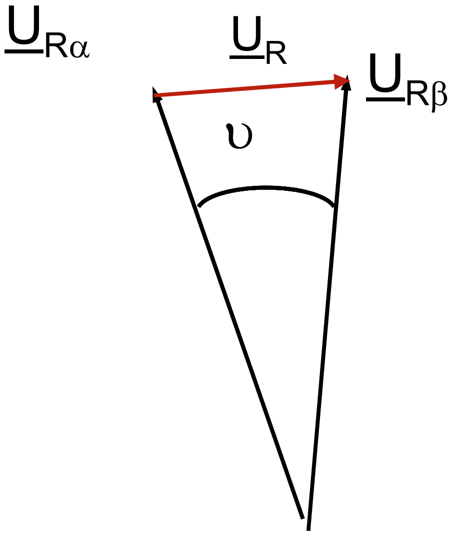


Arbore electric cu maşini de egalizare





Arbore electric cu maşini de egalizare



$$\underline{U}_S = \underline{Z}_{S\alpha} \cdot \underline{I}_{S\alpha} + \underline{Z}_{m\alpha}\left(\underline{I}_{S\alpha} + \underline{I}_{R\alpha}\right)$$

$$\frac{\underline{U}_{R\alpha}}{s} = \underline{Z}_{R\alpha} \cdot \underline{I}_{R\alpha} + \underline{Z}_{m\alpha}\left(\underline{I}_{S\alpha} + \underline{I}_{R\alpha}\right)$$

$$\underline{U}_S = \underline{Z}_{S\beta} \cdot \underline{I}_{S\beta} + \underline{Z}_{m\beta}\left(\underline{I}_{S\beta} + \underline{I}_{R\beta}\right)$$

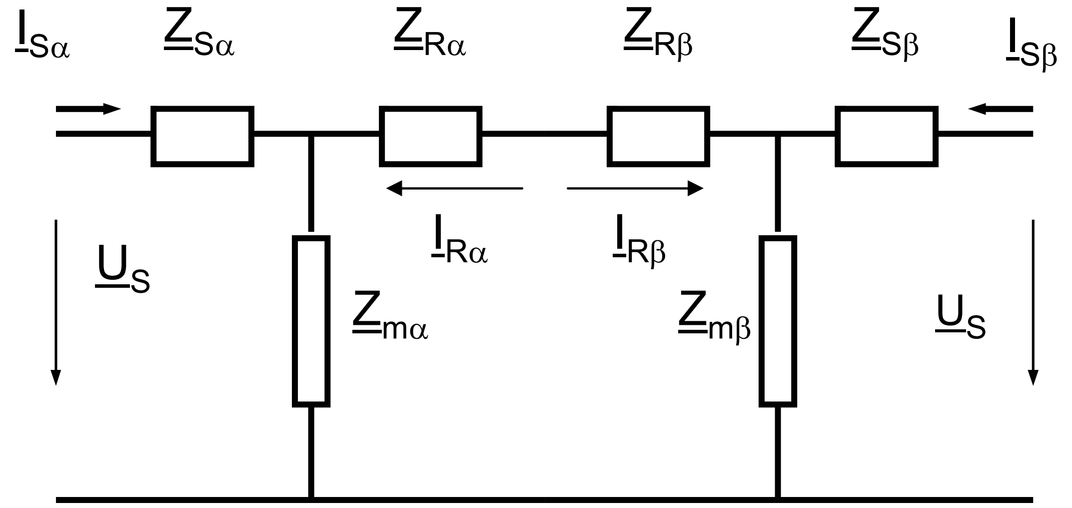
$$\frac{\underline{U}_{R\beta}}{s} = \underline{Z}_{R\beta} \cdot \underline{I}_{R\beta} + \underline{Z}_{m\beta}\left(\underline{I}_{S\beta} + \underline{I}_{R\beta}\right)$$

$$\frac{\underline{U}_{R\alpha}}{\underline{U}_{R\beta}} = e^{j\upsilon}$$

În circuitul rotoric nu este conectat nimic

$$0 = \underline{I}_{R\alpha} + \underline{I}_{R\beta}$$

Arbore electric cu maşini de egalizare

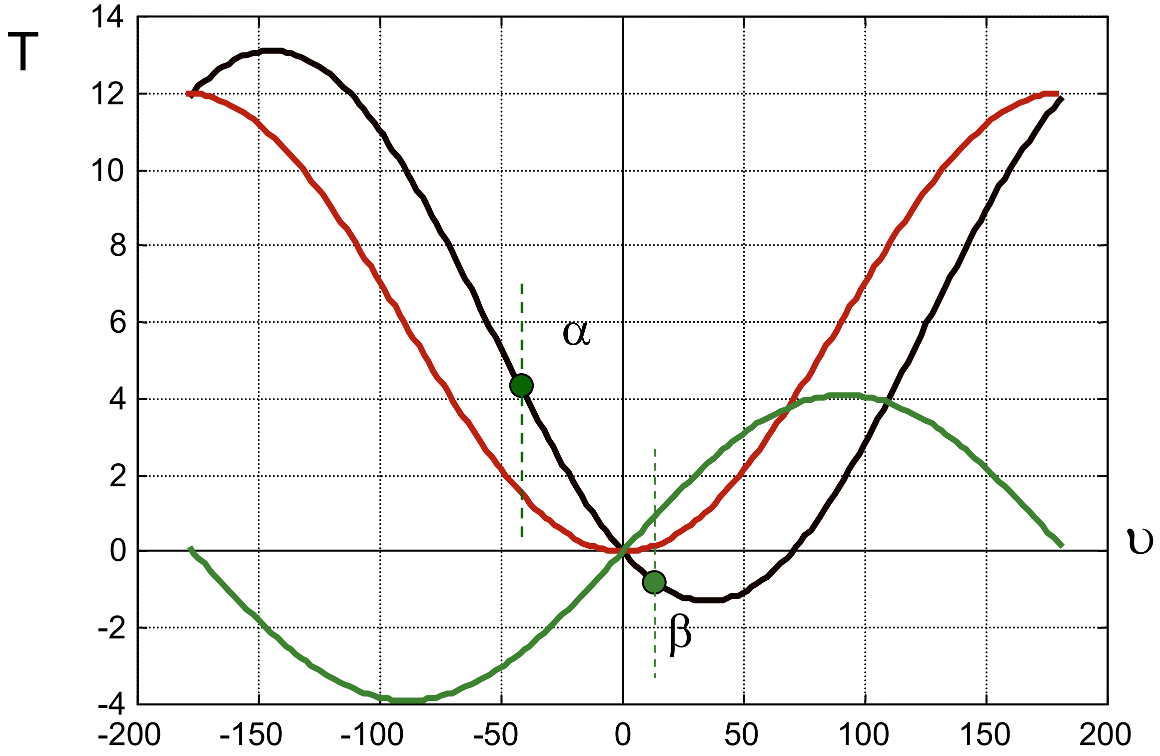


$$\underline{Z}_{R\alpha}\cdot\underline{I}_{R\alpha}+\underline{Z}_{m\alpha}\left(\frac{\underline{U}_S}{\underline{Z}_{m\alpha}\cdot\underline{C}_S}-\frac{\underline{I}_{R\alpha}}{\underline{C}_S}\right)=\left(\underline{Z}_{R\beta}\cdot\underline{I}_{R\beta}+\underline{Z}_{m\beta}\left(\frac{\underline{U}_S}{\underline{Z}_{m\beta}\cdot\underline{C}_{S\beta}}-\frac{\underline{I}_{R\beta}}{\underline{C}_S}\right)\right)\cdot e^{j\upsilon}$$

$$\underline{I}_{R\alpha}=\frac{\underline{U}_S}{\underline{C}_S}\,\frac{1-e^{j\upsilon}}{1+e^{j\upsilon}}\,\frac{1}{\dfrac{\underline{Z}_m}{\underline{C}_S}-\underline{Z}_{Rs}}$$

Arbore electric cu maşini de egalizare

$$T = T_k \frac{\underline{A} - \underline{B}\cos\upsilon}{\underline{C}} - T_k \frac{\underline{D}}{\underline{C}}\sin\upsilon$$



Stabilitatea arborelui electric

Cuplul masinii

$$T_{\alpha,\beta} = T_k \frac{\underline{A} \pm \underline{B}\cos\upsilon}{\underline{C}} - T_k \frac{\underline{D}}{\underline{C}}\sin\upsilon$$

Cuplul critic

$$T_k = \frac{p \cdot m_S}{\omega_S} \frac{U_S^2}{2 \cdot c_S} \frac{1}{R_S \pm \sqrt{R_S^2 + \left(X_{S\sigma} + c_S \cdot (X'_{R\sigma} + X')\right)^2}}$$

expresii

$$\underline{A}, \underline{B}, \underline{C}, \underline{D} = f(s, R, Z_S, Z_R, Z_m, \upsilon)$$

$$\underline{A} \approx \underline{B}$$

$$s_k < s < 1$$

Regimuri speciale ale maşinii de inducție

Regulator de inducție.

Bobină variabilă

Schimbător de frecvență

Definirea regimului special

Maşina de inducție cu rotor bobinat $f_S = f_R$

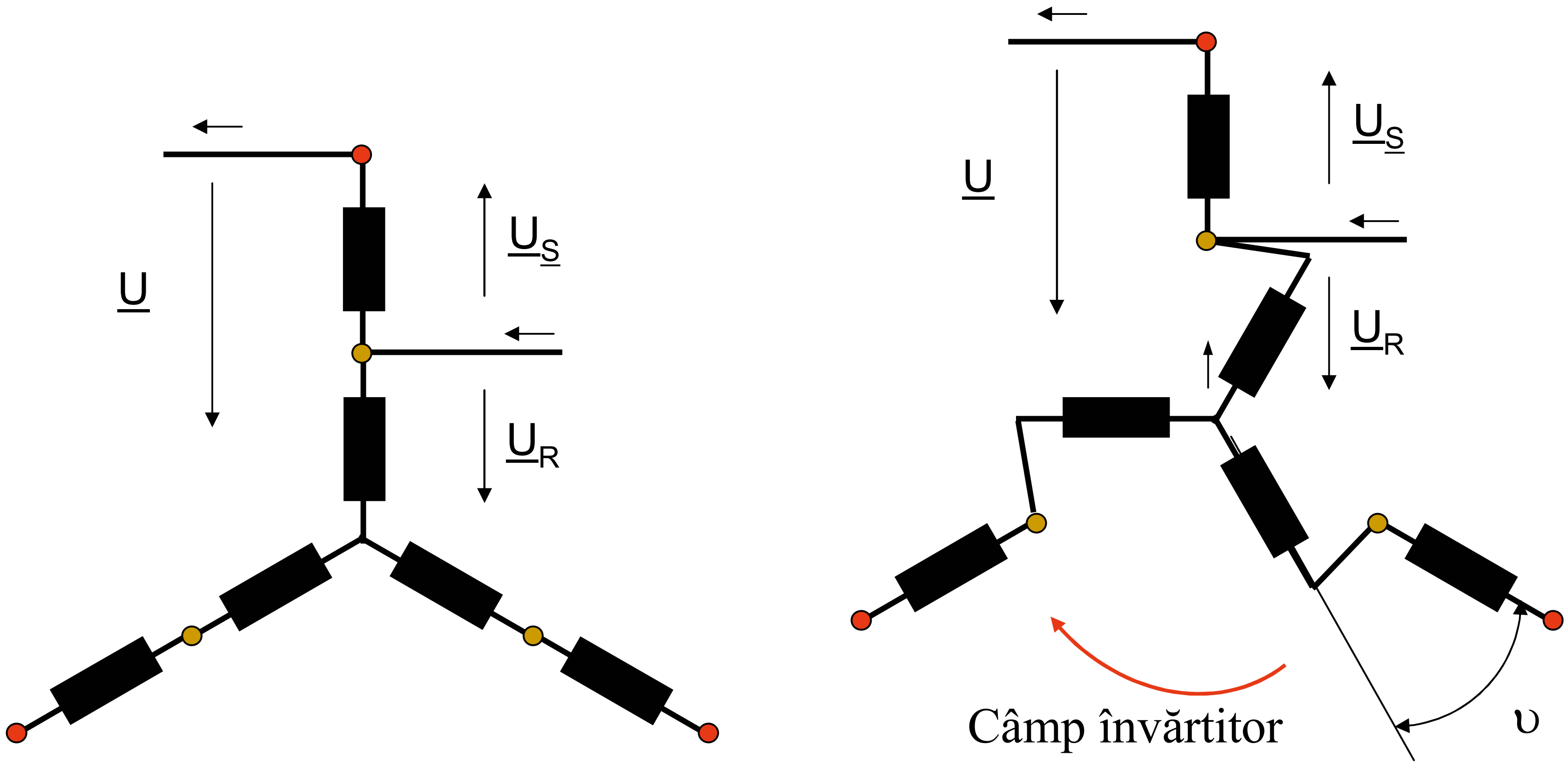
Viteza de rotație n = 0

Rotorul este blocat cu ajutorul unui dispozitiv, care permite rotirea rotorului cu $\pm \frac{\pi}{p}$

Raportul de transformare apropiat de unitate

$$k = \frac{w_S \cdot k_{bS}}{w_R \cdot k_{bR}}$$

Regulator de inducție

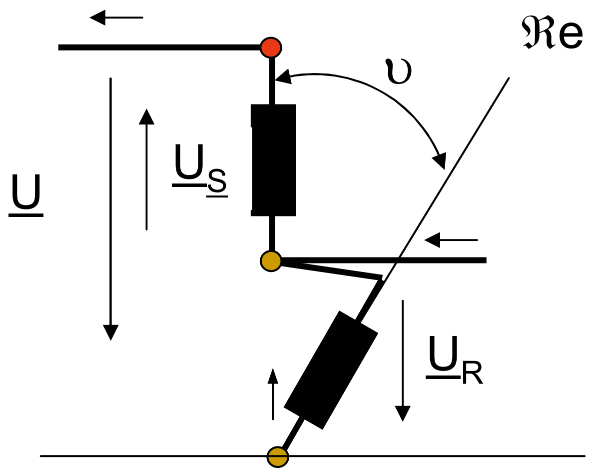


Regulator de inducție

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

$$-\underline{E}_S = \underline{Z}_m \cdot (\underline{I}_S \cdot e^{-j\upsilon} + \underline{I}_R)$$

$$\underline{E}_R = \frac{1}{k} \cdot \underline{E}_S \cdot e^{-j\upsilon}$$



$$\underline{U}_S = -\underline{Z}_S \cdot \underline{I}_S + \underline{E}_S$$

$$\underline{U} = \underline{U}_R - \underline{U}_S$$

$$\underline{U} = \underline{Z}_R \cdot \underline{I}_R + \underline{Z}_S \cdot \underline{I}_S - \underline{E}_R - \underline{E}_S$$

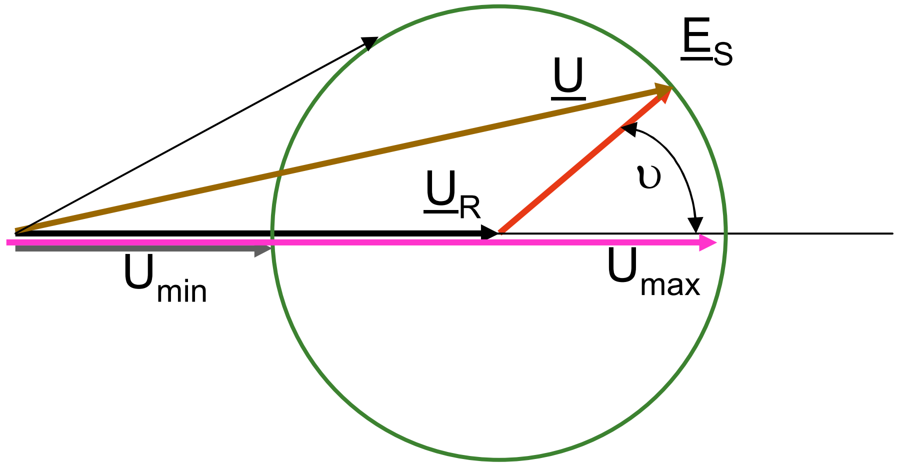
La mersul în gol

$$\underline{U} = \underline{U}_R + k \cdot \underline{U}_R \cdot e^{j\upsilon}$$

Regulator de inducție

$$\underline{U} = \underline{U}_R + \underline{E}_S$$

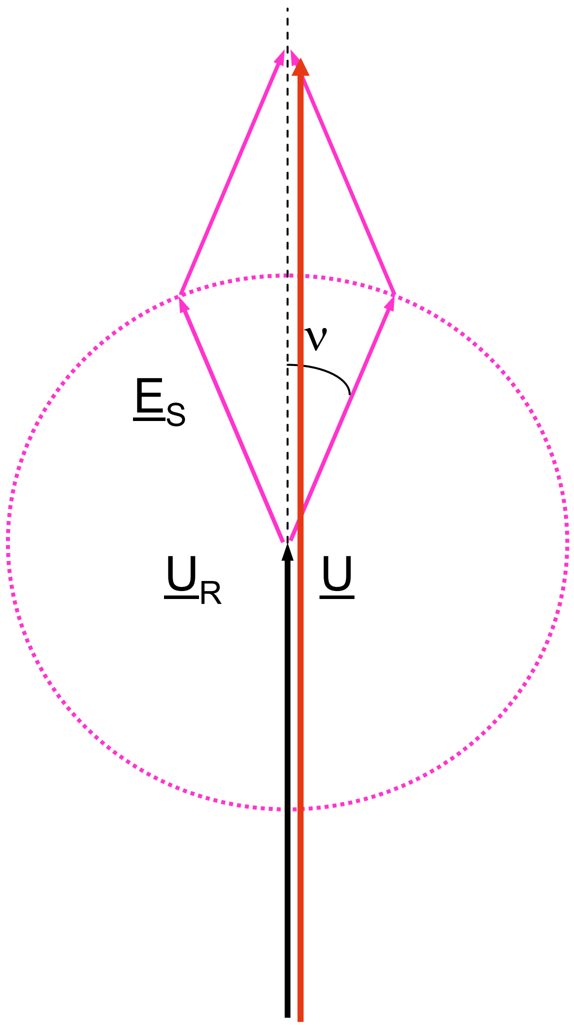
$$\underline{U} = \underline{U}_R + k \cdot \underline{U}_R \cdot e^{j\upsilon}$$



$$U_{\max} = U_R + k \cdot U_R$$

$$U_{\min} = U_R - k \cdot U_R$$

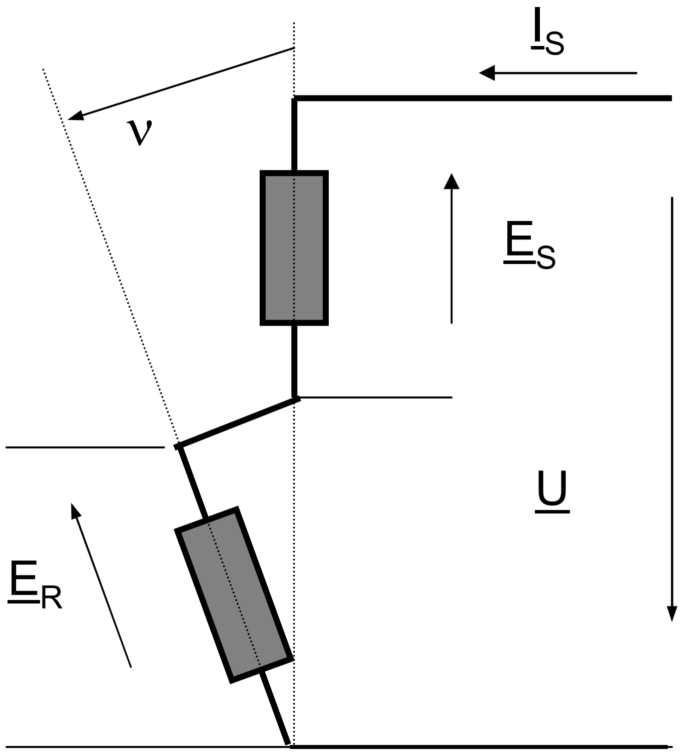
Regulator de inducție



Regulator de inducție dublu

Tensiunea nu-şi schimbă faza

Bobina variabilă



Solenația

$$\underline{\theta} = \frac{m_S}{2} k_{bS} \cdot w_S \cdot \underline{I}_S \left(1 + \frac{1}{k} e^{j\upsilon} \right)$$

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

$$\underline{U}_R = \underline{Z}_R \cdot \underline{I}_S - \underline{E}_R$$

$$\underline{E}_R = \frac{1}{k} \cdot \underline{E}_S \cdot e^{-j\upsilon}$$

$$-\underline{E}_S = \underline{Z}_m \cdot \underline{I}_S \left(1 + \frac{1}{k} \cdot e^{j\vartheta} \right)$$

$$\underline{U} = \underline{U}_R + \underline{U}_S$$

Bobina variabilă

$$\underline{U}=\left(\underline{Z}_S+\underline{Z}_R\right)\cdot\underline{I}_S+\underline{Z}_m\cdot\left(1+\frac{1}{k}e^{-j\upsilon}+\frac{1}{k}e^{j\upsilon}+\frac{1}{k^2}\right)\cdot\underline{I}_S$$

$$\underline{Z}_e=\frac{\underline{U}}{\underline{I}_S}=\underline{Z}_S+\underline{Z}_R+\underline{Z}_m\left(1+\frac{1}{k^2}+\frac{2}{k}\cos\upsilon\right)$$

$$\underline{Z}_{e\max}=\underline{Z}_S+\underline{Z}_R+\left(1+\frac{1}{k^2}+\frac{2}{k}\right)\cdot\underline{Z}_m$$

$$\underline{Z}_{e\min}=\underline{Z}_S+\underline{Z}_R+\left(1+\frac{1}{k^2}{}^{2}-\frac{2}{k}\right)\cdot\underline{Z}_m$$

Exemplu

Parametrii maşinii de inducţie:

$k = \sqrt{10}$

$rs := 1.1 \quad \Omega$ $\qquad rr := 1.4 \quad \Omega$ $\qquad rm := 2.8 \quad \Omega$

$xs\sigma := 2.4 \quad \Omega$ $\qquad xr\sigma := 3 \quad \Omega$ $\qquad xm := 39.8 \quad \Omega$

$$Zemax := Zs + Zm \cdot \left(1 + \frac{2}{k1} + \frac{1}{k1^2}\right) + \frac{Zr}{k1^2}$$

$Zemax = 6.091 + 71.652i$

$$\cos\alpha M := \frac{Re(Zemax)}{|Zemax|}$$

$\cos\alpha M = 0.085$

$$Zemin := Zs + Zm \cdot \left(1 - \frac{2}{k1} + \frac{1}{k1^2}\right) + \frac{Zr}{k1^2}$$

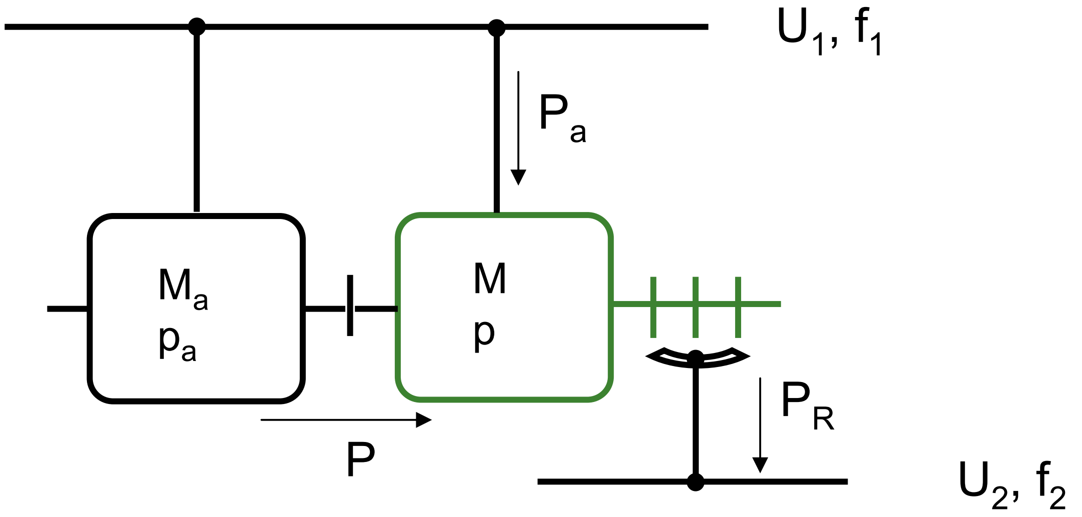
$Zemin = 2.549 + 21.308i$

$$\cos\alpha m := \frac{Re(Zemin)}{|Zemin|}$$

Rap= 3.31

$\cos\alpha m = 0.119$

Schimbător de frecvență



$$f_R = s \cdot f_S$$

$$f_2 = \left(1 \pm \frac{n}{n_S}\right) \cdot f_1$$

$$f_2 = \left(1 \pm \frac{p}{p_a}\right) \cdot f_1$$

Schimbător de frecvență

Bilanțul puterilor

$$P_S + P = P_R \qquad\qquad P_R = s \cdot P$$

Puterea absorbită în statorul schimbătorului

$$P_S = P_R \cdot \left(1 - \frac{1}{s}\right) = P_R \cdot \left(1 - \frac{f_1}{f_2}\right) = P_R \cdot \frac{p}{p \pm p_a}$$

Puterea dată de motorul de antrenare

$$P = P_R \frac{1}{s} = P_R \frac{f_1}{f_2} = P_R \frac{p_a}{p_a \pm p}$$

Exemplu

Motor de antrenare $P_a = 1.5$ kW $p_a = 1$

Masina de inductie cu rotor bobinat P=3 kW p=3

Neglijand alunecarea motorului de antrenare n≅3000 rot/min

-rotorul se roteste in sensul campului invirtitor statoric

$$s \cong \frac{1000-3000}{1000} \cong -2 \qquad f_2 = s \cdot f_1 \approx 100 \quad Hz$$

$$P_S = P_R \cdot \left(1 - \frac{1}{s}\right) = P_R \cdot \left(1 - \frac{1}{-2}\right) = P_R \cdot \frac{3}{3-1} = \frac{3}{2} P_R$$

$$P = P_R \frac{1}{s} = P_R \frac{1}{-2} = P_R \frac{1}{1-3} = -\frac{1}{2} P_R$$

Exemplu

-rotorul se roteste in sens invers campului invirtitor statoric

$$s \cong \frac{1000+3000}{1000} \cong 4 \qquad f_2 = s \cdot f_1 \approx 200 \quad Hz$$

$$P_S = P_R \cdot \left(1 - \frac{1}{s}\right) = P_R \cdot \left(1 - \frac{1}{4}\right) = P_R \cdot \frac{3}{3+1} = \frac{3}{4} P_R$$

$$P = P_R \frac{1}{s} = P_R \frac{1}{4} = P_R \frac{1}{1+3} = \frac{1}{4} P_R$$

Exemplu

La f_2 =100 Hz

$$P_R \cong \frac{2}{3} P_S = 2 \quad kW$$

$$P = -\frac{1}{2} P_R = -1 \quad kW$$

La f_2 =200 Hz

$$P_R \cong \frac{4}{3} P_S = 4 \quad kW$$

$$P = \frac{1}{4} P_R = 1 \quad kW$$