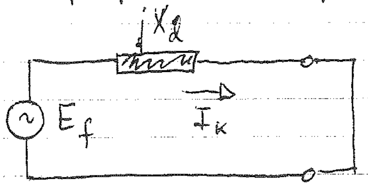
$S_n = 15\,\text{kVA}$; $U_n = 380\,\text{V}$

$I_k = I_a = 20\,\text{A}$ vid $E = 250\,\text{V}$

Med hjälp av ksl. prov kan X_d - beräknas :



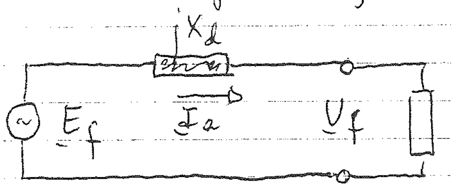
$$E_f = \frac{250}{\sqrt{3}}\ \text{V}$$

$$\underline{E}_f = jX_d \underline{I}_k$$

$$X_d = \frac{E_f}{I_k} = \frac{250}{\sqrt{3} \cdot 20} = 7{,}22\ \Omega/\text{fas}$$

a) Maskinens belastning : $R_\Delta = 27\,\Omega$

U - klämspänning - $U = 380\,\text{V}$; $E = ?$



$$R_Y = \frac{R_\Delta}{3} = 9\ \Omega/\text{fas}$$

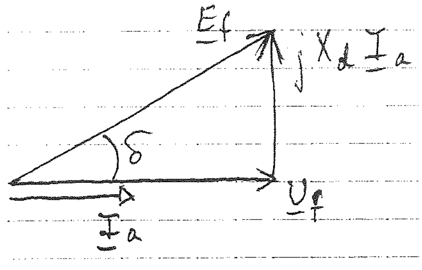
$$\underline{I}_a = \frac{\underline{U}_f}{R_Y} = \frac{380\angle 0^\circ}{\sqrt{3} \cdot 9} = 24{,}38\angle 0^\circ\ \text{A}$$

$$\underline{E}_f = \underline{U}_f + jX_d \underline{I}_a = \frac{380}{\sqrt{3}}\angle 0^\circ + j\,7{,}22 \cdot 24{,}38\angle 0^\circ =$$

$$= 219{,}4 + j\,176{,}0 = 281{,}3\ \underline{\angle 38{,}74}\ \text{V}$$

$$\underline{\underline{E}} = \sqrt{3}\,E_f = \underline{\underline{487\,\text{V}}}$$

b) lastvinkeln $\delta = ?$



$\delta = 38{,}74^\circ$ (se ovan)

c) Är maskinen överbelastad ?

$$I_n = \frac{S_n}{\sqrt{3}\, U_n} = \frac{15000}{\sqrt{3}\ 380} = 22{,}79\ \text{A}$$

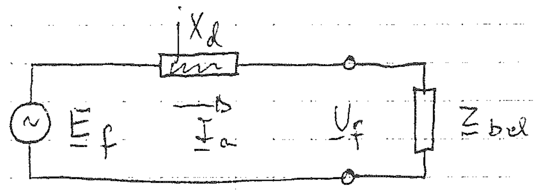
$\underline{\underline{I_a > I_n}}$ $\quad$ $24{,}38 > 22{,}79$

<u>överbelastad</u>

$U = 380\ V;\quad E = 450\ V;\quad X_d = 7{,}22\ \Omega/\text{fas}$

$\cos\varphi = 1$

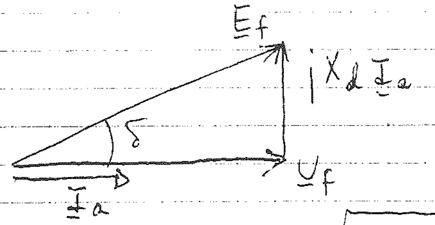
a) $I_a = ?$



$E_f = \dfrac{450}{\sqrt{3}}\ V$

$U_f = \dfrac{380}{\sqrt{3}}\ V$

om $\cos\varphi = 1 \rightarrow I_a$ i fas med U_f



enl. visardiagr.:

$$E_f^2 = U_f^2 + (X_d I_a)^2$$

$$\underline{\underline{I_a}} = \frac{\sqrt{E_f^2 - U_f^2}}{X_d} = \frac{\sqrt{\left(\frac{450}{\sqrt{3}}\right)^2 - \left(\frac{380}{\sqrt{3}}\right)^2}}{7{,}22} = \underline{\underline{19{,}27\ A}}$$

b) $P = ?$

$$\underline{\underline{P}} = 3 U_f I_a \cos\varphi = 3 \cdot \frac{380}{\sqrt{3}} \cdot 19{,}27 \cdot 1 = \underline{\underline{12{,}69\ kW}}$$

c) $\delta = ?$

$$\cos\delta = \frac{U_f}{E_f} = \frac{380}{450} = 0{,}844$$

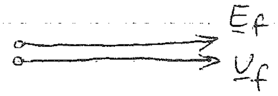
$$\underline{\underline{\delta = 32{,}38^\circ}}$$

P kan även beräknas enl. följande:

$$\underline{P} = \frac{E \cdot U}{X_d} \sin\delta = \frac{450 \cdot 380}{7{,}22} \cdot \sin 32{,}38 = \underline{12{,}69\ kW}$$

$U = 380\ V \quad ; \quad X_d = 7{,}22\ \Omega/\text{fas}$

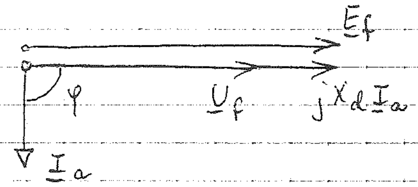
Infasning: $\quad I_a = 0 \longrightarrow \underline{E}_f = \underline{U}_f$



Ingen mekanisk effekt tillföres mask = ingen mek. belastning =

= ingen aktiv effekt = endast reaktiv effekt → strömmen 90°

efter U_f



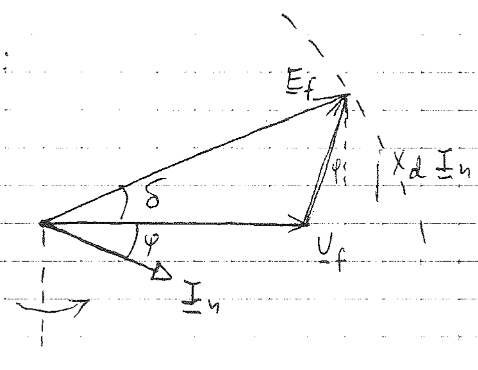
$$I_a = \frac{I_n}{2} = \frac{22{,}8}{2} = 11{,}4\ A$$

$$\underline{E}_f = \underline{U}_f + jX_d I_a = \frac{380}{\sqrt{3}} + 7{,}22 \cdot 11{,}4 = 301{,}7\ V$$

Oförändrad magnetisering $\rightarrow \quad E_f = 301{,}7\ V \ ; \ U_f = \frac{380}{\sqrt{3}}\ V$

P ökas tills $I_a = I_n$

Visardiagram:



I_a får en aktiv komponent

cos satsen:

$$(X_d I_n)^2 = U_f^2 + E_f^2 - 2 U_f E_f \cos\delta$$

$$(7{,}22 \cdot 22{,}8)^2 = \left(\frac{380}{\sqrt{3}}\right)^2 + (301{,}7)^2 - 2\,\frac{380}{\sqrt{3}} \cdot 301{,}7 \cos\delta$$

$$\cos\delta = 0{,}846$$

$$\underline{\underline{\delta = 32{,}16^\circ}}$$

$$\underline{\underline{P}} = \frac{E \cdot U}{X_d} \sin\delta = \frac{301{,}7 \cdot \sqrt{3} \cdot 380}{7{,}22} \sin 32{,}16^\circ = \underline{\underline{14{,}64 \text{ kW}}}$$

$$P = S_n \cos\varphi \Rightarrow \underline{\underline{\cos\varphi}} = \frac{14640}{1500} = \underline{\underline{0{,}976}}$$

övermagn. om maskinen avger reaktiv effekt $Q > 0$

$E_f > U_f$

alt.:

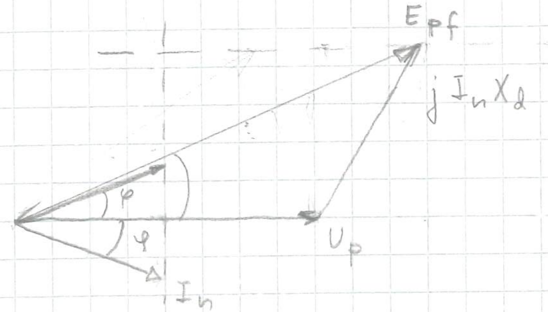
$$\left[E_f^2 = U_f^2 + (X_d I_n)^2 - 2\, U_f X_d I_n \cos(90+\varphi) \right]$$

Endast magnetiseringen förändras

→ belastningen ändras inte

Enl. 6.3

$P = 14.64\ kW$
$\cos\varphi = 0.976$
$I_n = 22.8A$
$U = 380V$
övermagn



$$I_{a\,min} = I_n \cos\varphi = 22.8 \cdot 0.976 = 22.25\ A$$

inträffar när $\varphi = 0$

$P = 3\, U_p I_a \cos\varphi$ $\qquad I_a \cdot \cos\varphi = \text{konst}$

$$I_{a\,min} = \frac{P}{3\,U_p \cos\varphi} = \frac{14640 \cdot \sqrt{3}}{3 \cdot 380 \cdot 1} = 22.25\,A$$

b) $\cos\varphi = 0.976$ kap

c) undermagn. (tar emot reaktiv eff.)

d)

1. starkt nät $\qquad U_p = \text{konst}$
2. avgev konst. P (kan endast förändras genom tillförd mek. eff. förändras)

→ pådraget konst

$P = 3\, U_p I_a \cos\varphi$ $\qquad I_a \cos\varphi = \text{konst}$

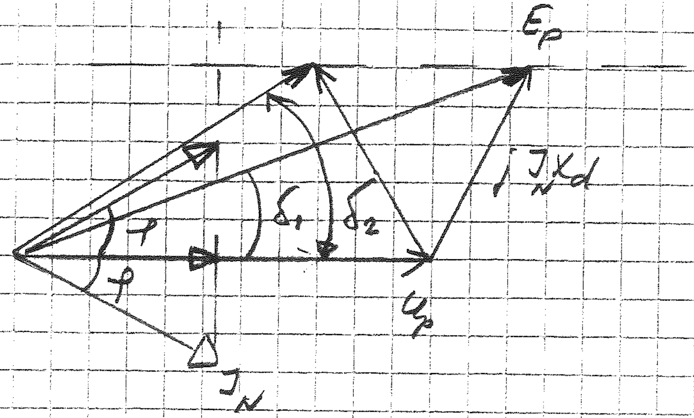
$I_a X_d \cos\varphi$ = konst → se visardiag.

$$P = 3\,\frac{U_p E_{fp}}{X_d} \sin\delta \qquad E_{fp} \sin\delta = \text{konst}$$

3. Magnetisering varieras $- E_{fp}$ förändras till belopp

→ orten för E_{fp} spets är en rät linje // med U_p

→ I_a // rör sig längs -"- $\perp$ mot U_p



Strömmen har min när $\varphi = 0$.

$I_{min} = I_N \cos\varphi = 22{,}8 \cdot 0{,}978 = 22{,}3\ A$.

$\cos\varphi = 0{,}978$ kap.

Maskinen är undermagn (tar emot reaktiv effekt).

Svar: a) $I_{min} = 22{,}3\ A$.

b) $\cos\varphi = 0{,}978$ (kap)

c) undermagnetiserad (tar emot reaktiv effekt)

d) Visardiagram enl ovan

3-fas SM kopplad till ångturbin

6.5

7.5

$S_n = 12\ MVA$; $U_n = 12\ kV$

1. infasning:

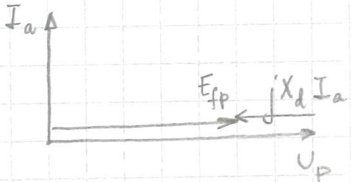
$Q = 5\ MVAr$ från nätet → maskinen undermagnetiserad

$E_f = 4.5\ kV$

2. Magnetisering o turbinpådrag regleras så att:

$P = 8.5\ MW$ $\cos\varphi = 1$

Från 1. kan X_d - bestämas



$\varphi = 90°$

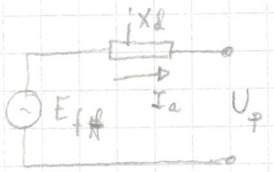
$$Q = \sqrt{3}\, U I_a \sin\varphi \Rightarrow I_a = \frac{Q}{\sqrt{3}\, U} = \frac{5 \cdot 10^6}{\sqrt{3} \cdot 12 \cdot 10^3} = 240.56\ A$$

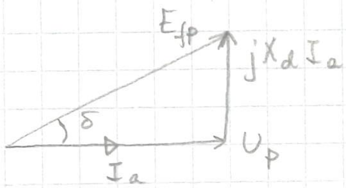
$$E_{pf} = U_p - X_d I_a \Rightarrow$$

$E_{pf} = U_p \pm X_d I_a$

$$X_d = \frac{U_p - E_{pf}}{I_a} = \frac{\left(\frac{12}{\sqrt{3}} - \frac{4.5}{\sqrt{3}}\right) 10^3}{240.56} = 18\ \Omega/\text{fas}$$

a) 2.





$\cos\varphi = 1$

I_a i fas med U_p

$$P = \sqrt{3}\, U I_a \cos\varphi \Rightarrow I_a = \frac{P}{\sqrt{3}\, U} = \frac{8500}{\sqrt{3} \cdot 12} = 408.96\ A$$

$$E_{f\phi} = \sqrt{U_p^2 + (X_d I_a)^2} = \sqrt{\left(\frac{12 \cdot 10^3}{\sqrt{3}}\right)^2 + (18 \cdot 408.96)^2} = 10.11\ kV$$

$$\underline{E_f} = \sqrt{3}\, E_{f\phi} = \underline{17.5\ kV}$$

$$\cos\delta = \frac{12{,}0}{\sqrt{3}\ 10.11} = 0.685 \qquad \underline{\delta = 46.74°}$$

2

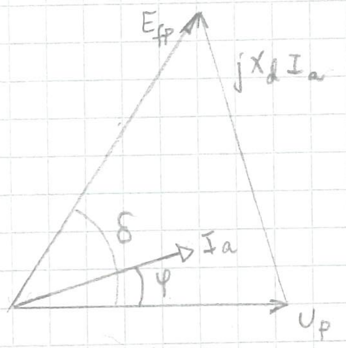
6.5
7.5

b) bibehållen magnetisering $E_f = 17{,}5\ kV$

$P = 10\ MW$ $\quad I_a, Q = ?$

$$P = \frac{E_f \cdot U}{X_d} \sin\delta \Rightarrow \sin\delta = \frac{10 \cdot 10^6 \cdot 18}{17.5 \cdot 12 \cdot 10^6} = 0{,}857$$

$\Rightarrow \delta = 59°$



cossatsen $(X_d I_a)^2 = U_p^2 + E_{fp}^2 - 2 U_p E_{fp} \cos\delta$

$$(X_d I_a)^2 = \left(\frac{12}{\sqrt{3}}\right)^2 + \left(\frac{17.5}{\sqrt{3}}\right)^2 - 2\,\frac{12 \cdot 17.5}{3} \cos 59° \qquad (I_a \text{ i kA})$$

$$(18 I_a)^2 = 48 + 102.08 - 72.1$$

$$I_a^2 = 77.97 / 324$$

$$\underline{\underline{I_a = 490.56\ A}}$$

$$P = \sqrt{3}\, U I_a \cos\varphi \Rightarrow \cos\varphi = \frac{10 \cdot 10^6}{\sqrt{3} \cdot 12 \cdot 10^3 \cdot 490{,}56} = 0.98$$

$\operatorname{tg}\varphi = 0.199$ $\qquad \cos\varphi = 0.98$ kap

11,48°

$Q = P \operatorname{tg}\varphi = -1.99\ MVAr$

$\underline{Q = -2\ MVAr}$

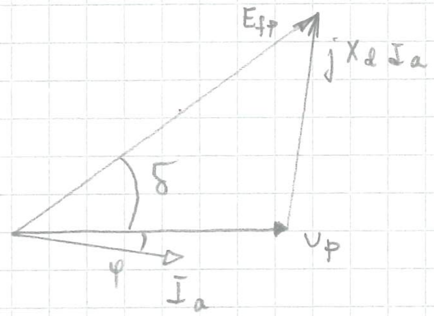
6.5

7.5

c) $E_f = 17.5\ kV$; $P = 7\ MW$

$$P = \frac{E_f U}{X_d} \sin\delta \quad \Rightarrow \quad \sin\delta = \frac{7 \cdot 18}{12 \cdot 17.5} = 0.6$$

$\delta = 36.87°$ $\quad \cos\delta = 0.8$



$$(18\, I_a)^2 = \left(\frac{12}{\sqrt{3}}\right)^2 + \left(\frac{17.5}{\sqrt{3}}\right)^2 - 2\, \frac{12 \cdot 17.5}{3} \cdot 0.8$$

$$(18\, I_a)^2 = 48 + 102.08 - 112$$

$$I_a^2 = 38.08 / 324$$

$$\underline{\underline{I_a = 342.8\ A}}$$

$$\cos\varphi = \frac{7 \cdot 10^6}{\sqrt{3} \cdot 12 \cdot 10^3 \cdot 342.8} = 0.982 \qquad \cos\varphi = 0.982_{ind}$$

$$tg\,\varphi = 0.19$$

$$Q = P\, tg\,\varphi = 7 \cdot 0.19 = 1.33\ MVAr$$

$$\underline{V}_f + jX_d \underline{I}_a = \underline{E}_{fp}$$

$$jX_d \underline{I}_a = \underline{E}_{fp} - \underline{V}_f$$

$$\underline{I}_a = \frac{\frac{17{,}5}{\sqrt{3}}\cos 59 + j\frac{17{,}5}{\sqrt{3}}\sin 59 - \frac{12}{\sqrt{3}}}{\cancel{jX_d}\; j\,18} = \frac{5{,}2 - 6{,}9 + j\,8{,}7}{j\,18}$$

$$= \frac{-1{,}7 + j\,8{,}7}{j\,18} = \frac{8{,}83\,\angle -78{,}9^\circ}{18\,\angle +90^\circ} = 490{,}56\,\angle +11{,}1^\circ$$

$\cos\varphi = 0{,}98$ kap

$$\underline{I}_a = \frac{\frac{17{,}5}{\sqrt{3}}\cos 36{,}87 + j\frac{17{,}5}{\sqrt{3}}\sin 36{,}87 - \frac{12}{\sqrt{3}}}{j\,18} =$$

$$= \frac{8{,}08 - 6{,}9 + j\,6{,}06}{j\,18} = \frac{1{,}18 + j\,6{,}06}{j\,18} = \frac{6{,}17\,\angle 78{,}98}{18\,\angle +90^\circ} =$$

$$= 342{,}8\,\angle -11{,}02^\circ \text{ A} \qquad \cos\varphi = 0{,}982 \text{ ind}$$

			I_a			
$U = 12$ kV	; $\cos\varphi = 1$;	$P = 8{,}5$ MW	409A	$Q = 0$	$E = 17{,}5$ kV	$\delta = 46{,}7^\circ$
— " —	$\cos\varphi = 0{,}98$ kap $+11^\circ$	$P = 10{,}0$ MW	491A	$Q = -2$ MVAr	— " —	$\delta = 59^\circ$
— " —	$\cos\varphi = 0{,}98$ ind -11°	$P = 7{,}0$ MW	343A	$Q = 1{,}33$ MVAr	— " —	$\delta = 36{,}9^\circ$

$S_n = 25\,kVA$; $U_n = 425\,V$; $\cos\varphi = 0{,}8$; $f = 60\,Hz$ (7.6)

$n = 1800\,rpm$

Ksl. provet $I_k = I_n$; $E_f = 340\,V$

50Hz - drift : $I_a = I_n$; $U = 380\,V$; $P, Q = ?$

1. Ksl. provet :
$$I_n = \frac{S_n}{\sqrt{3}\,U_n} = \frac{25\,000}{\sqrt{3}\cdot 425} = 33{,}96\,A$$

$$E_{fp} = X_d\,I_n \Rightarrow X_d = \frac{E_{fp}}{I_n} = \frac{340}{\sqrt{3}\cdot 33{,}96} = 5{,}78\,\Omega/\text{fas}$$

2. Normalt driftfall:

$\cos\varphi = 0{,}8$; $\sin\varphi = 0{,}6$

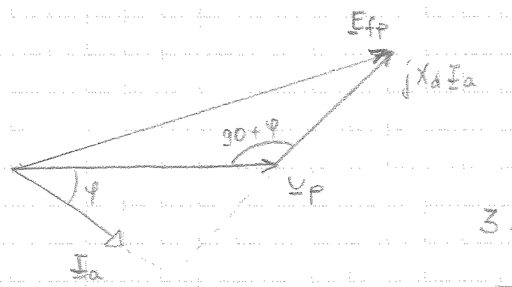
$$\underline{E}_{fp} = \underline{U}_p + jX_d\,\underline{I}_a = \frac{425}{\sqrt{3}}\angle 0 + j\,5{,}78\cdot 33{,}96(0{,}8 - j\,0{,}6) =$$

$$= 245{,}4 + j\,157 + 117{,}8 = 363{,}2 + j\,157 = 395{,}7\,\angle 23{,}38°\ V$$

3. 50Hz - drift

$$E_{fp} \sim \omega \Rightarrow E'_{fp} = \frac{50}{60}\cdot 395{,}7 = 329{,}75\,V$$

$$X_d \sim \omega \Rightarrow X'_d = \frac{50}{60}\cdot 5{,}78 = 4{,}82\,\Omega/\text{fas}$$



$$E'^{\,2}_{fp} = U_p^2 + (X'_d I_n)^2 - 2U_p X'_d I_n \cos(90+\varphi)$$
$$+ \qquad \sin\varphi$$

$$329{,}75^2 = \left(\frac{380}{\sqrt{3}}\right)^2 + (4{,}82\cdot 33{,}96)^2 + 2\cdot\frac{380}{\sqrt{3}}\cdot 4{,}82\cdot 33{,}96\,\sin\varphi$$

$$33{,}81\cdot 10^3 = 71{,}82\cdot 10^3 \sin\varphi$$

$$\sin\varphi = 0{,}47 \quad ; \quad \cos\varphi = 0{,}882$$

$\underline{P} = \sqrt{3}\,U\,I_n\cos\varphi = \sqrt{3}\cdot 380\cdot 33{,}96\cdot 0{,}882 = \underline{19{,}72\,kW}$

$\underline{Q} = \sqrt{3}\,U\,I_n\sin\varphi =$ — " — $\cdot\, 0{,}47 = \underline{10{,}51\,kVAr}$

b)

$$\underline{E}_{fp} = \underline{U}_p + jX_d \underline{I}_a$$

$$\underline{I}_a = \frac{\underline{E}_{fp} - \underline{U}_p}{jX_d} = \frac{E_{fp}\angle 59^\circ - U_p\angle 0^\circ}{jX_d} =$$

$$= \frac{\frac{17.5}{\sqrt{3}}(\cos 59 + j\sin 59) - \frac{12}{\sqrt{3}}}{j18} = \frac{8{,}83\angle 101.3}{18\angle 90}$$

$$= 0{,}481 + j\,0{,}0958 \hat{=} 490{,}58\angle 11.26^\circ \quad A$$

$$\cos\varphi = \cos 11.26 = 0{,}98 \text{ kap}$$

---

c)

$$\underline{E}_{fp} = \underline{U}_p + jX_d \underline{I}_a$$

$$\underline{I}_a = \frac{\frac{17.5}{\sqrt{3}}(0{,}8 + j\,0{,}6) - \frac{12}{\sqrt{3}}}{j18} = 0{,}337 - j\,0{,}064 \hat{=} 342{,}8\angle -10{,}77^\circ \text{ A}$$

$$\underline{S} = \sqrt{3}\,\underline{U}\,\underline{I}^* = \sqrt{3}\,12\angle 0 \cdot 490{,}6\angle -11{,}26 = \sqrt{3}\,5{,}77 - \sqrt{3}\,1{,}15 =$$

$$= 10 - 1{,}99$$