Fundamentos de Transformadores y Máquinas Eléctricas

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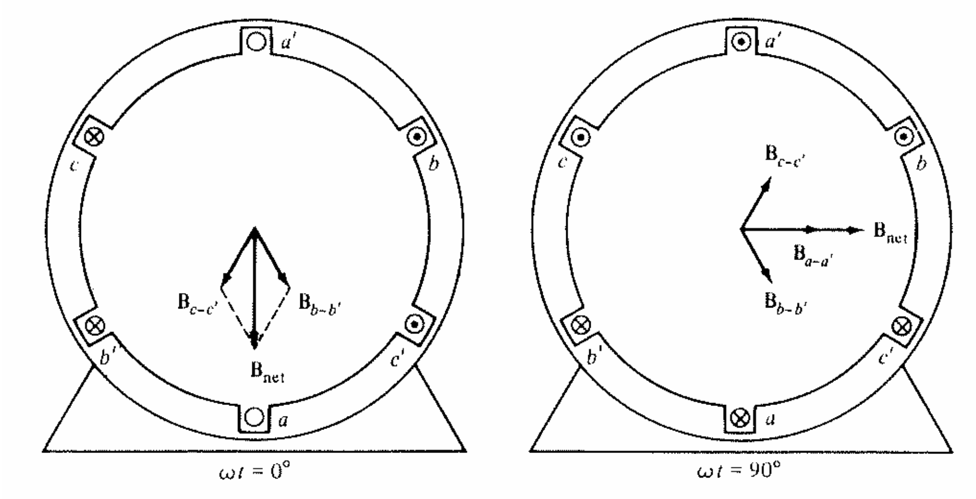
Clase 16

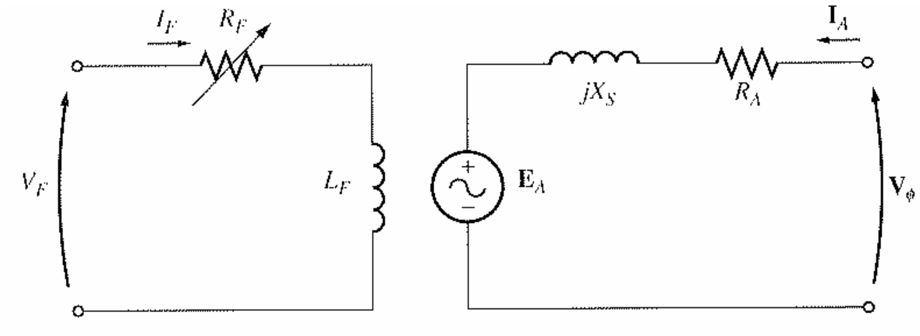
Motor Sincrónico



- Campo del Rotor tiende a alinearse con el Campo del Estator
- El Campo del Estator rota, ya que lo producen corrientes que oscilan defasadas a 120 grados

Dibuja el rotor

Motor Sincrónico



$E_A = k\phi\omega$

$\uparrow \propto I_F$

$$\boxed{\bar{E}_A = \bar{V}_\phi - jX_s\bar{I}_A - R_A\bar{I}_A}$$

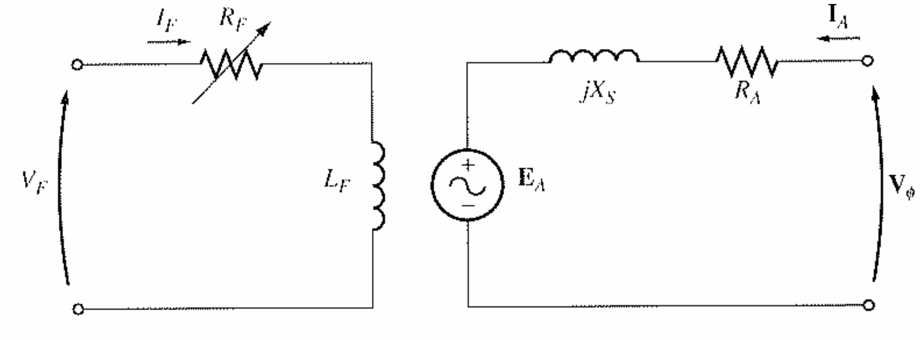
$\bar{V}_\phi$ - voltaje terminal por fase

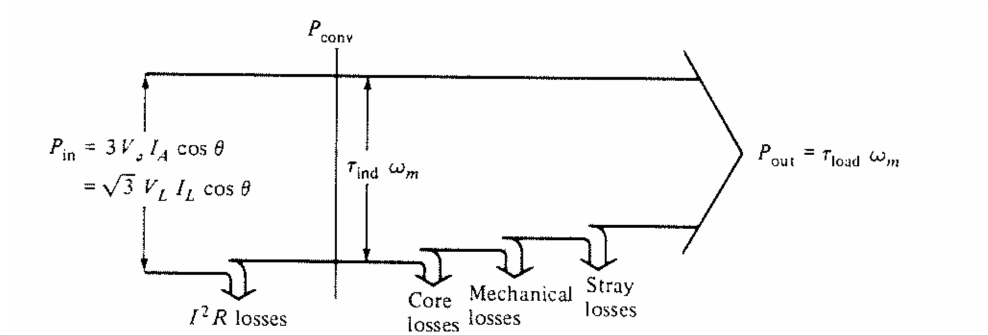
X_s - reactancia sincrónica

R_A - resistencia de Armadura

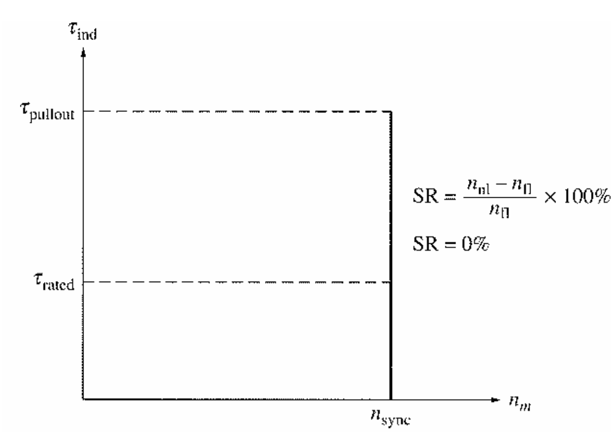
$\bar{I}_A$ - corriente de Armadura

Motor Sincrónico





Torque vs Velocidad



Caracteristica de Torque Vs Velocidad

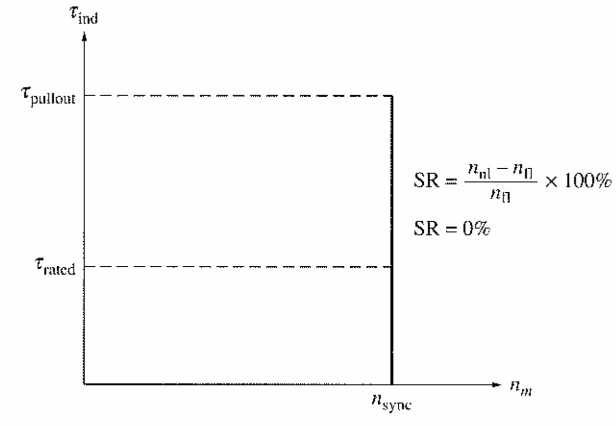
Velocidad de rotacioñ constante

a n_{sync}

$$SR = \frac{n_{FL} - n_{nL}}{n_{FL}} \times 100 \cong 0\%$$

Regulacioñ de Velocidad

Torque vs Velocidad



$$\tau_{ind} = \frac{3 V_\phi E_A}{\omega_r X_s} \sin\delta$$

; ω_r - velocidad del motor (rotor) (sincrónica)

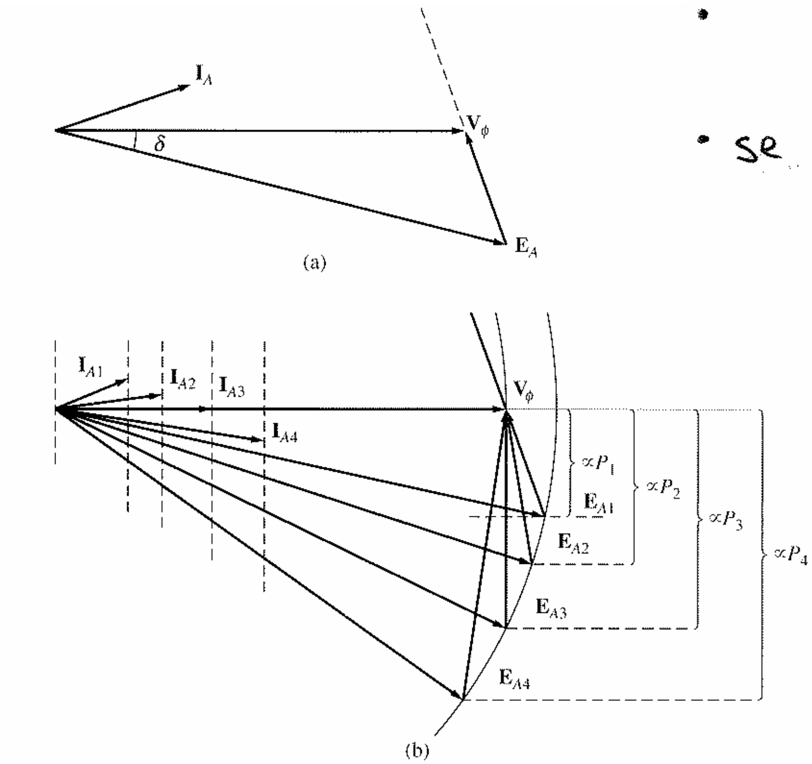
δ - ángulo de fase entre B_s y B_r

$$\boxed{P = \frac{3 V_\phi E_A \sin\delta}{X_s}}$$

Efecto de Cambio en la Carga

$\omega_r = \omega_{sync}$

- Aumenta Load
- ω_r disminuye, debido a que $E_A = K\phi\omega$ y I_F constante
- δ aumenta
- $\tau_{ind} = \dfrac{3 V_\phi E_A}{\omega_r X_s} \sin\delta$, $\tau_{ind} \uparrow$
- se mantiene $\omega_r = \omega_{sync}$



Ejemplo

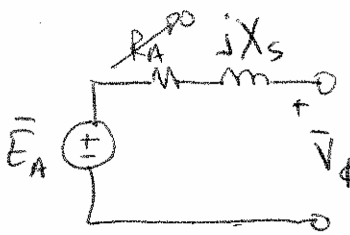
MS: 208v, 60Hz, 45KVA, 80% PF leading, Δ,

$X_S = 2{,}5\,\Omega$ $\qquad P_{F\&W} = 1{,}5\,KW$

$R_A = 0$ $\qquad P_c = 1\,KW$

Load$_1$ = 15 HP @ 80% PF lead

ⓐ Hallar $\bar{I}_L$, $\bar{I}_A$ y $\bar{E}_A$, dibujar diagrama de fasores.



$\bar{V}_\phi = \bar{V}_{LL} = 208\angle 0^\circ$

$P_{out} = 15\,HP\left(\frac{.746\,KW}{1\,HP}\right) = 11{,}19\,KW$

$P_{in} = P_{out} + P_{F\&W} + P_c + P_A$

$= 11{,}19\,KW + 1.5 + 1{,}0 + 0 = 13{,}69\,KW$

$$I_L = \frac{P_{in}}{\sqrt{3}\,V_{LL}\cos\theta} = \frac{13{,}69\,KW}{\sqrt{3}(208\,v)(.8)} = 47.5\,A$$

Ejemplo

En Δ $\quad I_L = \sqrt{3}\, I_\phi = \sqrt{3}\, I_A$

entonces $\quad I_A = \dfrac{I_L}{\sqrt{3}} = \dfrac{47.5A}{\sqrt{3}} = 27.4A \quad ; \quad \theta = \cos^{-1}(.8) = 36.87^\circ$ es el angulo entre $\bar{I}_A$ y $\bar{V}_\phi$

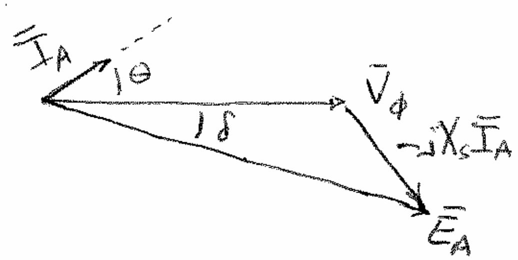
$$\underline{\bar{I}_A = 27.4\angle{+36.87^\circ}\,A}$$

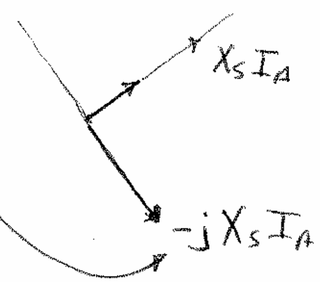
Del diagrama ;

$$\bar{E}_A = \bar{V}_\phi - \bar{I}_A(jX_s) = (208\angle 0^\circ\,V) - (27.4\angle 36.87^\circ)(j2.5)$$

$$\bar{E}_A = 255\angle{-12.4^\circ}\,V$$

δ - entre $\bar{V}_\phi$ y $\bar{E}_A$





Ejemplo

(b) La carga es aumentada a 30Hp, Hallar $\bar{I}_A$, $\bar{I}_L$ y $\bar{E}_A$

* Como no hay ΔI_F, entonces $|\bar{E}_A|$ es constante

$$P_{out} = 30\,Hp\left(\frac{.746\,KW}{1\,Hp}\right) = 22{,}38\,KW$$

$$P_{in} = P_{out} + P_{F\&W} + P_c + P_A$$

$$= 22{,}38\,KW + 1{,}5\,KW + 1{,}0\,KW + 0 = 24{,}88\,KW$$

$$P = \frac{3V_\phi E_A}{X_s}\sin\delta \qquad \delta = \sin^{-1}\left(\frac{X_s P}{3V_\phi E_A}\right) \ ; |E_A| \text{ constante}$$

$$= \sin^{-1}\left(\frac{(2{,}5)\,24{,}88\,KW}{3(208)(255)}\right)$$

$$\underline{\delta = 23.01^\circ}$$

Ejemplo

$$\delta = 23.01^\circ$$

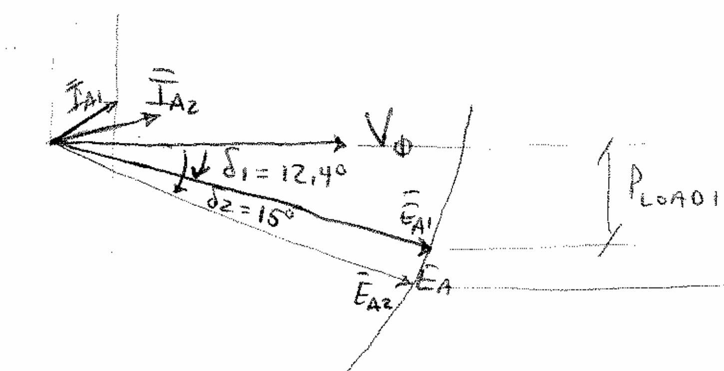
$$\bar{E}_A = 255 \angle -23.01^\circ \text{ V}$$

$$\bar{I}_A = \frac{-\bar{E}_A + \bar{V}_\phi}{jX_s} = \frac{(-255\angle -23.01^\circ) + (208\angle 0^\circ \text{ V})}{j\,2.5}$$

$$\bar{I}_A = 41,28\angle 15^\circ \text{ A}$$

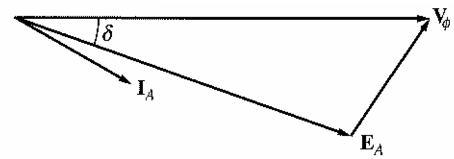
$$\bar{I}_L = \sqrt{3}\,\bar{I}_A \angle +30 = \sqrt{3}(41,28\angle 15^\circ \text{ A})(+30^\circ)$$

$$\bar{I}_L = 71.41\angle 45^\circ \text{ A} \leftarrow$$ respecto de $\bar{V}_\phi = \bar{V}_{LL}$ en Δ

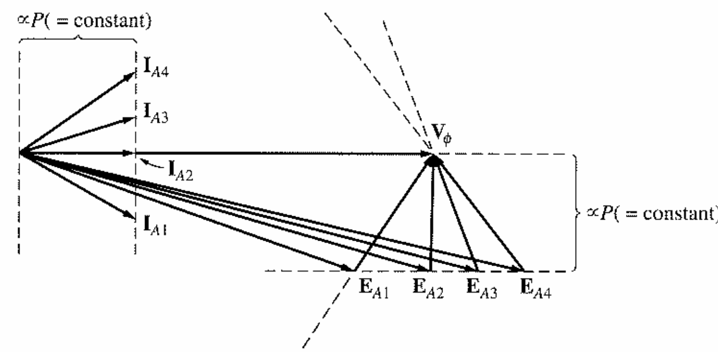


Efecto de ΔI_F en el Motor Sincrónico

- Aumento en I_F, aumenta $|\bar{E}_A|$
  $E_A \propto I_F$
- No afecta potencia que suple el motor (P_{out} const.)
- $\bar{I}_A$ atrasada "underexited", I_F es pequeña
- $\bar{I}_A$ adelantada "overexited", I_F es grande



(a)



(b)

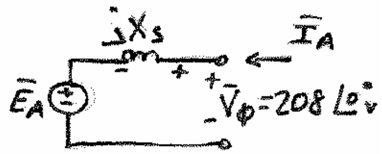
Ejemplo

MS: 208v Δ, 45 KVA, 80% PF leading, 60Hz, Δ

Pout 15hp, PF = .85 lagging

$X_s = 2.5\,\Omega$, $R_A = 0$, $P_{F\&W} = 1.5\,\text{KW}$, $P_c = 1\,\text{KW}$

(a) Hallar $\bar{E}_A$ e $\bar{I}_A$ y dibujar diagramas



$P_{in} = 13.69\,\text{KW}$ (igual que ejemplo anterior)

$$I_L = \frac{P_{in}}{\sqrt{3}\,V_\phi\,PF} = \frac{13.69\,\text{KW}}{\sqrt{3}(208)(.85)}$$

$I_L = 44.7\,A$ $\quad I_A = I_L/\sqrt{3} = 25.81\,A$ $\quad \theta = \cos^{-1}(.85) = 31.79^\circ$

$$\bar{I}_A = 25.81\angle -31.79^\circ\ A$$

$$\bar{E}_A = \bar{V}_\phi - jX_s\bar{I}_A = (208\angle 0^\circ\,\text{v}) - j(2.5\,\Omega)(25.81\angle -31.8^\circ\,A)$$

$$\bar{E}_A = 182.45\angle -17.5^\circ\ \text{v}$$

$$\delta = -17.5^\circ$$

Ejemplo

(b) I_F aumenta por 25%, hallar $\bar{E}_A$, $\bar{I}_A$ y los diagramas

Aumento en Field de 25%, E_A aumenta 25%

$$E_{A_2} = (1.25)\, E_{A_1} = (1.25)(182.45\,v) = 228\,v$$

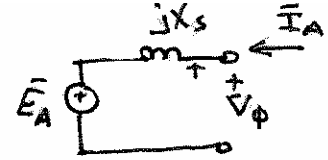
$$P = \frac{3 V_\phi E_A \sin\delta}{X_s} \quad y \quad P_1 = P_2 \quad \therefore$$

$$E_{A1} \sin\delta_1 = E_{A2} \sin\delta_2$$

$$\delta_2 = \sin^{-1}\left(\frac{E_{A1}}{E_{A2}} \sin\delta_1\right) = \sin^{-1}\left(\frac{182.45}{228} \sin(-17.5^\circ)\right)$$

$$\delta_2 = -13.92^\circ$$

Ejemplo



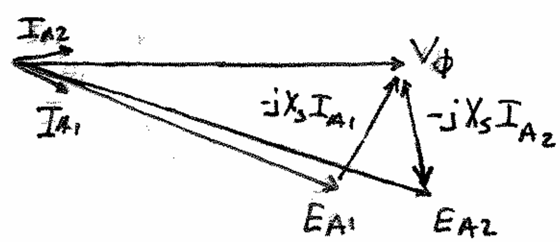
$$\bar{E}_{A_2} = 228 \angle -13.92^\circ \text{ V}$$

$$\bar{E}_A = \bar{V}_\phi - jX_s\bar{I}_A$$

$$\bar{I}_A = \frac{\bar{V}_\phi - \bar{E}_A}{jX_s} = \frac{(208\angle 0^\circ) - (228\angle -13.92^\circ)}{j(2.5)}$$

$$\bar{I}_{A_2} = 22.57 \angle 13.63^\circ \text{ A}$$

$$\theta_2 = 13.63^\circ$$



Conclusión: Aumento en I_F, I_A leading, injecta Q, P se queda igual.