8.1

8.1*

3-fas AM; 6 poler ; $f = 50\,Hz$; $f_r = 1{,}5\,Hz$

$s = ?$; $n = ?$

$$f_r = s f \Rightarrow s = \frac{f_r}{f} = \frac{1{,}5}{50} = 0{,}03 \qquad \underline{s = 3\,\%}$$

$$n_s = 60\,\frac{f}{p} = 60 \cdot \frac{50}{3} = 1000\,rpm$$

$p = 3$

$$s = \frac{n_s - n}{n_s} \Rightarrow n = n_s(1-s) = 1000(1-0{,}03) = 970\,rpm$$

$$\underline{n = 970\,rpm}$$

8.2

8.2*

$P = 20\,kW$; $U_s = 380\,V$; $f = 50\,Hz$; $n_n = 1440\,rpm$

P_μ - försummas $\Rightarrow$ $P = P_m$ (brutto mek. effekt)

$P_{cur} = ?$

$$s = \frac{\omega_s - \omega}{\omega_s} \qquad s\omega_s - \omega_s = -\omega \qquad \omega = (1-s)\,\omega_s$$

$$P_{cur} = s\,P_\delta \quad (1)$$

$$\frac{P_m}{\omega} = \frac{P_\delta}{\omega_s} \Rightarrow P_\delta = P_m \frac{\omega_s}{\omega} = \frac{P_m}{1-s} \quad (2)$$

(1) och (2) ger $P_{cur} = \frac{s}{1-s} P_m$

$n_s = 1500\,rpm$ (4 poler)

$$s = \frac{1500 - 1440}{1500} = 0{,}04 \Rightarrow s = 4\,\%$$

$$P_{cur} = \frac{0{,}04}{0{,}96} \cdot 20 = 0{,}833\,kW$$

$$\underline{P_{cur} = 833\,W}$$

8.3 8.3

3-fas AM ; $U_s = 380\,V$; $f = 50\,Hz$; 6 poler

$I_s = 35\,A$; $P_s = 18{,}5\,kW$; $R_s = 0{,}12\,\Omega/fas$

$P_{Fes} = 400\,W$; $P_\mu = 380\,W$; $n = 960\,rpm$

a) $P = ?$

$n_s = 1000\,rpm \quad (p = 3)$

$P_\delta = P_s - P_{cus} - P_{Fes} = P_s - 3R_s I_s^2 - P_{Fes} =$

$= 18500 - 3 \cdot 0{,}12 \cdot 35^2 - 400 = 17659\,W$

$s = \frac{1000 - 960}{1000} = 0{,}04 \quad (4\%)$

$P_m = P_\delta - P_{cur} = P_\delta - sP_\delta = (1-s)P_\delta$

$P_m = (1 - 0{,}04) \cdot 17659 = 16953\,W$

$P = P_m - P_\mu = 16953 - 380 = 16573\,W$

$\underline{P = 16{,}6\,kW}$

b) $\eta = ?$

$\eta = \frac{P}{P_s} = \frac{16573}{18500} = 0{,}896 \quad \underline{\eta = 89{,}6\,\%}$

alt. $P_{förl} = P_{cus} + P_{Fes} + \underbrace{sP_\delta}_{P_{cur}} + P_\mu = 1927\,W$

$\eta = 1 - \frac{P_{förl}}{P_s}$ = som ovan

c) $T = ?$

$T = \frac{P}{\omega} = \frac{P}{\frac{2\pi n}{60}} = \frac{16573 \cdot 30}{\pi \cdot 960} = 164{,}85\,Nm$

$\underline{T = 165\,Nm}$

8.4

3-fas AM ; $P_n = 7{,}5\ kW$; $U_s = 380\ V$; $f = 50\ Hz$;

$n_n = 1425\ rpm$; $P_\mu = 210\ W$; $P_{cus} + P_{Fes} = 550\ W$

$P_s = ?$; $\eta = ?$

$P_s = P_{förl} + P$

$P_{förl} = P_{cus} + P_{Fes} + P_{cur} + P_\mu$

$P_{cur} = s P_\delta$; $P_m = P_\delta - P_{cur}$

$P_m = (1-s) P_\delta \Rightarrow P_\delta = \frac{P_m}{1-s}$

$P_m = P + P_\mu = 7500 + 210 = 7710\ W$

$s = \frac{1500 - 1425}{1500} = 0{,}05 \quad (5\%)$

$P_\delta = \frac{7710}{1-0{,}05} = 8116\ W$

$P_{cur} = 0{,}05 \cdot 8116 = 406\ W$

$P_{förl} = 550 + 406 + 210 = 1166\ W$

$P_s = 7500 + 1166 = \underline{8666\ W}$

$\eta = \frac{7500}{8666} = 0{,}86_4 55 \quad \underline{\eta = 86{,}55\ \%}$

8.5 3-fas AM **8.5***

$P_n = 0{,}35\,kW$; $U_s = 220\,V$; $f = 50\,Hz$;

[liten motor] → $\eta = 0{,}65$; $\cos\varphi = 0{,}76$; 2 poler

$R_s = 5{,}7\,\Omega/fas$; $P_{Fes} = 45\,W$; ~~$P_\mu = 20\,W$~~

$n_n = ?$; $T_n = ?$

$$\eta = \frac{P_n}{P_s} \Rightarrow P_s = \frac{P_n}{\eta} = \frac{350}{0{,}65} = 538{,}5\,W$$

$$P_s = \sqrt{3}\,U_s\,I_s\cos\varphi \Rightarrow I_s = \frac{P_s}{\sqrt{3}\,U_s\cos\varphi} = \frac{538{,}5}{\sqrt{3}\cdot 220\cdot 0{,}76} = 1{,}86\,A$$

$$P_{cus} = 3\,R_s\,I_s^2 = 3\cdot 5{,}7\cdot 1{,}86^2 = 59{,}1\,W$$

$$P_\delta = P_s - P_{cus} - P_{Fes} = 538{,}5 - 59{,}1 - 45 = 434{,}4\,W$$

$$P_\delta = P_n + P_\mu + P_{cur}$$

$$P_{cur} = 434{,}4 - 350 - 20 = 64{,}4\,W$$

$$P_{cur} = s\,P_\delta \Rightarrow s = \frac{P_{cur}}{P_\delta} = 0{,}148\ (14{,}8\%)$$ [liten motor]

$$n_s = 60\cdot\frac{50}{1} = 3000\,rpm$$

$$s = \frac{n_s - n_n}{n_s} \Rightarrow \underline{n_n = n_s(1-s) = 3000(1-0{,}148) = 2556\,rpm}$$

$$\underline{T_n = \frac{P_n}{\omega_n} = \frac{P_n\cdot 30}{\pi\,n_n} = \frac{350\cdot 30}{\pi\cdot 2556} = 1{,}31\,Nm}$$

8.6 3-fas AM; $f = 50\,Hz$; $P = 120\,kW$ 8.6*

$U_{sn} = 3{,}3\,kV$; $I_{sn} = 28{,}5\,A$; $\cos\varphi = 0{,}82$; $n_n = 575\,rpm$

P_μ - försummas; $R_s = 1{,}05\,\Omega/fas$

Start

$I_{start} = 160\,A$; $P_{sstart} = 230\,kW$

a) $T_{start} = ?$

Vid start gäller: $s = 1$; $P = 0$

P_μ - försummas $\rightarrow P_m = 0$

$P_m = P_\delta (1-s)$

$\Rightarrow P_s = P_\delta + P_{cus}$ även P_{Fes} kan försummas

$T_{start} = \frac{P_\delta}{\omega_s}$; $\left[P_\delta = P_{cur}\right]$

$P_{cus} = 3 R_s I_{start}^2 = 3 \cdot 1{,}05 \cdot 160^2 = 80{,}64\,kW$

extra jämför med P_{cus} vid märkdrift: $P_{cus} = 3 \cdot 1{,}05 \cdot 28{,}5^2 = 2{,}56\,kW$

$(I_{start}/I_{sn} = 5{,}6)$ 31,5 ggr!

$P_\delta = P_{sstart} - P_{cus} = 230 - 80{,}64 = 149{,}36\,kW$

$n_s = 600\,rpm$ $p = ?$

$T_{start} = \frac{149360}{\frac{2\pi \cdot 600}{60}} = 2377\,Nm \approx 2380\,Nm$

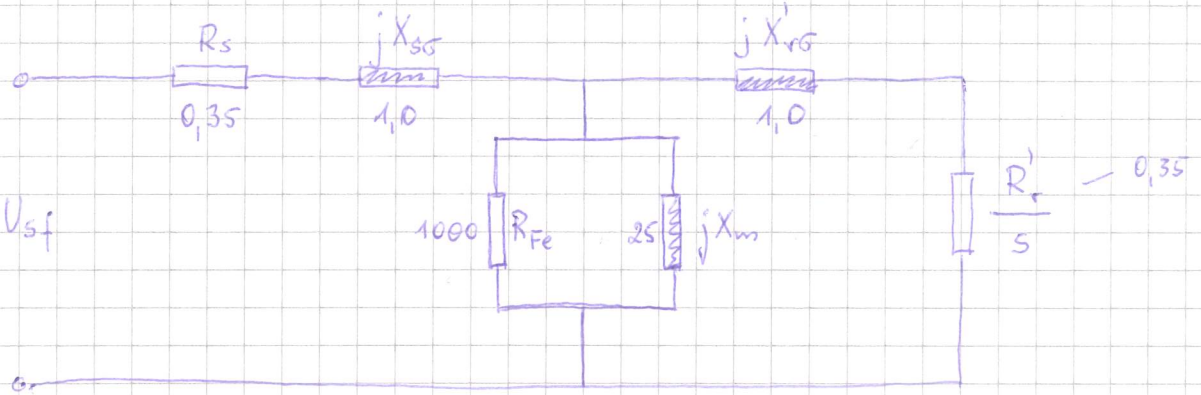
b) $P_n = \omega_n T_n \Rightarrow T_n = \frac{P_n}{\omega_n} = \frac{120 \cdot 10^3}{\frac{2\pi \cdot 575}{60}} = 1993\,Nm$

$\frac{T_{start}}{T_n} = \frac{2377}{1993} = 1{,}19$

8.7

8.7*

3-fas AM; $f = 50$ Hz; 4 poler

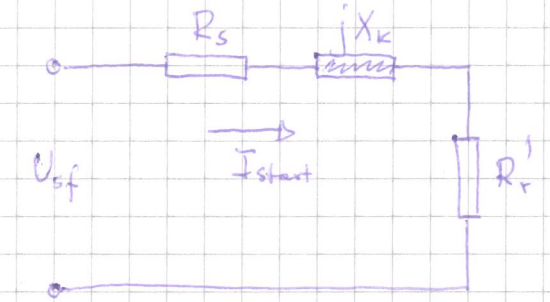


$T_{start} = ?$

Vid start $s = 1$; R_{Fe} och X_m kan försummas

då $Z_m \gg Z'_r$

Förenkla schema:



$X_k = X_{sσ} + X'_{rσ} = 2\ \Omega/\text{fas}$

$$|I_{start}| = \frac{U_{sf}}{\sqrt{(R_s + R'_r)^2 + X_k^2}} = \frac{380/\sqrt{3}}{\sqrt{0{,}7^2 + 2^2}} = 103{,}54\ \text{A}$$

Antag $P_\mu = 0 \Rightarrow T_m = T_n$ $\quad n_s = 1500$ rpm

$$T_{start} = \frac{1}{\omega_s} P_{\delta start} = \frac{1}{\omega_s} \frac{P_{cur}}{s} = \frac{1}{\omega_s} P_{cur} = \frac{1}{\omega_s} 3 R'_r I^2_{start} =$$

$$= \frac{3 \cdot 0{,}35 \cdot 103{,}54^2}{\frac{2\pi \cdot 1500}{60}} = 71{,}60\ \text{Nm}$$

8.8

8.8*

3-fas AM; 6 poler; $P_n = 15\,kW$; $n_n = 970\,rpm$

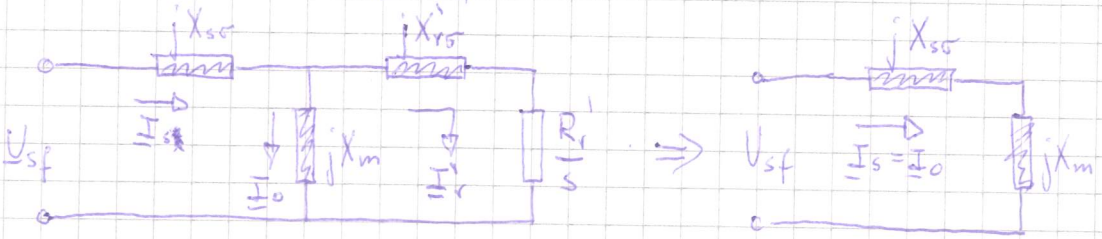
R_s och R_{Fe} - försummas

$X_{s\sigma} = 0{,}8\,\Omega/fas$; $X'_{r\sigma} = 0{,}65\,\Omega/fas$; $R'_r = \frac{0{,}19}{0{,}35}\,\Omega/fas$

$X_m = 13{,}4\,\Omega/fas$

a) $U_s = 400\,V$; $I_0 = ?$ - tomgång:

$s \approx 0 \Rightarrow \left|\frac{R'_r}{s}\right| \gg |X_m| \Rightarrow I'_r \approx 0 \Rightarrow I_s = I_0$



$$\underline{U}_{sf} = \underline{I}_0\, j\left(X_{s\sigma} + X_m\right)$$

$$\underline{I}_0 = \frac{400/\sqrt{3}\,\angle 0^\circ}{(13{,}4+0{,}8)\,\angle 90^\circ} = \underline{16{,}26\,\angle -90^\circ\ A}$$

b) $I_s = ?$ vid fullast

$$s = \frac{n_s - n_n}{n_s} = \frac{1000-970}{1000} = 0{,}03$$

$$\frac{R'_r}{s} = \frac{0{,}19}{0{,}03} = 6{,}33\,\Omega/fas$$

$$\underline{Z} = j X_{s\sigma} + \frac{j X_m\left(\frac{R'_r}{s} + j X'_{r\sigma}\right)}{j X_m + j X'_{r\sigma} + \frac{R'_r}{s}} = j0{,}8 + \frac{j13{,}4(6{,}33 + j0{,}35)}{6{,}33 + j14{,}05} =$$

$$= j0{,}8 + \frac{13{,}4\,\angle 90^\circ \cdot 6{,}36\,\angle 5{,}86^\circ}{15{,}41\,\angle 65{,}75^\circ} = j0{,}8 + 5{,}53\,\angle 30{,}11^\circ =$$

$$= j0{,}8 + 4{,}78 + j2{,}77 = 4{,}78 + j3{,}57 = 5{,}97\,\angle 36{,}75^\circ\ \Omega/fas$$

$$\underline{I}_s = \frac{\underline{U}_{sf}}{\underline{Z}} = \frac{400/\sqrt{3}\,\angle 0^\circ}{5{,}97\,\angle 36{,}75^\circ} = \underline{38{,}68\,\angle -36{,}75^\circ\ A}$$

$\cos\varphi = 0{,}8$

8.9 3-fas AM ; 4 poler ; $f = 50$ Hz

8.9*

Fall a) $T_a = 70$ Nm ; $n_a = 1480$ rpm

$$s_a = \frac{1500 - 1480}{1500} = \frac{20}{1500}$$

Fall b) $T_b = ?$; $n_b = 1455$ rpm

$$s_b = \frac{1500 - 1455}{1500} = \frac{45}{1500}$$

$T = k \cdot s$

$$\frac{T_b}{T_a} = \frac{s_b}{s_a} \Rightarrow T_b = 70 \cdot \frac{45}{20} = 157{,}5 \text{ Nm}$$

$$P_b = \omega_b T_b = \frac{2\pi \cdot 1455}{60} \cdot 157{,}5 \approx 24000 \text{ W}$$

$P_{cur} = s P_\delta = s \omega_s T$

Fall a) $P_{cura} = s_a \omega_s T_a$

Fall b) $P_{curb} = s_b \omega_s T_b$

$$\therefore \frac{P_{cura}}{P_{curb}} = \frac{20 \cdot 70}{45 \cdot 157{,}5} \approx 0{,}2 \quad (0{,}1975) \qquad 5{,}06$$

$$\frac{s_b}{s_a} = 2{,}25$$

$$\frac{P_{curb}}{P_{cura}} = 2{,}25^2 = 5{,}06$$

8.10

8.10

3 fas AM

$T_{start} = 12\ Nm$ vid direktstart (Δ)

10% sp fall Y/Δ - start $T_{stY} = ?$

$T = k \cdot U_s^2 \cdot s$ vid start $s = 1$

$T_{st\Delta} = 12\ Nm$ vid $U_s = U_\Delta$

$T_{stY} = ?$ $\qquad U_s = \frac{U_\Delta}{\sqrt{3}} \cdot 0{,}9$

$$\frac{T_{stY}}{T_{st\Delta}} = \frac{\left(\frac{U_\Delta}{\sqrt{3}} \cdot 0{,}9\right)^2}{U_\Delta^2} = \frac{0{,}81}{3} = 0{,}27$$

$$T_{stY} = 0{,}27 \cdot 12 = 3{,}24\ Nm$$

8.11

3-fas AM ; 50 Hz

$s = 5\%$ $\quad n_{last} = 900 \div 1200$ rpm

a) Välj $\underline{n_s = 1000 \text{ rpm}} \rightarrow$ 6 poler

b) Vid märkdrift av AM gäller $s = 0{,}05 = \dfrac{1000 - n}{1000}$

$\Rightarrow n = 950$ rpm

Vid $n = 950$ rpm fås ur diagram

$T_{last} = 1 + 950 \cdot 0{,}02 = 20$ Nm

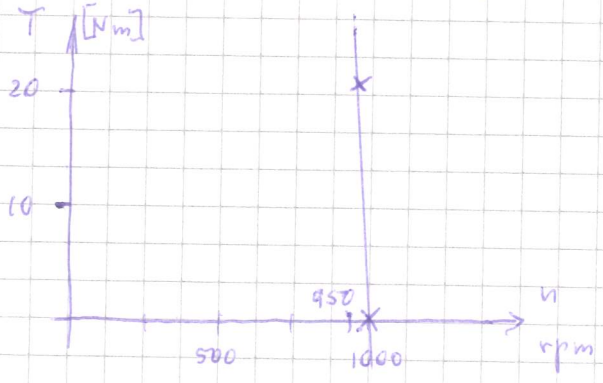
$P = \omega T \Rightarrow P = \dfrac{2\pi \cdot 950}{60} \cdot 20 \approx 1990$ W

$\Rightarrow$ välj $\underline{P_n = 2{,}2 \text{ kW}}$

c) $P_n = 2{,}2$ kW ; $n = 950$ rpm $\Rightarrow$

$\Rightarrow \bar{T} = \dfrac{2200}{\frac{2\pi \cdot 950}{60}} = 22{,}1$ Nm

Vid $n = n_s = 1000$ rpm är $\bar{T} = 0$



$$\begin{cases} y - y_0 = k(x - x_0) \\ k = \dfrac{y_1 - y_0}{x_1 - x_0} \end{cases}$$

Momentlinjens ekv. mellan 950 och 1000 rpm

$\bar{T} - 0 = \dfrac{22{,}1 - 0}{950 - 1000}(n - 1000)$

$\bar{T} = \dfrac{22{,}1}{50}(1000 - n)$

d) Skärningspunkten:

$$\begin{cases} T = \frac{22,1}{50}(1000 - n) \\ T = 1 + n \cdot 0,02 \end{cases}$$

$$22,1(1000 - n) = 50(1 + 0,02n)$$

$$22100 - 22,1n = 50 + n$$

$$23,1n = 22050$$

$$n = 954,55 \text{ rpm}$$

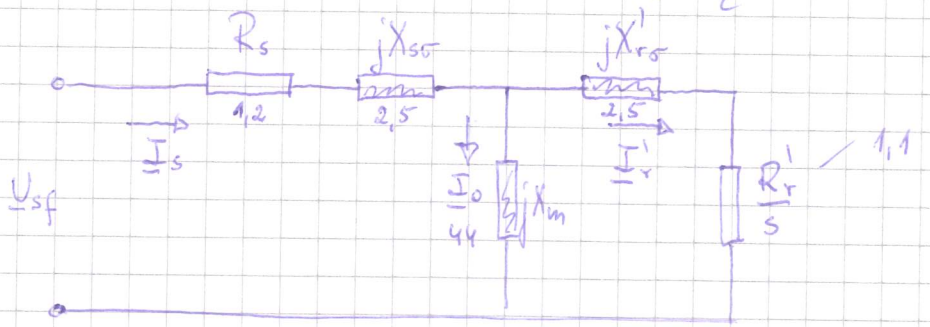
$$T = 1 + 954,55 \cdot 0,02 = 20,09$$

$$P = \omega T = \frac{2\pi \cdot 954,55}{60} \cdot 20,09 = 2008 \text{ W}$$

8.12

8.12*

3-fas AM; $P_n = 4\,kW$; $U_{sn} = 400\,V$; $n_n = 1446\,rpm$;
$\cos\varphi = 0{,}76$; $I_{sn} = 8{,}6\,A$; $\eta = 91\%$

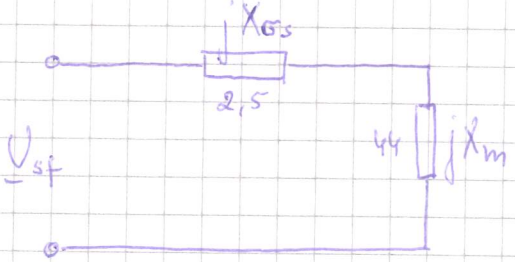


a)

$$Q = \sqrt{3}\, U_{sn}\, I_{sn} \sin\varphi = \sqrt{3} \cdot 400 \cdot 8{,}6 \cdot \sin 40{,}54^\circ = \underline{3872\ VAr}$$

b) Vid tomgång är s m. litet $\approx 0 \Rightarrow \frac{R'_r}{s}$ - stort

Ekv. schemat då:



$$Q = 3\,\frac{U_{sf}^2}{(X_{\sigma s} + X_m)} = 3\,\frac{\left(\frac{400}{\sqrt{3}}\right)^2}{46{,}5} = \underline{3439\ VAr}$$

Om man tar hänsyn till R_s får man $Q = 3435\ VAr$

Obs! Liten skillnad mellan driften vid märklast och tomgång – magnetiseringsström behövs

8.13

3-fas AM ; 4 poler ; $P_n = 55\,kW$; $U_{str} = 400\,V$;

$n_n = 1450$ rpm.

$T_{belastning} = 350\,Nm$ oberoende av n

a) $n_b = ?$; $P = ?$; $P_{cur} = ?$

För AM inom arbetsområdet gäller $T = k U_s^2 \cdot s$

$$T_n = \frac{P_n}{\omega_n} = \frac{55 \cdot 10^3}{\frac{2\pi \cdot 1450}{60}} = 362{,}2\,Nm$$

$$s_n = \frac{1500 - 1450}{1500} = \frac{1}{30}$$

$$\frac{T - 0}{362{,}2 - 0} = \frac{n - 1500}{-50}$$

$\therefore \quad 362{,}2 = k\,U_s^2 \frac{1}{30}$

Aktuell belastning $T_b = 350\,Nm$

$$350 = k\,U_s^2\,s_b$$

$$\frac{350}{362{,}2} = \frac{k\,U_s^2 \cdot s_b}{k\,U_s^2\,\frac{1}{30}} \Rightarrow s_b = 0{,}0322$$

$$0{,}0322 = \frac{1500 - n_b}{1500} \Rightarrow \underline{n_b = 1451{,}7\ rpm}$$

$$\underline{P = \omega T} = \frac{\pi \cdot 1451{,}7}{30} \cdot 350 = \underline{53208\,W}$$

om P_μ - försummas :

$$P_{cur} = s P_\delta = s\,\omega_s T$$

$$\underline{P_{cur}} = 0{,}0322 \cdot \frac{\pi \cdot 1500}{30} \cdot 350 = \underline{1770\,W}$$

8.13

b) $n_b = ?$; $T = ?$; $P_{cur} = ?$ om $U_s = 360\,V$

$$s_b' = \left(\frac{400}{360}\right)^2 \cdot 0{,}0322 = 0{,}0398 \qquad (3{,}98\,\%)$$

$$0{,}0398 = \frac{1500 - n_b'}{1500} \Rightarrow n_b' = 1440{,}3 \text{ rpm}$$

$$\Rightarrow T' = \frac{\pi \cdot 1440{,}3}{30} \cdot 350 = 52790\,W$$

$$P_{cur}' = s\,\omega_s\,T = 0{,}0398\,\frac{\pi \cdot 1500}{30} \cdot 350 = 2188\,W$$

eller $P_{cur}' = P_{cur}\,\frac{3{,}98}{3{,}22} = 1770 \cdot \frac{3{,}98}{3{,}22} = 2188\,W$

c) $s \nearrow \quad P_{cur} \nearrow$

8.14 8.14

3-fas AM; 6 poler ; $P_n = 0{,}37\,kW$; $U_{sn} = 400\,V$; $f = 50\,Hz$

$n_n = 920\,rpm$

Varvtalsstyrning med frekvensomriktare $\rightarrow n_n' = 1150\,rpm$

$T_n = T_n'$; Φ - konst

$f' = ?$

Momentkurvans lutning skall vara lika:

$$\frac{T_n}{n_n - n_s} = \frac{T_n}{n_n' - n_s'} \Rightarrow 1150 - n_s' = 920 - 1000$$

$$n_s' = 1230\,rpm$$

$$n_s' = 60\,\frac{f'}{p}\,[rpm]\,;\ p = 3$$

$$f' = \frac{p \cdot n_s'}{60} = \frac{3 \cdot 1230}{60} = 61{,}5\,Hz$$

Obs! för Φ - konst måste U_s ökas till ca 490V (klarar maskinen det?)