igor.albizu@ehu.eus

Azterketa %70 → %30 teoria
↘ %40 arloetako

entregagaiak (probak) %15 → transformadoreak, asink, mak. sin.
(6. astea) (10. astea) (13. astea)

Praktikak %15 (Txiskio)

PL2

Makina

Sarrera.

Transformadorea → energia elektrikoa sartzen da eta tentsioa aldatzen du, gero ere energia elektrikoa emanez.

Imanak: eremu magnetikoa ipar polotik irten eta hego polotik sartzen da. Harilduin norantzkoa jakiteko eskumako eskua, beharr potoloak iparra adierazten du.

1. $N = 2000$ espira $\Phi_1 = 5mWb$ imanak sortua $\Phi_2 = 2mWb$ $t = 1/10$ seg.
Zein da harilaren borneetan induzitutako $\mathcal{E}$ tentsioa?

$\Delta\Phi = 2-5 = -3mWb$ $\Delta t = 0'1$ segundu

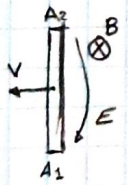
$$e(t) = -N\cdot\frac{d\Phi}{dt} = -N\frac{\Delta\Phi}{\Delta t} = -2000\cdot\frac{(-3\cdot10^{-3})}{0'1} = 60\,V$$

a) N handiagotzen bada, $\mathcal{E}$?
$\mathcal{E}$ handiagotuko da. N↑ $\mathcal{E}$↑

b) Fluxu aldaketa handiagotzen bada, $\mathcal{E}$?
$\mathcal{E}$ handiagotuko da. $\Delta\Phi$↑ $\mathcal{E}$↑

c) Imana 1/5 segundutan ateratzen bada, $\mathcal{E}$?
$\mathcal{E}$ txikiagoa izango da. ϵ↑ $\mathcal{E}$↑

2. $\mathcal{E}$? $V = 100\ m/s$ $B = 0'6T$ $L = 2\ m$



$$\mathcal{E} = VBL\sin\theta = 100\cdot0'6\cdot2\cdot\sin90° = 120\,V$$

3. $L = 3m$ $I = 200A$ $B = 0'5T$

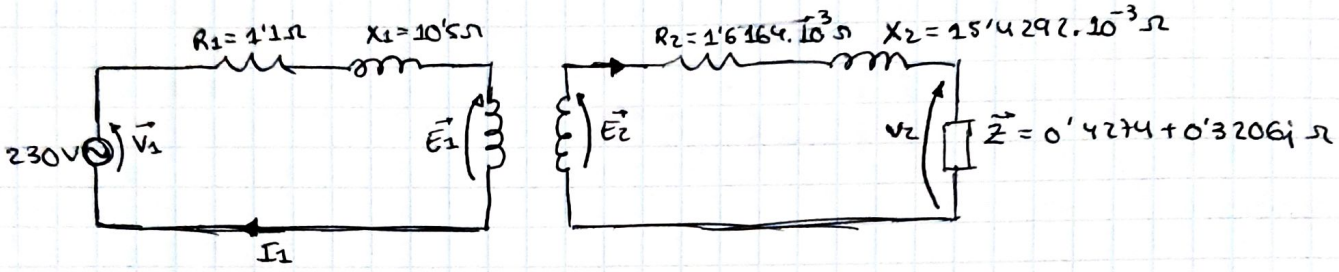
a) eroalea eta imana perpendikular, F?

$$F = BIL\sin\theta = 0'5\cdot200\cdot3\cdot\sin90° = 300\,N$$ beherantz (ezker eskua)

b) eroalea eta imana paralelo, F?

$F = 0'5 \cdot 200 \cdot 3 \cdot \sin 0° = 0\ N$

Transformadorea.
(adibidea zenbaketarekin)



$\vec{I}_2 = \frac{\vec{V}_2}{\vec{z}} = \frac{230}{0'5343\,|\,36'87} = 430'46\,|\,-36'87\ A$

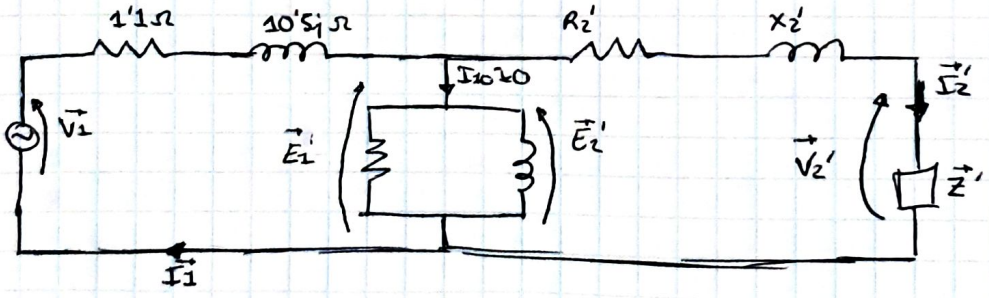
$\vec{E}_2 = \vec{V}_2 + \vec{I}_2\,(R_2 + i X_2) = 230 + 430'46\,|\,-36'87\ (1'6164 \cdot 10^{-3} + i \cdot 15'4292 \cdot 10^{-3}) =$
$= 234'6\,|\,1'2\ V$

$\vec{E}_1 = \vec{E}_2 \cdot a = 234'6\,|\,1'2 \cdot \left(\frac{6000}{230}\right) = 6119'8\,|\,1'2\ V$

$\vec{I}_1 = \vec{I}_{10^\circ} + \frac{\vec{I}_2}{a} = 430'46\,|\,-36'87 \cdot \left(\frac{230}{6000}\right) = 16'5\,|\,-36'87\ A$

$\vec{V}_1 = \vec{E}_1 + \vec{I}_1\,(R_1 + i X_1) = 6119'8\,|\,1'2 + 16'5\,|\,-36'87\ (1'1 + 10'5i) = 6242'2\,|\,2'35\ V$

zirkuitu baliokidea



$R_2' = R_2\,a^2 = 1'6164 \cdot 10^{-3} \cdot (6000/230)^2 = 1'1\ \Omega$
$X_2' = X_2 \cdot a^2 = 15'4292 \cdot 10^{-3} \cdot \left(\frac{6000}{230}\right)^2 = 10'5\ \Omega$

$I_2' = \frac{\vec{I}_2}{a} = \frac{430'46\,|\,-36'87}{(6000/230)} = 16'5\,|\,-36'87\ A$ ← erabilgarria, tresna bat da.

$V_2' = a V_2 = \frac{6000}{230} \cdot 230 = 6000\ V$

$V_{1L} = 1380\ V$ $\quad V_{2L} = 138\ V$

$S_N = V_1 \cdot I_1 \Rightarrow I_1 = 8'3\hat{3}\ A$

$I_2 = 83'\hat{3}\ A$

a) $\arctan \frac{1'86}{2'48} = 37°$

$\cos\varphi = 0'8$

b)

$a = 10$ $\quad \vec{Z}_k = 3'1\angle -36'87°$ $\quad \vec{Z}'_k = a^2 \vec{Z}_k = 310\angle 36'87°$

c)

$i =$

d) $P_J = J_{1N}^2 \cdot R_b = 8'3^2 \cdot 1'362 =$

Ariketak

2. Transformadore monofasikoak.

1. $S_N = 10\,kVA$, 220/380 V eta maiztasuna 50 Hz da.
hutseko saiakuntza: $V_{1O} = 220\,V$ $I_{1O} = 2\,A$ $P_O = 150\,W$
zirkuitulaburra: $V_{2zL} = 10V$ $I_{2zL} = I_{2N}$ $P_{zL} = 225\,W$

a) Transformadorearen zirkuitu baliokidearen parametroak (primarioan).

$$P_O = V_{1O}^2 \cdot G_O \Rightarrow G_O = \frac{P_O}{V_{1O}^2} = \frac{150}{220^2} = 3'099 \cdot 10^{-3}\,\Omega$$

$$Y_O = \frac{I_{1O}}{V_{1O}} = \frac{2}{220} = 0'009\,\Omega^{-1}$$

$$B_O = \sqrt{Y_O^2 - G_O^2} = \sqrt{0'009^2 - 3'099 \cdot 10^{-3}|^2} = 8'546 \cdot 10^{-3}\,\Omega$$

$$R_{b2} = \frac{P_{zL}}{I_{zL}^2} = \frac{225}{I_{2N}^2} = \frac{225}{(10 \cdot 10^3/380)^2} = 0'3249\,\Omega$$

$$a = \frac{V_{1O}}{V_{2O}} = \frac{220}{380} = 0'5789$$

$$R_{b1} = a^2 R_{b2} = \left(\frac{220}{380}\right)^2 \cdot 0'3249 = 0'1089\,\Omega$$

$$Z_{b2} = \frac{V_{2zL}}{I_{2zL}} = \frac{10}{10 \cdot 10^3/380} = 0'38$$

$$X_{b2} = \sqrt{Z_{b2}^2 - R_{b2}^2} = \sqrt{0'38^2 - 0'3249^2} = 0'19708\,\Omega$$

$$X_b = X_{b2} \cdot a^2 = 0'19708 \cdot 0'5789^2 = 0'066\,\Omega$$

b) V_2 eta ε tentsio-erregulazioa, $V_1 = V_{1N}$, $\cos\varphi = 0'8$ eta karga (intentsitatearekiko) izenda-tua direnean.

$$\vec{V}_1 = \vec{V}_2' + \vec{I}_2' (R_b + jX_b)$$

$$\vec{V}_2 = \vec{V}_{1N} = 220\,V$$

$$I_2' = I_{2N}' = \frac{I_{2N}}{a} = \frac{26'316}{0'5789} = 45'45\,A = I_{1N}$$

$\cos\varphi = 0'8$ atzeratzailea $\varphi = 36'89° \Rightarrow \vec{I}_2' = 45'45\,\angle -36'89°\,A$

hasieran ordezkatuz,

$$220 = \vec{V}_2' + 45'45\,\angle -36'89° \cdot (0'1089 + j\,0'066) \Rightarrow \vec{V}_2' = 214'24\,\angle 0'15°\,V$$

$$V_2 = \frac{V_2'}{a} = \frac{214'24}{0'5789} = 370'02\,V$$

$$\varepsilon = \frac{V_1 - V_2'}{V_1} = \frac{220 - 214'24}{220} = \%2'62$$

2. $S_N = 500\,KVA$, $3300/500\,V$ eta maiztasuna $50Hz$. $\eta_{max} = \%97$ $S = 3/4\,S_N$ denean $\cos\varphi = 1$.

Zirkuitulaburra: $V_{1zL} = 330\,V$ $I_{1zL} = I_{1N}$

Kalkulatu ε_R eta ε_X.

ekuazioak

$$\varepsilon_R = \frac{R_b \cdot I_{1N}}{V_{1N}} \cdot 100$$

$$\varepsilon_X = \frac{X_b \cdot I_{1N}}{V_{1N}} \cdot 100$$

errendimendu maximotik P_{JN}:

$$\eta_{max} = \frac{i_{Nmax} \cdot S_N \cdot \cos\varphi}{i_{Nmax} \cdot S_N \cdot \cos\varphi + 2P_{Fe}}$$

$$i = \frac{3}{4} = 0'75$$

$$0'97 = \frac{0'75 \cdot 500 \cdot 10^3 \cdot 1}{0'75 \cdot 500 \cdot 10^3 \cdot 1 + 2P_{Fe}} \Rightarrow P_{Fe} = 5799\,W$$

$$P_{Fe} = i^2 \cdot P_{JN} \Rightarrow P_{JN} = \frac{P_{Fe}}{i^2} = \frac{5799}{0'75^2} = 10309\,W$$

P_{JN}-tik R_b:

$$P_{JN} = I_{1N}^2 R_b \Rightarrow R_b = \frac{P_{JN}}{I_{1N}^2} = \frac{10309}{(500 \cdot 10^3/3300)^2} = 0'449\,\Omega$$

zirkuitu laburreko saiakuntzatik:

$$Z_b = \frac{V_{1zL}}{I_{1zL}} = \frac{330}{(500 \cdot 10^3/3300)} = 2'178\,\Omega$$

$$X_b = \sqrt{Z_b^2 - R_b^2} = \sqrt{2'178^2 - 0'449^2} = 2'1312\,\Omega$$

$$\varepsilon_R = \frac{0'449 \cdot 500 \cdot 10^3/3300}{3300} \cdot 100 = \%\,2'06$$

$$\varepsilon_X = \frac{2'1312 \cdot 500 \cdot 10^3/3300}{3300} \cdot 100 = \%\,9'78$$

3. $S_N = 20\,kVA$, 460/220 V, eta maiztasuna 50Hz da. $P_{Fe} = 360\,W$ eta $P_m = 500\,W$.

a) Errendimendua karga erdian $\eta_{1/2}$, $\cos\varphi = 0'8$ (atzeraturiko) denean.

Karga erdiaren karga-indizea:

$$i = \frac{1}{2} = 0'5$$

errendimendua:

$$\eta = \frac{i \cdot S_N \cdot \cos\varphi}{i\,S_N \cos\varphi + P_{Fe} + i^2 P_{JN}}$$

$$\eta_{1/2} = \frac{0'5 \cdot 20\cdot10^3 \cdot 0'8}{0'5 \cdot 20\cdot10^3 \cdot 0'8 + 360 + 0'5^2 \cdot 500} = \%94'3$$

b) Errendimendu maximoa denean S itxurazko potentzia.

$$S_2 = i \cdot S_N$$

$$i_{\eta max} = \sqrt{\frac{P_{Fe}}{P_{JN}}} = \sqrt{\frac{360}{500}} = 0'8485$$

$$S_2 = 0'8485 \cdot 20\cdot10^3 = 16970\,VA = 16'97\,kVA$$

c) Errendimendu maximoa $\cos\varphi = 1$ denean.

$$\eta_{max} = \frac{0'8485 \cdot 20\cdot10^3 \cdot 1}{0'8485 \cdot 20\cdot10^3 \cdot 1 + 360 + 0'8485^2 \cdot 500} = \%95'9$$

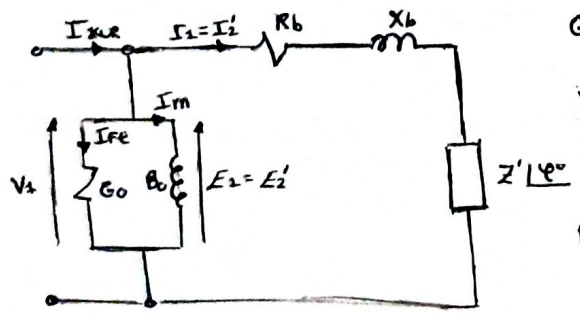
4. $S_N = 125\,kVA$, 3000/380 V eta maiztasuna 50Hz dira.

hutseko saiakuntza: $V_{10} = 3000\,V$ $I_{10} = 0'8\,A$ $P_0 = 1000\,W$

zirkuitulaburra: $V_{2zk} = 10\,V$ $I_{2zk} = 300\,A$ $P_{zk} = 750\,W$

a) $V_1 = V_{1N}$ denean paraleloko adarreko I_{Fe} eta I_m.

hutseko saiakuntzatik:



$$G_0 = \frac{P_0}{V_{10}^2} = \frac{1000}{3000^2} = 1'111\cdot10^{-4}\,\Omega^{-1}$$

$$Y_0 = \frac{I_{10}}{V_{10}} = \frac{0'8}{3000} = 2'666\cdot10^{-4}\,\Omega^{-1}$$

$$B_0 = \sqrt{Y_0^2 - G_0^2} = \sqrt{(2'666\cdot10^{-4})^2 - (1'111\cdot10^{-4})^2} = 2'42\cdot10^{-4}\,\Omega^{-1}$$

$$I_{Fe} = G_0 V_1 = 1'111\cdot10^{-4} \cdot 3000 = 0'333A$$

$$I_m = B_0 V_1 = 2'42\cdot10^{-4} \cdot 3000 = 0'7272A$$

b) Burdinaleo galerak eta kobreko galerak transformadorearen itxuraleko potentzia izendatua denean.

elementalak: $P_{FE} = P_0 = 1000\ W$. $P_{JN} = I_{1N}^2 \cdot R_b$

Zirkuitu laburreko saialkuntzetik,

$$Z_b^s = \frac{V_{2zl}}{I_{2zl}} = \frac{10}{300} = 0'03\ \Omega$$

$$P_{zl} = I_{2zl}^2 R_b^s \Rightarrow R_b^s = \frac{P_{zl}}{I_{2zl}^2} = \frac{750}{300^2} = 0'0083\ \Omega$$

$$X_b^s = \sqrt{Z_b^{s2} - R_b^{s2}} = \sqrt{0'03^2 - 0'0083^2} = 0'0323\ \Omega$$

primarora pasatuz:

$$a = \frac{3000}{380} = 7'895$$

$$R_b = a^2 R_b^s = 7'895^2 \cdot 0'0083 = 0'517\ \Omega$$

$$X_b = a^2 X_b^s = 7'895^2 \cdot 0'0323 = 2'012\ \Omega$$

ondorioz,

$$P_{JN} = I_{1N}^2 \cdot R_b = \left(\frac{125 \cdot 10^3}{3000}\right)^2 \cdot 0'517 = 897'6\ W$$

c) Errendimendua (η) itxuraleko potentzia izendatua denean eta hiru kasu hauetan: karga izendatua denean $i=1$.

- $\cos\varphi = 1$.

$$\eta = \frac{i \cdot S_N \cdot \cos\varphi}{i \cdot S_N \cdot \cos\varphi + P_{FE} + i^2 P_{JN}} = \frac{1 \cdot 125 \cdot 10^3 \cdot 1}{1 \cdot 125 \cdot 10^3 \cdot 1 + 1000 + 1^2 \cdot 897'6} = \%98'5$$

- $\cos\varphi = 0'8$ (atzeraturik, induktiboa).

$$\eta = \frac{125 \cdot 10^3 \cdot 0'8}{125 \cdot 10^3 \cdot 0'8 + 1000 + 897'6} = \%98'14$$

- $\cos\varphi = 0'8$ (aurreraturik, kapazitiboa).

$$\eta = \frac{125 \cdot 10^3 \cdot 0'8}{125 \cdot 10^3 \cdot 0'8 + 1000 + 897'6} = \%98'14$$

} aurreratua edo atzeratua egoteak ez du eraginik errendimenduan.

d) Sekundarioko tentsioa (V_2) eta ε tentsio-erregulazioa $V_1 = V_{1N}$ eta itxuraleko potentzia izendatua direnean eta hiru kasu hauetan:

$$\vec{V_1} = \vec{V_2'} + \vec{I_2'}(R_b + j X_b)$$

itxuraleko potentzia izendatua bada, intentsitatea ere bai.

$$I_2' = I_{2N}' = I_{1N} = \frac{S_N}{V_{1N}} = \frac{125 \cdot 10^3}{3000} = 41'66\ A$$

- $\cos\varphi = 1$.

$$3000 = \vec{V_2'} + 41'66(0'517 + j\,2'012) \Rightarrow \vec{V_2'} = 2979'6\ \underline{|-1'61}\ V$$

$$V_2' = 2979'6\ V \Rightarrow V_2 = \frac{V_2'}{a} = \frac{2979'6}{7'895} = 377'4\ V$$

$$\varepsilon = \frac{V_1 - V_2'}{V_{1N}} = \frac{3000 - 2979'6}{3000} = \%0'68$$

- $\cos\varphi = 0'8$ (atzeraturiko, induktiboa).

$\vec{I_2}' = 41'66 \angle -36'89°$ A

$3000 = \vec{V_2}' + 41'66 \angle -36'89° \, (0'517 + j\, 2'012) \Rightarrow \vec{V_2}' = 2932'9 \angle -1'06$ V

$V_2 = \frac{V_2'}{a} = \frac{2932'9}{7'895} = 371'49V$

$\varepsilon = \frac{V_1 - V_2'}{V_{1N}} = \frac{3000 - 2932'9}{3000} = \%\, 2'24$

- $\cos\varphi = 0'8$ (aurreraturiko, kapazitiboa).

$\vec{I_2}' = 41'66 \angle 36'89°$ A

$3000 = \vec{V_2}' + 41'66 \angle 36'89° \, (0'517 + j\, 2'012) \Rightarrow \vec{V_2}' = 3034'2 \angle -1'51$ V

$V_2 = \frac{V_2'}{a} = \frac{3034'2}{7'895} = 384'3V$

$\varepsilon = \frac{V_1 - V_2'}{V_{1N}} = \frac{3000 - 3034'2}{3000} = \%\, -1'14$

5. $S_N = 75$kVA, 3000/220 V eta maiztasuna 50Hz da.

zirkuitulaburra: $V_{1zl} = 200V$ $I_{1zl} = I_{1N}$ $P_{zl} = 2$kW

a) ε tentsio-erregulazioa, $V_1 = V_{1N}$ eta itxurazko potentzia izendatua direnean eta hiru luma hauetan:

zirkuitulaburra:

$I_{1zl} = I_{1N} = \frac{75 \cdot 10^3}{3000} = 25A$

$Rb = \frac{P_{zl}}{I_N^2} = \frac{2 \cdot 10^3}{25^2} = 3'2\,\Omega$

$Zb = \frac{V_{1zl}}{I_{1zl}} = \frac{200}{25} = 8\,\Omega$

$Xb = \sqrt{Zb^2 - Rb^2} = \sqrt{8^2 - 3'2^2} = 7'33\,\Omega$

Kapp-en hurbilketa erabiliz:

$V_1 \simeq V_2' + I_2' (Rb \cos\varphi + Xb \cdot \sin\varphi)$

- $\cos\varphi = 1$.

$3000 = V_2' + 25(3'2 \cdot 1 + 0) \Rightarrow V_2' = 2920$ V

$\varepsilon = \frac{V_1 - V_2'}{V_1} = \frac{3000 - 2920}{3000} = \%\, 2'7$

- $\cos\varphi = 0'8$ (atzeraturiko, induktiboa).

$3000 = V_2' + 25(3'2 \cdot 0'8 + 7'33 \cdot 0'6) \Rightarrow V_2' = 2826V$

$\varepsilon = \frac{V_1 - V_2'}{V_1} = \frac{3000 - 2826}{3000} = \%\, 5'8$

• $\cos\varphi = 0'8$ (aurreratuta, kapazitiboa).

$$3000 = V_2' + 25(3'2 \cdot 0'8 + 7'33 \cdot (-0'6)) \Rightarrow V_2' = 3045'9V$$

$$\varepsilon = \frac{V_1 - V_2'}{V_1} = \frac{3000 - 3045'9}{3000} = \%-1'5$$

b) Burdinezko galerak 1'5kW balditza, errendimendua kargaizendatuan η_N eta kargaerdian $\eta_{1/2}$, $\cos\varphi = 0'8$ (atzeratuta) denean.

$P_{FE} = 1'5\,kW$

Kargaizendatua denean $i = 1$.

$$\eta = \frac{i \cdot S_N \cdot \cos\varphi}{i \cdot S_N \cdot \cos\varphi + P_{FE} + i^2 P_m} = \frac{75 \cdot 10^3 \cdot 0'8}{75 \cdot 10^3 \cdot 0'8 + 1500 + 1^2 \cdot 2000} = \%94'5$$

erdia denean $i = 0'5$.

$$\eta = \frac{0'5 \cdot 75 \cdot 10^3 \cdot 0'8}{0'5 \cdot 75 \cdot 10^3 \cdot 0'8 + 1500 + 0'5^2 \cdot 2000} = \%93'7$$

6. $S_N = 100\,kVA$. $\cos\varphi = 0'8$ (atzeratua), $\eta_N = \%93'02$. $\cos\varphi = 1$, $\eta_{1/2} = \%94'34$.
η_{max}?

Karganominala denean $i = 1$.

$$\eta_N = \frac{i \cdot S_N \cdot \cos\varphi}{i \cdot S_N \cdot \cos\varphi + P_{FE} + i^2 P_m} = \frac{1 \cdot 10^5 \cdot 0'8}{1 \cdot 10^5 \cdot 0'8 + P_{FE} + P_m} = 0'9302$$

$P_{FE} = 2\,kW$
$P_m = 4\,kW$

erdia denean $i = 0'5$.

$$\eta_{1/2} = \frac{0'5 \cdot 1 \cdot 10^5 \cdot 1}{0'5 \cdot 10^5 + P_{FE} + 0'5^2 P_m} = 0'9434$$

errendimendu maximoa,

$$i_{N\,max} = \sqrt{\frac{P_{FE}}{P_m}} = \sqrt{\frac{2}{4}} = 0'707$$

$$\eta_{max} = \frac{0'707 \cdot 10^5}{0'707 \cdot 10^5 + 2000 + 0'707^2 \cdot 4000} = 0'9464 = \%94'65$$

7. $S_N = 132\,kVA$, $6000/230\,V$. Serieko parametroaren balioak $R_b = 2'2\,\Omega$ eta $X_b = 21\,\Omega$. dira. Sekundarioan karga elektriko bat dago parametro hauek dituena: $R = 0'4274\,\Omega$ eta $X = 0'3706\,\Omega$ dira.

Karga elektrikoa tentsio nominalarekin eliatzen bada ($V_2 = 230\,V$), kalkulatu:

a) Primarioko V_1 tentsioa.

sekundarioko tentsioa primariora pasatuz:

$$V_2' = V_2 \cdot a = 230 \cdot \frac{6000}{230} = 6000\,V$$

sekundarioko karga elektrikoa primariora pasatuz:

$$\vec{z}' = \vec{z} \cdot a^2 = (0'4274 + j \cdot 0'3706) \cdot \left(\frac{6000}{230}\right)^2 = 363'6 \angle 36'87\,\Omega$$

I_2' intentsitatea V_2' eta z'-ren araberakoa izango da:

$$\vec{I}_2' = \frac{\vec{V}_2'}{\vec{z}'} = \frac{6000}{363'6 \angle 36'87} = 16'5 \angle -36'87°\,A$$

Kapp-en hurbilketa:

$$V_1 \simeq V_2' + I_2' (R_b \cdot \cos\varphi + X_b \cdot \sin\varphi) = 6000 + 16'5 (2'2 \cdot 0'8 + 21 \cdot 0'6) = 6236'9\,V$$

b) Transformadorearen i karga-indizea.

$$i = \frac{I_2'}{I_{1N}} = \frac{16'5}{(132000/6000)} = \frac{16'5}{22} = 0'75$$

c) ε tentsio-erregulazioa.

$$\varepsilon = \frac{V_1 - V_2'}{V_{1N}} = \frac{6236'9 - 6000}{6000} = \%\,3'9$$

Transformadorea tentsio izendatuarekin eliatzen bada ($V_1 = 6000\,V$), kalkulatu:

d) Sekundarioko V_2 tentsioa.

Kasu honetan, I_2' intentsitatea V_1, z' eta z_b-ren araberakoa izango da:

$$\vec{I}_2' = \frac{\vec{V}_1}{(\vec{z}' + \vec{z}_b)} = \frac{6000}{290'9 + j \cdot 21 + 2'2 + j \cdot 21} = 15'86 \angle -39'22\,A$$

Kapp hurbilketa:

$$V_1 \simeq V_2' + I_2' (R_b \cdot \cos\varphi + X_b \cdot \sin\varphi)$$

$$6000 \simeq V_2' + 15'86 \cdot (2'2 \cdot 0'775 + 21 \cdot 0'632) \Rightarrow V_2' = 5762'4\,V$$

e) Transformadorearen i karga-indizea.

$$i = \frac{I_2'}{I_{1N}} = \frac{15'86}{22} = 0'72$$

f) ε tentsio-erregulazioa.

$$\varepsilon = \frac{V_1 - V_2'}{V_{1N}} = \frac{6000 - 5762'4}{6000} = \%\,4$$

3. Transformadore trifasikoak.

8. $S_N = 2000\,kVA$, $6600/33000\,V$, maiztasuna $50Hz$, $\Delta - Y$. Serieko adarrean:

$R_1 = 0'5\,\Omega$ $\quad X_1 = 2'6\,\Omega$ $\quad R_2 = 4'3\,\Omega$ $\quad X_2 = 21'7\,\Omega$

a) Transformadorearen zirkuitu baliokidearen serieko parametroak (primarioan).

$$a = \frac{V_{1N/f}}{V_{2N/f}} = \frac{6600}{33000/\sqrt{3}} = 0'34641$$

$$R_b = R_1 + a^2 R_2 = 0'5 + 0'34641^2 \cdot 4'3 = 1'016\,\Omega$$

$$X_b = X_1 + a^2 X_2 = 2'6 + 0'34641^2 \cdot 21'7 = 5'2\,\Omega$$

b) Sekundarioko V_{2f} faseko eta U_{2L} lineako tentsioak eta ε tentsio-erregulazioa, $V_1 = V_{1N}$, $\cos\varphi = 0'8$ (atzeratutakoa) eta kargaren itxurazko potentzia transformadorearen itxurazko potentzia izendatua direnean.

Kapp-en hurbilketa:

$$V_{1f} = V_{2'f} + I'_{2f}(R_b \cos\varphi + X_b \sin\varphi)$$

$$V_{1f} = V_{1N/f} = 6600\,V$$

$$I_{2f} = I'_{2N/f} = I_{N/f} = \frac{S_N}{3 \cdot V_{1N/f}} = \frac{2000 \cdot 10^3}{3 \cdot 6600} = 101'01\,A$$

ordezkatuz,

$$6600 = V_{2'f} + 101'01 \cdot (1'016 \cdot 0'8 + 5'2 \cdot 0'6)$$

$$V_{2'f} = 6202'8\,V$$

$$V_{2f} = \frac{V_{2'f}}{a} = \frac{6202'8}{0'34641} = 17905'8\,V$$

sekundarioa izarrean dagoenez:

$$U_{2L} = V_{2f} \cdot \sqrt{3} = 31013'8\,V$$

Tentsio-erregulazioa:

$$\varepsilon = \frac{V_{1f} - V_{2'f}}{V_{1N/f}} = \frac{6600 - 6202'8}{6600} = \%6$$

9. $S_N = 400\,kVA$, 20000/230 V, maiztasuna 50 Hz, Y-Y lonexioa.

Hutseko saialkuntzan: $U_{10} = U_{1N}$ $\quad I_{10} = 0'02\ I_{1N}$ $\quad P_0 = 1200\,W$

Adar paraleloko I_{Fe} eta I_m.

$$I_{Fe} = I_{10} \cdot \cos\varphi \qquad I_m = I_{10} \cdot \sin\varphi$$

$$\cos\varphi = \frac{P_0}{3 \cdot V_{10/f} \cdot I_{10/f}}$$

$$V_{10/f} = \frac{U_{10/f}}{\sqrt{3}} = \frac{20\,000}{\sqrt{3}} = 11547\,V$$

$$I_{10/f} = 0'02 \cdot I_{1N/f} = 0'02 \cdot \frac{S_N}{3 \cdot V_{1N/f}} = 0'02 \cdot \frac{400 \cdot 10^3}{3 \cdot 11547} = 0'2309\ A$$

$$\cos\varphi = \frac{1200}{3 \cdot 11547 \cdot 0'2309} = 0'15$$

$$I_{Fe} = I_{10} \cdot \cos\varphi = 0'2309 \cdot 0'15 = \underline{0'03464\,A}$$

$$I_m = I_{10} \sin\varphi = 0'2309 \cdot 0'989 = \underline{0'2283\,A}$$

10. $S_N = 1500\,kVA$, 380/20000 V, maiztasuna 50 Hz, Y-Δ lonexioa.

Zirkuitulaburra: $U_{2zL} = 1000\,V$ $\quad I_{2zL} = 43'3\,A$ $\quad P_{zL} = 16350\,W$

Hutseko sai.: $P_0 = 9000\,W$

a) ε_{zL} ?

$$\varepsilon_{zL} = \frac{V_{1z}}{V_{1N}} = \frac{V_{2z}}{V_{2N}} = \frac{U_{2z/f}}{U_{2NL}} = \frac{1000}{20000} = 0'05 = \underline{\%5}$$

b) Transformadorearen zirkuitu baliduidearen serieko parametroak (primarioan).

$$R_b^s = \frac{P_{zL}}{3 \cdot I_{2z/f}^2} = \frac{16350}{3 \cdot (43'3/\sqrt{3})^2} = 8'72\,\Omega$$

$$Z_b^s = \frac{V_{2z/f}}{I_{2z/f}} = \frac{1000}{(43'3/\sqrt{3})} = 40\,\Omega$$

$$X_b^s = \sqrt{40^2 - 8'72^2} = 39'04\,\Omega$$

$$a = \frac{(380/\sqrt{3})}{20\,000} = 0'010969655$$

$$R_b = R_b^s \cdot a^2 = 8'72 \cdot 0'010969655^2 = \underline{0'00105\,\Omega}$$

$$X_b = X_b^s \cdot a^2 = 39'04 \cdot 0'010969655^2 = \underline{0'0047\,\Omega}$$

c) ε tentsio-erregulazioa, $V_1 = V_{1N}$ eta itxurazko potentzia izendatua direnean eta bi kasu hauetan:

- $\cos\varphi = 0'8$ (atzeraturik)

Kapp-en hurbilketa:

$$V_{1f} = V_{2'f} + I_{2f}'(R_b \cos\varphi + X_b \sin\varphi)$$

$$V_{1f} = V_{1N/f} = 380/\sqrt{3} = 219'4\,V$$

$$I_{2f}' = I_{2N/f}' = I_{1N/f} = \frac{1500 \cdot 10^3}{3 \cdot 219'4} = 2279\,A$$

$$219'4 = V_{2'f} + 2279 \cdot (0'00105 \cdot 0'8 + 0'0047 \cdot 0'6)$$

$$V_{2'f} = 211'06\,V \qquad \varepsilon = \frac{219'4 - 211'06}{219'4} = \%\,3'8$$

- $\cos\varphi = 0'8$ (aurreraturik)

$$V_{1f} = V_{2'f} + I_{2'f}(R_b \cos\varphi - X_b \sin\varphi)$$

$$219'4 = V_{2'f} + 2279(0'00105 \cdot 0'8 - 0'0047 \cdot 0'6)$$

$$V_{2'f} = 223'9\,V \qquad \varepsilon = \frac{V_{1f} - V_{2f}'}{V_{1N/f}} = \frac{219'4 - 223'9}{219'4} = \%\,-2'1$$

d) Errendimendu maximoko itxurazko potentzia eta karga-indizea eta errendimendua maximoa.

$$i_{\eta max} = \sqrt{\frac{P_{Fe}}{P_{2N}}} = \sqrt{\frac{2 \cdot 10^3}{4 \cdot 10^3}} = 0'707$$

$$P_{Fe} = P_0 = 9000\,W$$

$$I_{2NL} = I_{2Nf} \cdot \sqrt{3} = \frac{1500000}{3 \cdot 20000} \cdot \sqrt{3} = 43'3\,A$$

$I_{2zzL} = I_{2NL}$ denez,

$$P_{2N} = P_{zL} = 16350\,W$$

$$i_{\eta max} = \sqrt{\frac{P_{Fe}}{P_{2N}}} = \sqrt{\frac{900}{16350}} = 0'742$$

$$S_{\eta max} = i_{\eta max} \cdot S_N = 0'742 \cdot 1500 \cdot 10^3 = 1112'9\,kVA$$

$$\eta_{max} = \frac{i_{\eta max} S_N \cdot \cos\varphi}{i_{\eta max} S_N \cdot \cos\varphi + i_{\eta max}^2 P_{2N} + P_{Fe}} = \frac{0'742 \cdot 150 \cdot 10^3}{0'742 \cdot 150 \cdot 10^3 + 9000 + 0'742^2 \cdot 16350} = \%\,98'4$$

e) Istripuz, selundarioan zirkuitulaburra ematen bada, kalkulatu zirkuitulaburreko intentsitatea.

zirkuitu laburrean $V'_{2f} = 0$

$$\vec{V}_{1f} = \vec{V}'_{2f} + \vec{I}_{1f}(R_b + jX_b)$$

$$\vec{I}_{1f} = \frac{\vec{V}_{1f}}{R_b + jX_b} = \frac{380/\sqrt{3}}{0'00105 + j0'00417} = 45556'38 \angle -77'4^\circ \text{ A}$$

11. Transformadore trifasiko batean $S_N = 100\text{kVA}$, transformazio erlazioa 400/6600V maiztasuna 50Hz. Y-Δ konexioa.
Saiakuntza hauek egin dira:
hutsekoa: $U_{10/L} = 400\text{V}$ $P_0 = 1250\text{W}$
zirkuitulaburra: $U_{22k/L} = 314\text{V}$ $I_{22k/L} = I_{2N/L}$ $P_{kL} = 1600\text{W}$

a) Errendimendu izendatua η_N $\cos\varphi = 0'8$ (atzeratua).

$$\eta_N = \frac{i \cdot S_N \cdot \cos\varphi}{i \cdot S_N \cdot \cos\varphi + P_{Fe} + i^2 P_{JN}} = \frac{1 \cdot 100 \cdot 10^3 \cdot 0'8}{1 \cdot 100 \cdot 10^3 \cdot 0'8 + 1250 + 1^2 \cdot 1600} = \%96'6$$

b) Errendimendua karga erdian $\eta_{1/2}$, $\cos\varphi = 1$ denean.

$i = 0'5$

$$\eta = \frac{0'5 \cdot 100 \cdot 10^3 \cdot 1}{0'5 \cdot 100 \cdot 10^3 \cdot 1 + 1250 + 0'5^2 \cdot 1600} = \%96'8$$

c) $S_{\eta max}$ eta η_{max}.

$$i_{\eta max} = \sqrt{\frac{P_{Fe}}{P_{JN}}} = \sqrt{\frac{1250}{1600}} = 0'884$$

$$S_{\eta max} = S_N \cdot i_{\eta max} = 100 \cdot 10^3 \cdot 0'884 = 88400\text{ VA}$$

$$\eta_{max} = \frac{i_{\eta max} \cdot S_N \cdot \cos\varphi}{i_{\eta max} \cdot S_N \cdot \cos\varphi + P_{Fe} + i^2 P_{JN}} = \frac{0'884 \cdot 100 \cdot 10^3 \cdot 1}{0'884 \cdot 100 \cdot 10^3 \cdot 1 + 1250 + 0'884^2 \cdot 1600} = \%97'23$$

d) E tentsio-erregulazioa, $U_{2/L} = 6600\text{V}$, $\cos\varphi = 0'8$ (atzeratua) eta karga izendatua direnean.

$$\varepsilon = \frac{V_{1f} - V'_{2f}}{V_{1Nf}} \quad \text{eta} \quad V_{1f} = V'_{2f} + I'_{2f}(R_b \cdot \cos\varphi + X_b \cdot \sin\varphi)$$

$$I_{2N/f} = \frac{S_N}{3 \cdot V_{2fN}} = \frac{100 \cdot 10^3}{3 \cdot 6600} = 5'05\text{ A}$$

$$R'_b = \frac{P_{kL}}{3 \cdot I_{22k/f}} = \frac{1600}{3 \cdot 5'05^2} = 20'91\ \Omega$$

$$Z^s_b = \frac{V_{22cc/f}}{I_{2cc/f}} = \frac{314}{5'05} = 62'18\ \Omega$$

$$X^s_b = \sqrt{Z^{s2}_b - R^{s2}_b} = \sqrt{62'18^2 - 20'91^2} = 58'55\ \Omega$$

selundariotik primariordio baliokidea atera:

$$a = \frac{(400/\sqrt{3})}{6600} = 0'035$$

$$Rb = R^s_b \cdot a^2 = 20'91 \cdot 0'035^2 = 0'0256\ \Omega$$

$$Xb = X^s_b \cdot a^2 = 58'55 \cdot 0'035^2 = 0'717\ \Omega$$

$$V_{1f} = V_{2'f} + I_{2'f}(Rb\cos\varphi + Xb\sin\varphi)$$

$$V_{2'f} = V_{1N} = 400/\sqrt{3}\ V$$

$$I_{2'f} = I_{1Nf} = \frac{S_N}{3 \cdot V_{2'f}} = \frac{100 \cdot 10^3}{3 \cdot (400/\sqrt{3})} = 144'34\ A$$

$$V_{1f} = 400/\sqrt{3} + 144'34 \cdot (0'0256 \cdot 0'8 + 0'0717 \cdot 0'6) = 240'1\ V$$

$$\varepsilon = \frac{V_{1f} - V_{2'f}}{V_{1N/f}} = \frac{240'1 - 400/\sqrt{3}}{400/\sqrt{3}} = \%\,3'97$$

12. 690V → $P_N = 2'1$ MW. 20 kV-eko barne-sarea. 690/20 000 V

$S_N = 25$ MVA Y-Δ konexio $Rb = 1'31 \cdot 10^{-3}\ \Omega$ $Xb = 11'43 \cdot 10^{-3}\ \Omega$

$P_{Fe} = 2400$ W $\cos\varphi = 0'92$ (aurreraturiko)

Transformadore galerak, errendimendua, sorgailuaren borneetako tentsioa eta E sorgailuak potentzia aktibo kaudu ematen baditu:

a) 525 kW. $P_1 = 525$ kW

$$S_1 = \frac{P_1}{\cos\varphi} = \frac{525}{0'92} = 570\ kVA$$

$$i = \frac{S_1}{S_N} = \frac{570}{25 \cdot 10^3} = 0'228$$

$$V_{1f} = V_{2'f} + I_{2'f}(Rb\cos\varphi + Xb\sin\varphi)$$

$$I_{2'f} = i\,I_{1N} = i \cdot \frac{S_N}{3\,V_{1f}} = 0'228 \cdot \frac{25 \cdot 10^6}{3 \cdot (690/\sqrt{3})} = 476'94\ A$$

$$V_{2'f} = V_{2f} \cdot a = 20\,000 \cdot \frac{(690/\sqrt{3})}{20\,000} = 690/\sqrt{3} = 398'37\ V$$

$$V_{1f} = 398'37 + 476'94(1'31 \cdot 10^{-3} \cdot 0'92 - 11'43 \cdot 10^{-3} \cdot 0'39) = 396'8\ V$$

$$\varepsilon = \frac{V_{1f} - V_{2'f}}{V_{1N1f}} = \frac{396'8 - 398'37}{398'37} = \%\,-0'39$$

$$P_J = 3 \cdot I^2_{2'f} \cdot Rb = 3 \cdot 476'94^2 \cdot 1'31 \cdot 10^{-3} = 894\ W$$

$$P_{gal} = P_J + P_{Fe} = 894 + 2400 = 3294\ W$$

$$\eta = \frac{P_1 - P_{gal}}{P_1} = \frac{525 \cdot 10^3 - 3294}{525 \cdot 10^3} = \%99'37$$

b) 2100kW.

$P_1 = 2100\,kW$

$S_1 = P_1 / \cos\varphi = 2100 / 0'92 = 2282'6\,kVA$

$i = S_1 / S_N = 2282'6 \cdot 10^3 / 2'5 \cdot 10^6 = 0'eee913$

$I_2'_f = i \cdot I_{1N} = 0'eee913 \cdot \frac{2'5 \cdot 10^6}{3 \cdot (690/\sqrt{3})} = 1909'95A$

$a = \frac{690/\sqrt{3}}{20\,000} = 0'0199$

$V_2'_f = a \cdot V_{2f} = 0'0199 \cdot 20\,000 = 398'37V$

$V_{1f} \simeq V_2'_f + I_2'_f (R_b \cos\varphi + X_b \sin\varphi)$

$V_{1f} \simeq 398'37 + 1909'95 (1'31 \cdot 10^{-3} \cdot 0'92 - 11'43 \cdot 10^{-3} \cdot 0'39) \simeq 392'1\ V$

$U_{1L} = 679'2\,V$

$P_J = 3 \cdot I_2'^2_f \cdot R_b = 3 \cdot 1909'95^2 \cdot 1'31 \cdot 10^{-3} = 14336'26\,W$

$P_{gal} = P_J + P_{Fe} = 14336'26 + 2400 = 16736'26\,W$

$$\eta = \frac{P_1 - P_{gal}}{P_1} = \frac{2100 \cdot 10^3 - 16736'26}{2100 \cdot 10^3} = \%99'2$$

Makina asinkronoak.

Momentu mekanikoa (Ce)

Errotorearen egerteen den indarra tentsioaren ondorioz. Abiadura erlatiboa aldatzean indarra aldatu egiten da. Abiadura 0 bada $P=0$ baina $Ce \neq 0$!! Abiadura sinkronoa denean $Ce=0$ ez delako induzitzen.

Momentu magnetikoaren birdreta

Teon bezala sartuko da. Uhertu nola sortzen den. Wave space distribution.

Azterketa → Teoria

Aurreko ariketaren antzekoa izango da. kontzeptuak uhertzea, agian frogapen bat.

$Rx \uparrow \rightarrow \varphi \downarrow \rightarrow s \downarrow \rightarrow \cos\varphi \uparrow$

Rb Xb finkoak dira, konst (errealak)

Potentzia maximoan Sw da, izendatua.

Abiadura izendatua bada, potentzia, RL... izendatua izango da.

4. Ariketa.

$R_1 = 3\Omega$ $R_2' = 2\Omega$ $X_1 = 5\Omega$ $X_2' = 4\Omega$

$f_1 = 50$ Hz

$p = 2$

$U_{1N/L} = 220$ V

Estatorea Y izar konexioan

simplifikazioa $B_0 = 0$, $G_0 = 0$ $R_{Fe} = 0$

$Cerg_2 = 4 \cdot 10^{-4} \cdot \omega_2^2$

$n_2 > n_1$ $s(-)$

sorgailuan P_2 $(-)$ potentzia sortzen dugulako, ez kontsumitzen (Ce DA SARTUKO)

c) Bolanta ez da oso erabiltzen (Ce DA SARTUKO)

bolantean n_2 aldatuko dugu.

n_2 (abiadura sinkronoa) beti ere kontuan, zeinu interpretazioa

a)

Zerradura hasierako orduko puntuan.

$$n_1 = \frac{60 \cdot f}{p} = \frac{60 \cdot 50}{2} = 1500 \text{ bira/min}$$

$$Ce = Cerg_2 = 4 \cdot 10^{-4} \cdot \left(\frac{n_2 \cdot 2\pi}{60}\right)^2 = \frac{3 \cdot V_{s/f}^2 \, R_2'}{2\pi(n_1/60) \cdot s\left[\left(R_2 + \frac{R_2'}{s}\right)^2 + (X_2 + X_2')^2\right]}$$

$$4 \cdot 10^{-4} \cdot \left(\frac{(n_1 - s n_1) 2\pi}{60}\right)^2 = \frac{3 \cdot (220/\sqrt{3})^2 \cdot 2}{2\pi(1500/60) \cdot s \cdot [(3 + 2/s)^2 + (5+4)^2]} =$$

$$= 4 \cdot 10^{-4} \left(\frac{2\pi \cdot 1500 (1 - s)}{60}\right) \Rightarrow s = 0'074$$ ekuazio horretatik s ebatzi eta (+)

$$s = \frac{n_1 - n_2}{n_1} \Rightarrow -n_2 = s \cdot n_1 - n_1 \Rightarrow n_2 = n_1 - s n_1 = 1500(1 - 0'074) = 1389 \text{ bira/min}$$

izar konexioan $I_{1f} = I_{1L}$ beraz,

$$\vec{I}_{1L} = \frac{\vec{V}_{1f}}{R_1 + R_2' + R_k' + (X_1 + X_2')j} = \frac{220/\sqrt{3}}{3+2+25'03+(5+4)j} = 4'052\ \angle -16'65°\ A$$

$$R_k' = R_2'\left(\frac{1-s}{s}\right) = 2\cdot\left(\frac{1-0'074}{0'074}\right) = 25'03\ \Omega$$

$$P_2 = 3\, V_{2f}\, I_{2f} \cdot \cos\varphi = 3\cdot 220/\sqrt{3}\cdot 4'052\cdot \cos(16'65) = 1479'283\ W$$

$$P_{me} = P_{mb} - P_M^{\circ} = 1232'6\ W$$
$$P_{mb} = 3 R_k' I_{2f}^2 = 3\cdot 25'03\cdot 4'052^2 = 1232'6\ W$$

$$Ce = \frac{P_{me}}{\omega_2} = \frac{1232'6}{(2\pi\cdot 1389/60)} = 8'5\ Nm$$

b) Abiadura 201 bira/min handiagotzen bada, kalkulatu η.

$$\eta = \frac{P_2}{P_{me}}$$

$n_2 = 1389 + 201 = 1590$ bira/min $> n_1$ denez, makina asinkronoa sorgailu moduan dago lanean.

$$s = (1500 - 1590)/1500 = -0'06$$

$$I_{1f} = \frac{220/\sqrt{3}}{3+2-36'33+(5+4)j} = 4'015\ \angle -163'31°\ A \qquad \varphi = 0 + 165'31 = 165'31°$$

$$R_k' = R_2'\left(\frac{1-s}{s}\right) = 2\left(\frac{1+0'06}{-0'06}\right) = -36'33\ \Omega$$

$$P_1 = 3\, V_{1f}\, I_{1f} \cos\varphi = 3\cdot 220/\sqrt{3}\cdot 4'015\cdot \cos 163'31° = -1467\ W$$

$$P_{mb} = 3 R_k' I_{2f}^2 = 3\cdot(-36'33)\cdot 4'015^2 = -1756'9\ W$$
$$P_{me} = P_{mb} - P_M = -1756'9 - 0 = -1756'9\ W$$

$$\eta = \frac{-1467}{-1756'9} = \%\ 83'5$$

c) Balaztatze-momentua eta makinak xurgatzen duen potentzia osoa.

Balaztatzerakoan n_2 eremu magnetikoaren aurka doanez,

$n_2 = -1389$ bira/min

$$R_k' = R_2'\left(\frac{1-s}{s}\right) = 2\cdot\left(\frac{1-1'926}{1'926}\right) = -0'9615\ \Omega$$

$$s = \frac{1500 + 1389}{1500} = 1'926$$

$$I_{1f} = \frac{220/\sqrt{3}}{3+2-0'9615+(4+5)j} = 12'88\ \angle -65'82°\ A \qquad \varphi = 65'82°$$

$$P_J = 3 R_b I_{1f}^2 = 3\cdot(3+2)\cdot 12'88^2 = 2488'4\ W$$
$$P_{mb} = 3 R_k' I_{1f}^2 = 3\cdot(-0'9615)\cdot 12'88^2 = -478'7\ W$$
$$P_{me} = P_{mb} - P_M^{\circ} = -478'7\ W$$

$$Ce = \frac{P_{me}}{\omega_2} = \frac{-478'7}{\frac{(2\pi\cdot(-1389))}{60}} = 3'3\ Nm$$

1. Arikleta.

$R_1 = 0'5\ \Omega$ $R_2 = 0'125\ \Omega$ $X_1 = 2\ \Omega$ $X_2 = 0'5\ \Omega$
$p = 3$ $a = 2$ $f = 50\,Hz$ estatorea: Y
$n_{2N} = 971$ bira/min
Simplifikazioak: $I_{Fe} = 0$, $I_m = 0$, $P_M = 0$
$U_{1/L} = 500\,V$

a) n_1?

$$n_1 = \frac{60 f_1}{p} = \frac{60 \cdot 50}{3} = 1000 \text{ bira/min}$$

b) S_N.

$$S_N = \frac{n_1 - n_{2N}}{n_1} = \frac{1000 - 971}{1000} = 0'029$$

c) f_{SN} errotoreko maiztasuna.

$$f_{SN} = f_1 \cdot S_N = 50 \cdot 0'029 = 1'45\ Hz$$

d) R'_{KN} karga mekanikoko erres.

$$R'_{KN} = a^2 R_2 \left(\frac{1 - S_N}{S_N}\right) = 2^2 \cdot 0'125 \cdot \left(\frac{1 - 0'029}{0'029}\right) = 16'74\ \Omega$$

e) $I_{1/f}$ estatoreko faseko intentsitatea.

$$I_{1/f} = I_{1/L} = \frac{V_{1/f}}{R_b + R'_K + X_b i} = \frac{500/\sqrt{3}}{1 + 16'74 + 4i} = 15'91\ |-12'73^\circ\ A$$

$R_b = R_1 + a^2 R_2 = 0'5 + 2^2 \cdot 0'125 = 1\ \Omega$
$X_b = X_1 + a^2 X_2 = 2 + 2^2 \cdot 0'5 = 4\ \Omega$

f) P_{mb} barne potentzia mekanikoa.

$$P_{mb} = 3 \cdot R'_K I_{1f}^2 = 3 \cdot 16'74 \cdot 15'91^2 = 12712'09\ W$$

g) P_1 kurgaturiko potentzia elektrikoa eta η.

$$P_1 = 3 V_{1/f} I_{1/f} \cos\varphi = 3 \cdot 500/\sqrt{3} \cdot 15'91 \cdot \cos(12'73) = 13439'78\ W$$

$$P_{me} = P_{mb} - P_M^{\,0} = 12712'09\ W$$

$$\eta = \frac{P_{me}}{P_1} = \frac{12712'09}{13439'78} = 0'9458 = \%94'58$$

2. Ariketa.

Estatorea Δ lotuxioan, $U_L = 400V$, $f = 50Hz$, $R_2 = 0'1\,\Omega$, $X_2 = 1\,\Omega$
$f_{SN} = 2Hz$, $p = 3$, $a = 2$, $R_1 = 0\,\Omega$, $X_1 = 0\,\Omega$, $P_{Fe} = 0W$, $P_M = 0W$

a) Momentu eragile izendatua (C_{eN}).

$$f_{SN} = f \cdot S_N \Rightarrow S_N = \frac{f_{SN}}{f} = \frac{2}{50} = 0'04$$

$$n_1 = \frac{60 f_1}{p} = \frac{60 \cdot 50}{3} = 1000 \text{ bira/min}$$

↗ KONTUZ! Δ lotuxioa

$$C_e = \frac{3 V_{1f}^2 R_2'}{2\pi (n_1/60) S \left[\left(R_1 + \frac{R_2'}{S}\right)^2 + (X_1 + X_2')^2\right]} = \frac{3 \cdot 400^2 \cdot 2^2 \cdot 0'1}{2\pi (1000/60) \cdot 0'04 \cdot \left[\left(2^2 \cdot \frac{0'1}{0'04}\right)^2 + (2^2 \cdot 1)^2\right]}$$

$C_e = 305'1433$ Nm

b) Momentu eragile maximoa ematen den biraketa-abiadura (n_{2cmax}).

$$S_{cmax} = \frac{R_2'}{\sqrt{R_1^2 + (X_1 + X_2')^2}} = \frac{2^2 \cdot 0'1}{\sqrt{0^2 + (0 + 2^2 \cdot 1)^2}} = 0'1$$

$$S_{cmax} = \frac{n_1 - n_{cmax}}{n_1} \Rightarrow n_{cmax} = n_1 (1 - S_{cmax}) = 1000 (1 - 0'1) = 900 \text{ bira/min}$$

c) Momentu eragile maximoa $C_{e,max}$.

$$C_{emax} = \frac{3 V_{1f}^2 R_2'}{2\pi (n_1/60) S_{cmax} \left[(R_2'/S_{cmax})^2 + X_2'^2\right]} = \frac{3 \cdot 400^2 \cdot 2^2 \cdot 0'1}{2\pi \cdot (1000/60) \cdot 0'1 \left[(2^2 \cdot 0'1/0'1)^2 + (2^2 \cdot 1)^2\right]}$$

$C_{e,max} = 572'96$ Nm

3. Ariketa.

$P_{MEN} = 20kW$, $f = 50Hz$, $p = 2$, $n_{2N} = 1425$ bira/min, $P_{Fe} = P_M$ eta P_{MEN}-ren %5 dira.
$P_{J2} = 0W$
η_{on}?

$$n_1 = \frac{60 f}{p} = \frac{60 \cdot 50}{2} = 1500 \text{ bira/min}$$

$$S_N = \frac{n_1 - n_{2N}}{n_1} = \frac{1500 - 1425}{1500} = 0'05$$

$$P_{Fe} = P_M = 0'05\, P_{MEN} = 0'05 \cdot 20 \cdot 10^3 = 1000\ W = 1kW$$

$$P_{MG} = P_{MEN} + P_M = 20 \cdot 10^3 + 1000 = 21000\ W = 21kW$$

$$\frac{P_{MG}}{P_{J2}} = \frac{(1 - S)}{S} \Rightarrow P_{J2} = \frac{21000 \cdot 0'05}{(1 - 0'05)} = 1105'26\ W$$

$$P_1 = P_{me} + P_M + P_{J2} + P_{Fe} + P_{J1} = 20.10^3 + 2.1000 + 1105'26 = 23105'26\,W = 23'10526$$

$$\eta = \frac{P_{me}}{P_1} = \frac{20}{23'10526} = 0'8656 = \%86'56$$

Makina sinkronoak

1 Ariketa.

Alternadore trifasiko bat. Bere $V = 13kV$ eta (Y). Ematen duen $P = 5000kW$ eta $\cos\varphi = 1$. Fase hutseko E_0 tentsioaren eta Ie esitazio-intentsitatearen arteko erlazioa:

$$E_0 = \frac{23430\, Ie}{70 + Ie}$$

$Xs = 7\,\Omega$; $R = 0$

a) Turbinaren momentua konst bada eta esitazioa %40 igotzen bada, $\vec{I}$?

Hasieran intentsitatea → $P = 3VI\cos\varphi \Rightarrow I = \frac{P}{3V\cos\varphi} = \frac{5000 \cdot 10^3}{3 \cdot (13 \cdot 10^3/\sqrt{3}) \cdot 1} = 222A$

$$\vec{E_0} = \vec{V} + \vec{I}(R + jXs) = (13 \cdot 10^3/\sqrt{3}) + 222 \cdot (0 + j7) = 7664'7\angle 22'7° \; V$$

Ondorioz, Ie esitazioa: $7664'7 = \frac{23430\, Ie}{70 + Ie} \Rightarrow Ie = 34'03A$

%40 igotzen denez, $Ie = 1'4 \cdot 34'03 = 47'64\,A$

$$E_0 = \frac{23430 \cdot 47'64}{70 + 47'64} = 9488'3V$$

Baina ez daukigu θ berria, beraz ezin dugu aurreko ekuazio erabili.

$$P = 3 \cdot V \cdot \frac{E_0}{Xs} \cdot \sin\theta \Rightarrow \sin\theta = \frac{5000 \cdot 10^3 \cdot 7}{3 \cdot (13 \cdot 10^3/\sqrt{3}) \cdot 9488'3} = 0'1638 \Rightarrow \theta = 9'43°$$

$\varphi \neq \theta$, orain erabil generalera ekuazioa,

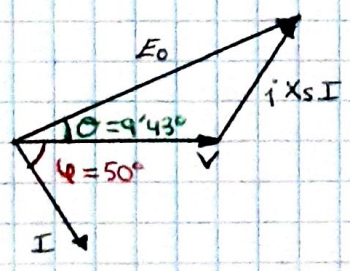
$$\vec{E_0} = \vec{V} + \vec{I}(R + jXs) \Rightarrow \vec{I} = \frac{E_0 - V}{(R + jXs)} = \frac{9488'3\angle 9'43° - 13 \cdot 10^3/\sqrt{3}}{7j} = 345'7\angle -50° \; A$$

b) Sorgailuak sareari ematen dion edo hartzen duen potentzia errealtiboa.

Sorgailuak sareari ematen, $Qsor = 3VI\sin\varphi$ $\quad \varphi = \varphi_V - \varphi_I = 0 - (-50) = 50°$

$$Qsor = 3 \cdot 13 \cdot 10^3/\sqrt{3} \cdot 345'7 \cdot \sin 50° = 5965'4\,kvar$$

Positiboa denez, sorgailuak sareari ematen dio.



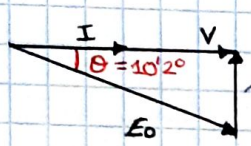
2. Ariketa.

Motor sinkrono trifasikoa. (Y), $P_N = 736$ kW, $\cos\varphi = 1$, $U_L = 3200$ V, $2p = 30$ polo, $X_s = 2'5\,\Omega$, $f_1 = 50$ Hz eta tentsio konst. $\cos\varphi = 1$.
Momentu maximoa?

$$P = 3VI\cos\varphi \Rightarrow I = \frac{P}{3V\cos\varphi} = \frac{736\cdot10^3}{3(3'2\cdot10^3/\sqrt{3})\cdot1} = 132'8\,A$$

$\varphi = 0$

$$\vec{V} = \vec{E_0} + \vec{I}(R + jX_s) \Rightarrow \vec{E_0} = 3'2\cdot10^3/\sqrt{3} - 132'8(0 + j2'5) = 1877'1\,\underline{/-10'2^\circ}\ V$$



$\varphi = 0$ (V I)
$\theta = 10'2°$ (E_0-V)

Hau aldiz P nominalarekin eta $\cos\varphi = 1$ izanik egin dugu. Momentu maximoan, aldiz, ezitazio kordin, ondorioz E_0 balioa kordin, baina $\theta = 90°$ denean ematen da.

$$P_{max} = 3V\frac{E_0}{X_s}\sin\theta = 3\cdot3'2\cdot10^3/\sqrt{3}\cdot\frac{1877'1}{2'5}\cdot1 = 4161577'7\ W$$

momentua, $C_{max} = \frac{P_{max}}{\omega_2} = \frac{P_{max}}{(n_1\cdot2\pi/60)} = \frac{4161577'7}{200\cdot2\pi/60} = 198701\ Nm$

$$n_1 = \frac{60f_1}{p} = \frac{60\cdot50}{15} = 200\ \text{bira/min}$$

3. Ariketa.

30A xurgatu, $U_L = 440$ V, $\cos\varphi = 0'8$ (atzeraturik). $\frac{2}{3}$ 8832 W Perab, motor sinkronoa orain $\cos\varphi = 1$. $\eta_{mot} = \%80$.

a) Kontsumitutako edo sortutako Q, motorrak.

Hasieran karga trifasikoarekin, $P_{karga} = \sqrt{3}\,U_L I_L\cos\varphi = \sqrt{3}\cdot440\cdot30\cdot0'8 = 18'29$ kW

$Q_K = \sqrt{3}\,U_L I_L\sin\varphi = \sqrt{3}\cdot440\cdot30\cdot\sin(\arccos0'8) = 13'72$ kVar

ondoren, motor sinkronoa (ms) gehituz,

$P_{osoa} = P_K + P_{ms}$ $\quad Q_{osoa} = Q_K + Q_{ms}$

eman diguten $\cos\varphi_{osoa} = 1$ da, beraz, $Q_{osoa} = 0 \Rightarrow Q_{ms} = \underline{-13'72\ kVar}$

Xurgatu egin du (-).

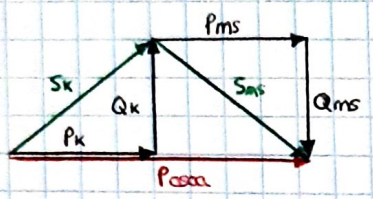
b) Motorraren S irteerako potentzia.

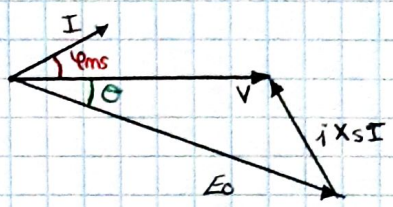
Lehenik aldiboa: $\eta = \frac{P_{mek}}{P_{elek}} \Rightarrow 0'8 = \frac{8832}{P_{ms}} \Rightarrow P_{ms} = 11040\ W$

beraz,

$$S_{ms} = \sqrt{P^2 + Q^2} = \sqrt{11040^2 + (-13720)^2} = \underline{17'61\ kVA}$$

Potentzien bektore-diagrama:





c) Motorraren $\cos\varphi$.

$$\tan\varphi_{ms} = \frac{Q_{ms}}{P_{ms}} = \frac{-13720}{11040} = -1'243 \Rightarrow \varphi_{ms} = -51'18°$$

$\cos\varphi_{ms} = 0'627$ (kapazitiboa, aurreraturik)

Intentsitatea aurreraturik dago φ_{ms} balioa negatiboa delako.

4. Ariketa.

$U_L = 220V$, Y konexioa, $2p=4$, $f=50Hz$ eta $P=18'4$ kW xurgatzen duen motor sinkrono batek, 3°-ko momentu-angelua du ($\theta=-3°$). $E_0 = 110V$.

a) errealtantzia sinkronoaren (X_s) balioa.

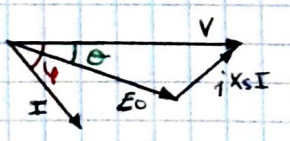
$$P = 3 \cdot V \frac{E_0}{X_s} \sin\theta \Rightarrow X_s = 3V\frac{E_0}{P}\sin\theta = \frac{3 \cdot 220/\sqrt{3} \cdot 110 \cdot \sin(+3°)}{18'4 \cdot 10^3} = 0'1192\ \Omega$$

b) Potentzia-faktorea ($\cos\varphi$).

$$\vec{V} = \vec{E_0} + \vec{I}(R + jX_s) \Rightarrow \vec{I} = \frac{220/\sqrt{3} - 110\angle -3°}{0 + 0'1192j} = 151\angle -71'46°\ A$$

$$\varphi = \varphi_V - \varphi_I = 0 - (-71'46°) = 71'46°$$

$\cos\varphi = 0'318$



c) Motorrak kontsumitutako edo sortutako Q potentzia erreaktiboa.

$$Q_{kon} = 3VI\sin\varphi = 3 \cdot 220/\sqrt{3} \cdot 151 \sin 71'46° = 54'55\ Kvar$$

Positiboa denez, motorrak kontsumitu egiten du.

Makina sinkronoa.

$U_N = 1'2\,kV$, λ konexioa, $X_s = 3'24\,\Omega$. Sorgailuak $100\,kW$ sortzen ditu, IN. $Q = 45\,kvar$ kontsumitu.

a) $\cos\varphi$ eta I.

$$\cos\varphi = \frac{P}{3VI} \qquad \sin\varphi = \frac{Q}{3VI} \qquad \text{ondorioz,}$$

$$\tan\varphi = \frac{Q}{P} = \frac{45\cdot10^3}{100\cdot10^3} = 0'45 \Rightarrow \varphi = 24'228^\circ$$

$$\cos\varphi = \cos 24'228^\circ = 0'912$$

$$I = \frac{P}{3V\cos\varphi} = \frac{100\cdot10^3}{3\cdot(1'2\cdot10^3/\sqrt{3})\cdot0'912} = 52'76\,A$$

$$\vec{I} = 52'76\,\angle -24'228^\circ\,A$$

b) E_0 eta θ.

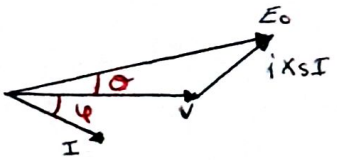
$$\vec{E_0} = \vec{V} + \vec{I}(R + jX_s) = 1'2\cdot10^3/\sqrt{3} + 52'76\,\angle -24'228^\circ\,(3'24j) = 778'73\,\angle 11'55^\circ\,V$$

$$\theta = 11'55^\circ$$

c) Sorgailua gainezitatua ala azpiezitatua? Zergatik? Beltore-diagrama.

$$E_0\cos\theta = 778'73\cdot\cos 11'55^\circ = 762'96 > V = 692'82\,V$$

ondorioz, gainezitatua da.



Potentzia altiboa %10 ↑. $E_0 = 740\,V$.

d) θ.

$$P = 1'1\cdot100\cdot10^3 = 110\,kW$$

$$P = 3\frac{VE_0}{X_s}\cdot\sin\theta \Rightarrow \sin\theta = \frac{110\cdot10^3\cdot3'24}{3\cdot1'2\cdot10^3/\sqrt{3}\cdot740} = 0'2317 \Rightarrow \theta = 13'40^\circ$$

e) $\cos\varphi$ eta I.

$$Q = 3\cdot\frac{V(E_0\cdot\cos\theta - V)}{X_s} = 3\cdot\frac{1'2\cdot10^3/\sqrt{3}\,(740\cdot\cos 13'4^\circ - 1'2\cdot10^3/\sqrt{3})}{3'24} = 17345'33\,VAR$$

$$\tan\varphi = \frac{Q}{P} = \frac{17345'33}{110\cdot10^3} = 0'157 \Rightarrow \varphi = 8'96^\circ \Rightarrow \cos\varphi = 0'988$$

$$I = \frac{P}{3V\cos\varphi} = \frac{110.10^3}{3.1'2.10^3/\sqrt{3}.0'988} = 53'58\ A \Rightarrow \vec{I} = 53'58\ \underline{|-8'96^\circ}\ A$$

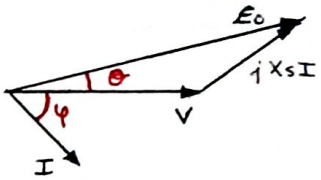
f) Q.

Aurretik kalkulatu dut. $Q = 17345'33\ VAr$

g) Gainezitatua edo azpiezitatua? Zergatik? Motore-diagrama.

$E_0 . \cos\theta = 740 . \cos 13'4 = 719'85 > V$

ondorioz, gainezitatua da.



Miren Matias Alkaiaga

1. Transformadore trifasikoa. 690/20 000 V $S_N = 2'5$ MVA Y-Δ
$U_{1cc/f} = 41'7$ V $I_{1cc/L} = I_{1N/L}$ $P_{cc} = 17'2$ kW P_{1N} $U_{1cc/L} = U_{1N/L}$
$P_0 = 2'4$ kW $= P_{Fe}$

a) R_b eta X_b.

$U_{1c/L} = U_{1N/L} = 690$ V $\quad V_{1N/f} = 690/\sqrt{3}$ V

$S_N = 3 V_{1N/f} \cdot I_{1N/f} \Rightarrow I_{1N/f} = \frac{2'5 \cdot 10^6}{3 \cdot 690/\sqrt{3}} = 2091'85\ A = I_{1N/L}$

$P_{cc} = 3 I^2_{1cc/f} R_b \Rightarrow R_b = \frac{17'2 \cdot 10^3}{3 \cdot 2091'85^2} = 1'31 \cdot 10^{-3}\ \Omega$

$Z_b = \frac{V_{1cc/f}}{I_{1cc/f}} = \frac{41'7/\sqrt{3}}{2091'85} = 0'011509\ 2\ \Omega$

$X_b = \sqrt{Z_b^2 - R_b^2} = \sqrt{0'011509\ 2^2 - (1'31 \cdot 10^{-3})^2} = 0'011434\ \Omega$

b) $i_{\eta max}$, η_{max}, $\cos\varphi = 1$.

$i_{\eta max} = \sqrt{\frac{P_{Fe}}{P_{1N}}} = \sqrt{\frac{2'4}{17'2}} = 0'37354\ \angle -1$

$\eta_{max} = \frac{i_{\eta max} S_N \cos\varphi}{i_{\eta max} S_N \cos\varphi + 2 P_{Fe}} = \frac{0'37354 \cdot 2'5 \cdot 10^6 \cdot 1}{0'37354 \cdot 2'5 \cdot 10^6 \cdot 1 + 2 \cdot 2'4 \cdot 10^3} = 0'9949 = \%99'49$

c) $\cos\varphi = 1$ $\quad I_N \rightarrow \varepsilon$?

$\varepsilon = \frac{V_1 - V_2'}{V_{1N}} = \frac{I_2' R_b \cos\varphi}{V_{1N}} = \frac{1'31\ 10^{-3} \cdot 1 \cdot 781'397}{690/\sqrt{3}} = 0'002\ 57 = \%0'257$

Kappa → $V_2 = V_2' + I_2' (R_b \cos\varphi + X_b \sin\varphi)$ goian ordezkatuz,

$I_2' = I_{1N} \cdot i = 2091'85 \cdot 0'37354 = 781'397$ A

d) $\ell = 0'5$ $\quad P_{Fe}$? $\quad U_{1/L} = U_{1N/L}$.

$P_{Fe} = 3 \frac{V_{1c}^2}{R_b} = 3 \cdot \frac{(690/\sqrt{3})^2}{1'31\ 10^{-3}} = 363'372$ MW

$U_{1/L} = 0'5\ U_{1N/L}$

$P_{Fe} = \frac{3 (0'5 \cdot 690/\sqrt{3})^2}{1'31\ 10^{-3}} = 90'843$ MW

Karga indizeak ez dira eraginik P_{Fe}-ren balioan.

Hiren Matias Alkaiaga

2. Makina asinkronoa MOTORRA $R_1 = 0'26\,\Omega$ $R'_2 = 0'39\,\Omega$ $X_1 + X'_2 = 8'11\,\Omega$
$f_1 = 50\,Hz$ $p = 2$ $U_{1N/L} = 400\,V$ estatorea (Δ) $P_M = 1200\,W$
$B_0 = 0$ $G_0 = 0$

a) Kalkulatu.

Abiaraztean unean errotorearen kasuan $s = 1$ da.

$$Ce,\,abi = \frac{3\,V_{1/f}^2 \cdot R'_2}{2\pi (n_1/60)\, s\, [(R_1 + R'_2/s)^2 + (X_1 + X'_2)^2]} = \frac{3 \cdot (400/\sqrt{3})^2 \cdot 0'39}{2\pi\, 1500/60\, [(0'26 + 0'39)^2 + 8'11^2]} = 6\,Nm$$

$$V_{1/f} = 400/\sqrt{3}\;V \qquad n_1 = \frac{50 \cdot 60}{2} = 1500\,bira/min$$

b) $n_{2,cmax}$ eta Ce,max.

$$Sc,max = \frac{R'_2}{\sqrt{R_1^2 + (X_1 + X'_2)^2}} = \frac{0'39}{\sqrt{0'26^2 + 8'11^2}} = 0'048 \quad [-]$$

$$n_{2,cmax} \Rightarrow \quad Sc,max = \frac{n_1 - n_{2,cmax}}{n_1} \Rightarrow n_{2,cmax} = (1 - Scmax)\, n_1$$

$$n_{2,cmax} = (1 - 0'048) \cdot 1500 = 1427'91\,bira/min$$

$$Ce,max = \frac{3\,V_{1/f}^2\, R'_2}{2\pi\,(n_1/60)\,Scmax\,[(R_1 + R'_2/Scmax)^2 + (X_1 + X'_2)^2]} =$$

$$= \frac{3\,(400/\sqrt{3})^2 \cdot 0'39}{2\pi\,(1500/60) \cdot 0'048\,[(0'26 + 0'39/0'048)^2 + 8'11^2]} = 60'817\,Nm$$

$s = 0'03$ izanik,

c) n_2 eta Ce.

$$n_2 = (1 - s)\, n_1 = (1 - 0'03)\, 1500 = 1455\,bira/min$$

$$Ce = \frac{3\,(400/\sqrt{3})^2 \cdot 0'39}{2\pi\,(1500/60) \cdot 0'03\,[(0'26 + 0'39/0'03)^2 + 8'11^2]} = 54'808\,Nm$$

d) η ?

$$\eta = \frac{Pme}{P_1} = \frac{8233'605}{8782'886} = 0'93746 = \%93'746$$

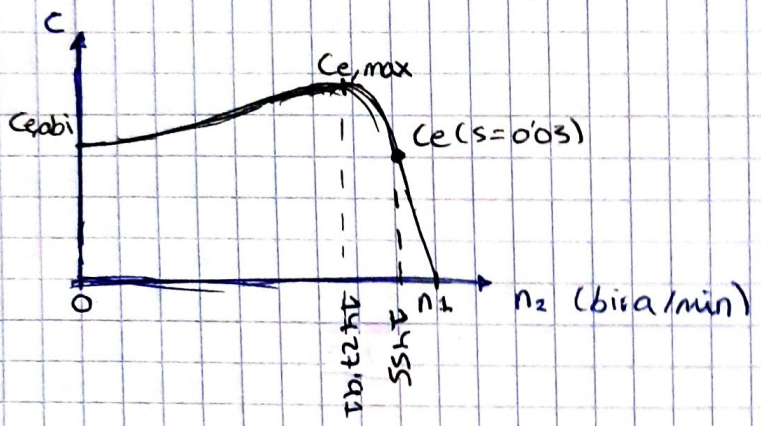
$$Pme = Pmb - P_M = 3RK'\,I'^2_{2/f} - P_M = 3 \cdot 0'39\left(\frac{1 - 0'03}{0'03}\right) \cdot 14'86^2 - 120 = 8233'605\,W$$

$$\vec{I}_{2/f} = \frac{\vec{V}_{2/f}}{\sqrt{(R_1 + R'_2/s)^2 + (X_1 + X'_2)^2}} = \frac{400/\sqrt{3}\;\angle 0^\circ}{\sqrt{(0'26 + 0'39/0'03)^2 + 8'11^2}} = 14'86\;\underline{/-31'45^\circ}\;A$$

$$P_1 = 3\,V_{1/f}\,I_{1/f}\cos\varphi = 3 \cdot 400/\sqrt{3} \cdot 14'86 \cdot \cos 31'45^\circ = 8782'886\,W$$

ordezkatuz gero,

e) n_2 - Ce ardatzak 3 puntuak irudikatu.



f) Rz -ren abiadura eragingo balu Scmax txikiagotzea, hauda maximoa eskubirantz desplazatzea. Abiadura handituko litzateke, eta abiadura sinkronoa baina handiago izango litzateke, lerradura negatibo bihurtuz.

Miren Matias Alkaiaga

3. Sorgailu sinkrono trifasikoa, $V_{AA'} = 400V$ λ $X_s = 0'71\ \Omega$
$P_{sor} = 25 kW$ $Q_{kontsumitu} = -18 Kvar$

a) $\cos\varphi$ eta $\vec{I}$?

$$\varphi = \arctan\frac{Q}{P} = \arctan\left(\frac{-18.10^3}{25.10^3}\right) = -35'754°$$

$$\cos\varphi = \cos 35'754° = 0'8115$$

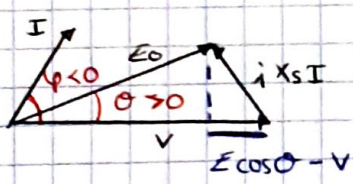
$$P_{sor} = 3VI\cos\varphi \Rightarrow I = \frac{P_{sor}}{3.V\cos\varphi} = \frac{25.10^3}{3.400/\sqrt{3}.0'8115} = 44'46\ A$$

$$\vec{I} = 44'46\ \angle +35'754°\ A$$

b) E_0 eta θ ?

$$\vec{E_0} = \vec{V} + \vec{I}(R + jX_s) = 400/\sqrt{3}\ \angle 0° + 44'46\ \angle -35'754° \cdot (0'71j) =$$
$$= 214'634\ \angle 6'874°\ V \Rightarrow \theta = 6'874°$$

c) Sorgailua azpieszitatua dago Q kontsumitzen duelako.



P %15 igo → $P_{sor} = 25 + 25.0'15 = 28'75\ kW$ $E_0 = 245V$

d) θ.

$$P_{sor} = 3\frac{VE_0}{X_s}.\sin\theta \Rightarrow \sin\theta = \frac{P_{sor}.X_s}{3VE_0} = \frac{28'75.10^3.0'71}{3.400/\sqrt{3}.245} = 0'12$$

$$\theta = 6'9069°$$

e) $\cos\varphi$ eta I.

$$Q = 3\frac{V(E_0\cos\theta - V)}{X_s} = \frac{3.400/\sqrt{3}(245.\cos 6'9069 - 400/\sqrt{3})}{0'71} = 11984'7\ VAr$$

$$\varphi = \arctan\frac{Q}{P} = \arctan\left(\frac{+11984'7}{28'75.10^3}\right) = 22'629°$$

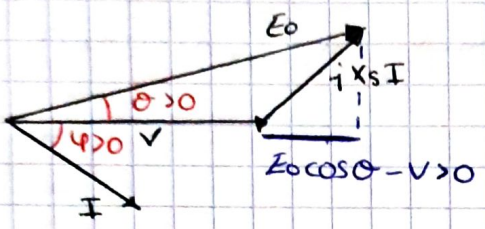
$$\cos\varphi = \cos(+22'629°) = 0'923$$

$$I = \frac{P_{sor}}{3V\cos\varphi} = \frac{28'75.10^3}{3.400/\sqrt{3}.0'923} = 44'958\ A$$

$$\vec{I} = 44'958\ \angle -22'629°\ A$$

11 e atalean kalkulatu dut, $Q = 11984'7\ VAr$

g) Sorgailuaren gainexzitatua egongo da Q sortzen denelako.



P mantsiten bada eta Eo mantendu.

h) Θ aldatuko da?

$P = \frac{3VEo}{Xs} \sin\Theta$ formulan ikusten dugun bezala, P gero eta txikiagoa orduan eta Θ txikiagoa, zuzenki proportzionalak dira.

i) Q aldatuko da?

$Q = 3\frac{V(Eo\cos\Theta - V)}{Xs}$ formulan ikusten den bezala eta aurreko atalean esandakoa kontuan hartuz ($P\downarrow \rightarrow \Theta\downarrow$), Θ txikiagotzeak Q handiagotzea dakar, izan ere alderantziz proportzionalak dira.