Løsningsforslag

Oppg. 1

a)

$$\underline{\underline{i_1}} = \frac{V_1}{R_1 + \frac{R_2 \cdot R_3}{R_2 + R_3}} = \frac{20}{20+10} A = \underline{\underline{\frac{2}{3} A = 0.667 A}}$$

$$\underline{\underline{v_2}} = i_1 \cdot \frac{R_2 \cdot R_3}{R_2 + R_3} = \frac{2}{3} \cdot 10 V = \underline{\underline{\frac{20}{3} V = 6.667 V}}$$

b)

$$V_s = i_1 R_1 + i_2 R_2 \rightarrow 20 = i_1 \cdot 20 + i_2 \cdot 20$$
$$I_s = -i_1 + i_2 \qquad 9 = -i_1 + i_2$$

$$\left.\begin{array}{l} 1 = i_1 + i_2 \\ 9 = -i_1 + i_2 \end{array}\right\} \quad 2 i_1 = 1 - 9 = -8 \Rightarrow \quad \underline{\underline{i_1 = -4.0 A}}$$

$$\underline{\underline{i_2}} = 9 + i_1 = 9 - 4 = \underline{\underline{5.0 A}}$$

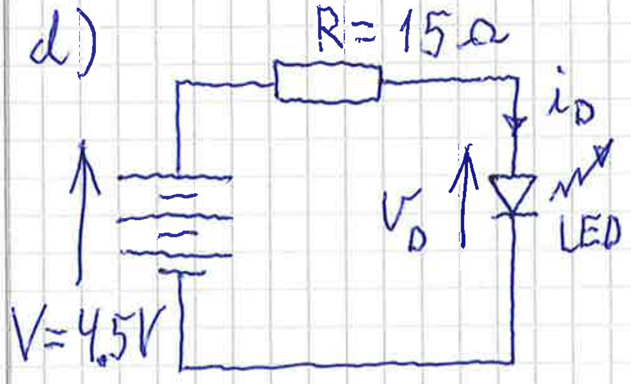
$$\underline{\underline{i_3}} = I_s = \underline{\underline{9.0 A}}$$

c)

$$C = \varepsilon_0 \varepsilon_r \frac{A}{t} = 8.854 \cdot 10^{-12} \cdot 3.8 \cdot \frac{1 \cdot 10^{-6}}{0.1 \cdot 10^{-6}} F$$

$$= 336 \cdot 10^{-12} F = \underline{\underline{336 \mu F}}$$

d) (2a)



$V = R \cdot i_D + v_D$

Bruk arbeidslinje

$\underline{i_D = 0}$: $v_D = V = \underline{4.5\,V}$

$\underline{v_D = 0}$: $i_D = \frac{V}{R} = \frac{4.5}{15}\,A$

$\underline{= 0.3\,A}$

Fra figuren får vi : Se neste side

$$\underline{\underline{i_D \approx 0.10\,A = 100\,mA}}$$

e) $\cancel{i_G = 0 \quad , \quad V_{GS} + i_D \cdot R_S = 15\,V}$

$\cancel{V_{GS} = (15 - 3.0 \cdot 10^{-3} \cdot 3 \cdot 10^{3})\,V = 6.0\,V}$

Se neste side → ~~erstatt~~

f) Amperes lov : $\oint \vec{H} \cdot d\vec{l} = \sum_{alle\,k} I_k$

For toroiden, se figuren side 5 i formelsamlingen, velger vi en integrasjonsvei langs senterlinja (stiplet i figuren). $\vec{H}$ og $d\vec{l}$ går i samme retning slik at (regner H konstant langs banen)

$$\oint \vec{H} \cdot d\vec{l} = \oint H\,dl = H \oint dl = N \cdot I$$

$$H \cdot 2\pi R = N \cdot I \Rightarrow \underline{H = \frac{N \cdot I}{2\pi R}}$$

(2b)

e) $V_m = 15\,V$, $T = 20\,ms \Rightarrow f = \frac{1}{T} = 50\,Hz$

$\theta = 360° \cdot \frac{4}{20} = 72°$ $\underline{\underline{v(t) = 15 \cdot \cos(2\pi 50 t + 72°)}}$

$\underline{\underline{V_{eff}}} = \frac{15}{\sqrt{2}} V = \underline{\underline{10.61\,V}}$

g) (a) Asynkron (induksjon-) vekselstrømsmotor (3

(b) Synkron — " —

(c) "Shunt"-koblet likestrømsmotor

(d) Serie-koblet — " —

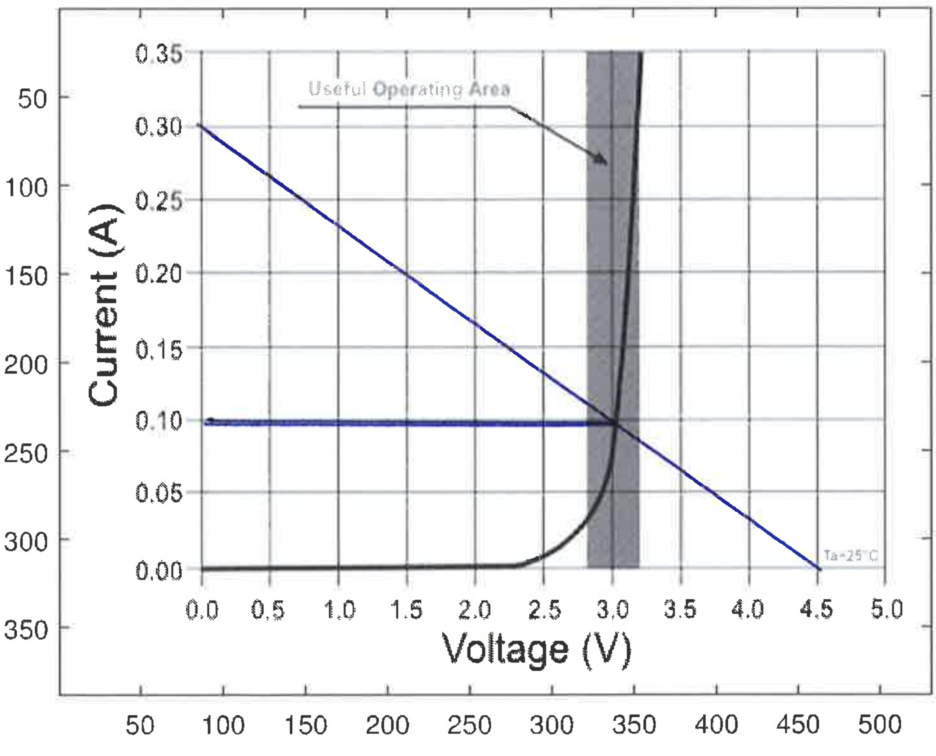
h) Se lærboka / forelesningspresentasjon

i) $\omega_m = n_m \cdot \frac{2\pi}{60} = 1450 \cdot \frac{2\pi}{60}\ \text{rad/s} = \underline{\underline{151.84\ \text{rad/s}}}$

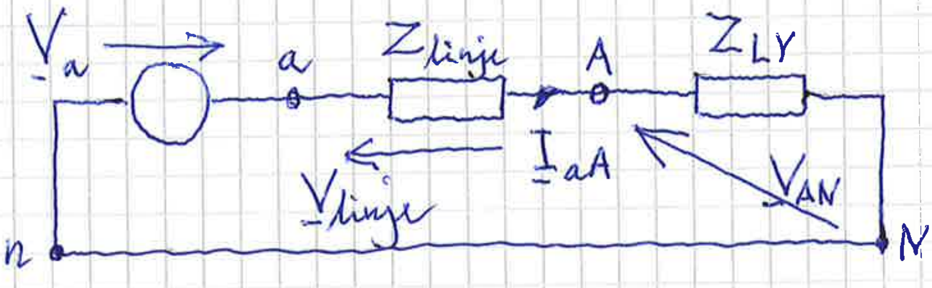
$$T_{ut} = \frac{P_{ut}}{\omega_m} = \frac{100 \cdot 745.7}{151.84}\ \text{Nm} = \underline{\underline{491.1\ \text{Nm}}}$$

j) Se lærboka

Til d)



Oppg. 2 a)



$$Z_{LY} = \frac{Z_\Delta}{3} = \frac{Z_L}{3} = \frac{4.5 + j1.8}{3} = (1.5 + j0.6)\,\Omega$$

Fasespenningen : $|\underline{V}_{AN}| = \frac{1}{\sqrt{3}} \cdot |V_{AB}| = \frac{762.1}{\sqrt{3}}\,V$

$= 440\,V$

For et symmetrisk trefasesystem har vi da

$$\underline{V}_{AN} = 440V\angle 0^\circ$$

b)

$$\underline{I}_{aA} = \frac{\underline{V}_{AN}}{Z_{LY}} = \frac{440}{1.5 + j0.6}\,A = (253 - j101)\,A$$

$$= 272\,A\angle -22^\circ$$

c) $\underline{V}_{linje} = \underline{I}_{aA} Z_{linje} = 272A\angle -22^\circ \cdot \underbrace{(0.03 + j0.04)}_{0.05\,\Omega\,\angle 53^\circ}$

$= (11.6 + j7.08)\,V$

$= 13.6\,V\angle 31^\circ$

$\underline{V}_a = \underline{V}_{linje} + \underline{V}_{AN} = 11.6 + j7.08 + 440$

$= (452 + j7.1)\,V = 452V\angle 0.9^\circ$

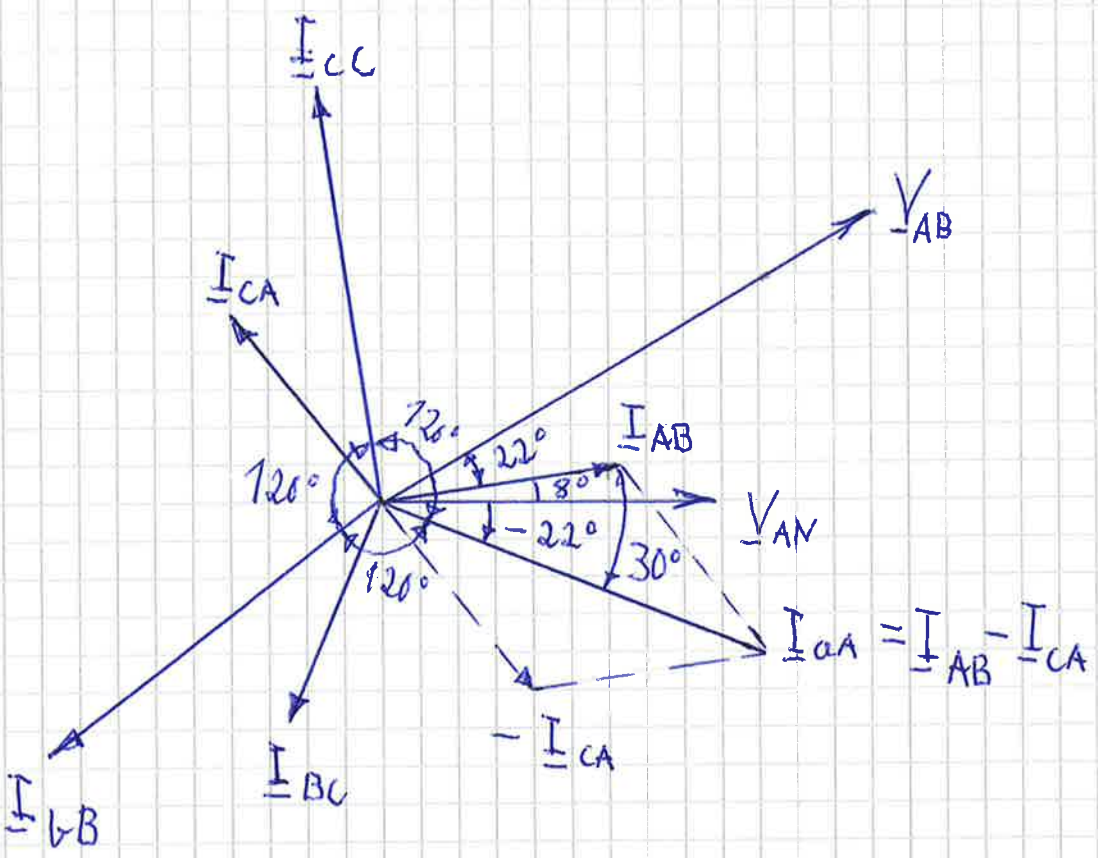
(5

d) $\underline{I}_{ZL}^{AB} = \dfrac{\underline{V}_{AB}}{Z_L} = \dfrac{762.1\angle 30^\circ}{4.5+j1.8} = (156+j22.4)\,A$

$= 157A\angle 8^\circ$

$|\underline{I}_{ZL}|\cdot\sqrt{3} = 157\cdot\sqrt{3}\,A = 272A = |I_{aA}|$

Tallverdien til linjestrømmen er $\sqrt{3}\cdot$ tallverdien til fasestrømmen for en Δ-kobling!
Vinkelen mellom dem er $30^\circ = 22^\circ + 8^\circ$!
Dette gjelder for et symmetrisk trefase-system.

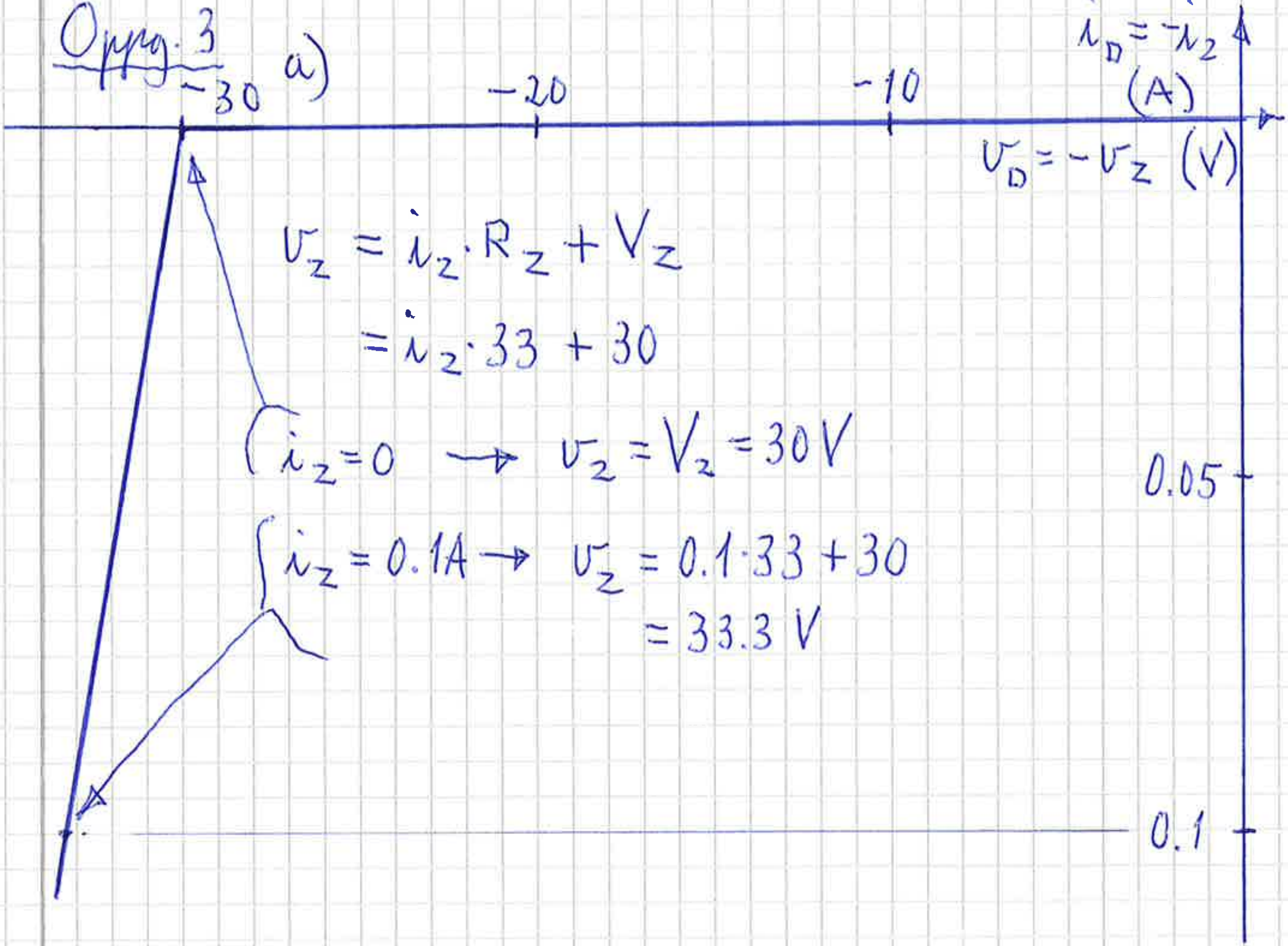


Viserdiagram for strømmene. Spenningen for fase A er også med som referanse.

6)

Oppg. 3

a)

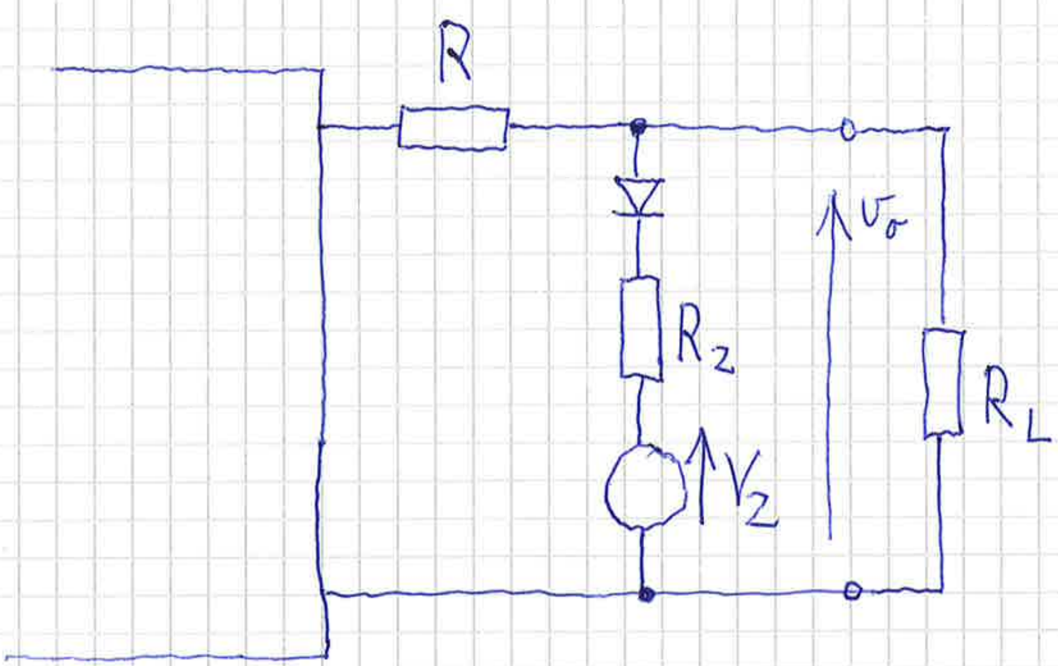


$$v_Z = i_Z \cdot R_Z + V_Z$$
$$= i_Z \cdot 33 + 30$$

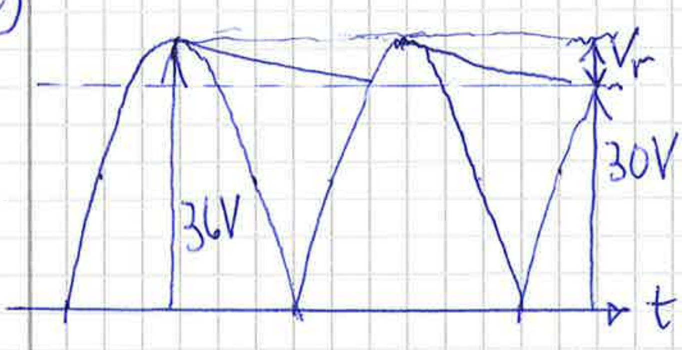
$i_Z = 0 \rightarrow v_Z = V_Z = 30\,V$

$i_Z = 0.1A \rightarrow v_Z = 0.1 \cdot 33 + 30$
$= 33.3\,V$

b)



c)



For at zenerdioden skal lede i bakoverretning må

$\underline{V_r < 36 - 30 = \underline{6V}}$

7) Oppg. 4 a) $n_s = \frac{120 f}{p} = \frac{120 \cdot 50}{6}$ o/min $= \underline{\underline{1000 \text{ o/min}}}$

b) $n_m = 995$ o/min for $T_{ut} \approx 500$ Nm

$$s = \frac{n_s - n_m}{n_s} = \frac{1000 - 995}{1000} = \underline{\underline{0.005}}$$

c) "Pull-out" momentet er maksimum moment avlest fra kurven:

$\underline{\underline{T_{pullout} \approx 2200 \text{ Nm}}}$ ved ca. 940 o/min.

d) Fasestrømmen ved start.

Ved start er $n_m = 0$, $s = 1$

Regner først ut impedansene når $s = 1$.

$$Z_r' = R_r' + jX_r' = (0.04 + j0.2)\Omega$$

$$Z_{eq} = \frac{Z_m \cdot Z_r}{Z_m + Z_r} = \frac{j8 \cdot (0.04 + j0.2)}{j8 + 0.04 + j0.2} = 0.0381 + j0.1953$$

$$Z_{tot} = Z_s + Z_{eq} = R_s + jX_s + Z_{eq} = 0.48 + j0.3 + 0.0381 + j0.1953$$
$$= 0.518 + j0.495$$

$$I_{s\,start} = \frac{V_s}{Z_{tot}} = \frac{440}{0.518 + j0.495} \text{ A} = (443.7 - j424.2) \text{ A}$$
$$= \underline{\underline{614 \text{ A} \angle -43.7^\circ}}$$

8) (8

e) $P_{Cu} = P_{Cus} + P_{Cur} = 3 \cdot \left[R_s \cdot |I_s|^2 + R_r' \cdot |I_r'|^2 \right]$

$= 3 \cdot \left[0.48 \cdot 71.665^2 + 0.04 \cdot 50.045^2 \right] W$

$\underline{\underline{= 7696\ W}}$

f) For å finne virkningsgraden trenger vi inn- og utgangseffekt.

$P_{inn} = \text{real}\{3 \cdot \underline{V}_s \cdot \underline{I}_s^*\}$

$= \text{real}\{3 \cdot 440 \cdot 71.665 (\cos(44.47) - j \sin(-44.47))\}$

$= 3 \cdot 440 \cdot 71.665 \cdot \cos(44.47°)\ W$

$\underline{= 67507\ W}$

$R_{ut} = \frac{1-s}{s} \cdot R_r' = \frac{1-0.005}{0.005} \cdot 0.04\ \Omega = 7.96\ \Omega$

$P_{utv.} = 3 \cdot R_{ut} \cdot |I_r'|^2$

$= 3 \cdot 7.96 \cdot 50.045^2\ W = 59808\ W$

$P_{ut} = P_{utv.} - P_{rot} = (59808 - 6000)\ W = \underline{53808\ W}$

$\eta = 100\% \cdot \frac{P_{ut}}{P_{inn}} = 100\% \cdot \frac{53808}{67507} = \underline{\underline{79.7\%}}$

(Effektfaktoren:

$pf = \cos(-44.47°) = \underline{\underline{0.714}}$

$\underline{I}_s = 71.665\ A \angle -44.47°$, $\underline{V}_s = 440\ V \angle 0°$

Oppg. 5

a) $n_m = n_s = \frac{120 \cdot f}{P} = \frac{120 \cdot 50}{8} = \underline{\underline{750\,^o/min}}$

b) $|I_a| = \frac{P_{inn}}{3 \cdot V_a \cdot \cos(\theta)}$ Uten tap er $P_{inn} = P_{ut} = 500 \cdot 745.7\,W$

$= \frac{500 \cdot 745.7}{3 \cdot 480 \cdot 0.9} A = 287.7\,A$

$\theta = \mathrm{Arccos}(0.9) = 25.84°$ Induktiv $\Rightarrow$

$\underline{\underline{\underline{I}_a = 287.7\,A \angle -25.84°}}$

c) $Z_s = jX_s = j0.5$

$\underline{\underline{\underline{E}_r}} = \underline{V}_a - \underline{I}_a Z_s = 480 - 287.7 \angle -25.84 \cdot 0.5 \angle 90°$

$= (417.3 - j129.5)\,V = \underline{\underline{437\,V \angle -17.2°}}$

$\delta = 17.2°$ Momentvinkelen

Se viserdiagram på neste side.

d) Når effekten er konstant flytter den induserte spenningen seg langs en horisontal linje, se viserdiagrammet.
Den nye momentvinkelen blir da

$\underline{\underline{\delta_2}} = \mathrm{Arcsin}\left(\frac{V_v}{|E_{r2}|}\right)$

$= \mathrm{Arcsin}(129.5/570)$

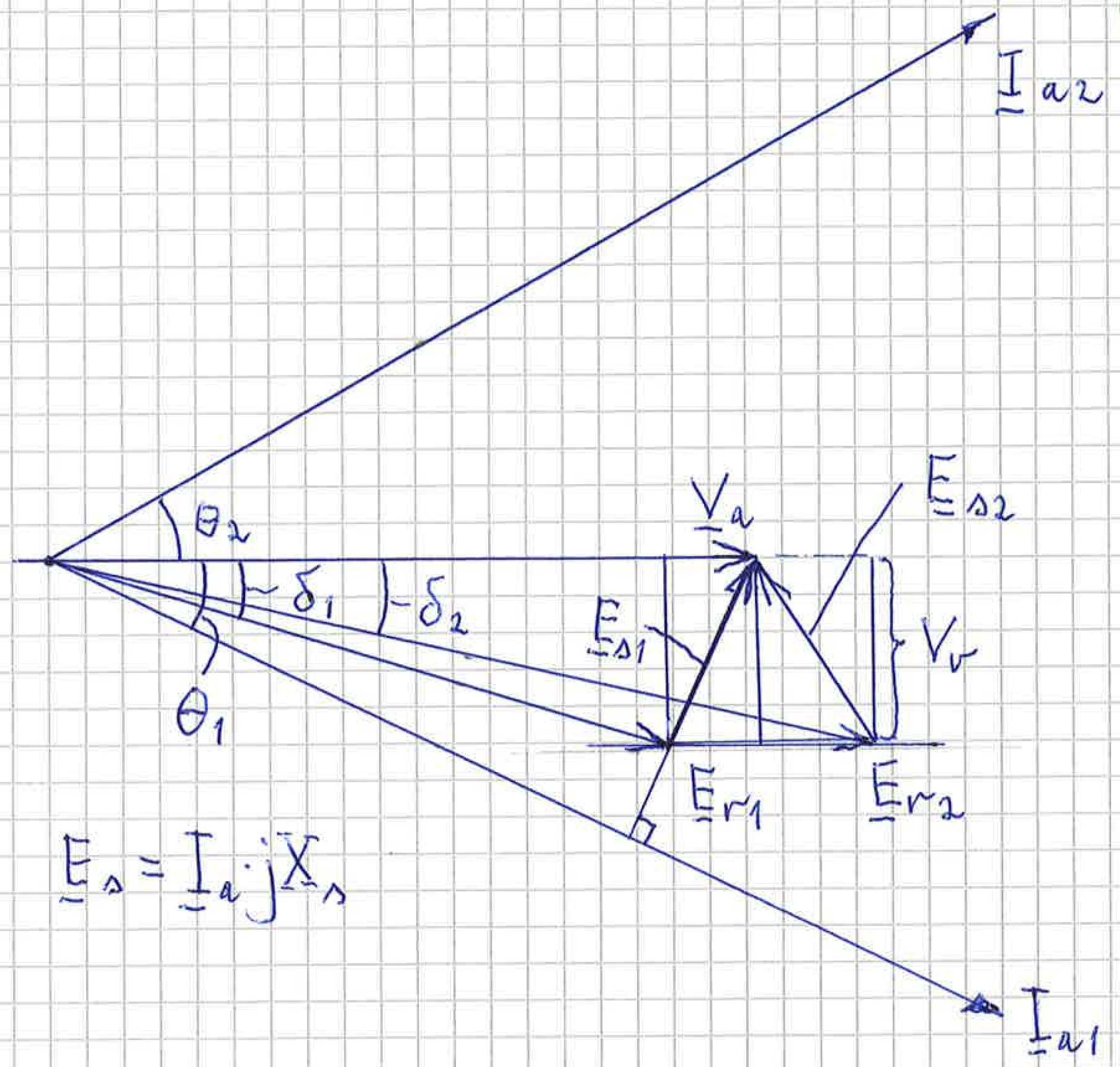
$= \underline{\underline{13.1°}}$

$V_v = |E_{r1}| \cdot \sin(\delta_1)$

$= 437 \cdot \sin(17.2°)$

$= 129.5\,V$

(10



$$\underline{E}_s = \underline{I}_a \cdot jX_s$$

e) $V_h = E_{r2} \cdot \cos\delta_2 = 555.1\,V$

$$\underline{E}_{s2} = -(V_h - V_a) + jV_v = -(555.1 - 480) + j\,129.5$$

$$\underline{I}_{a2} = \frac{\underline{E}_{s2}}{jX_s} = \frac{-75.1 + j129.5}{j \cdot 0.5} = 258.9 + j150.2$$

$$= \underline{\underline{299.3\,A \angle 30.1^\circ}}$$

$\therefore$ Kapasitiv last, strømmen ligger foran spenningen.

Oppg. 6

a) $V_{GS} = 20 \cdot \dfrac{R_2}{R_1 + R_2} = 5$

$$20 \cdot R_2 = 5 \cdot 300 \cdot 10^3 + 5 \cdot R_2$$

$$R_2 = \frac{5 \cdot 300 \cdot 10^3}{20 - 5}\,\Omega = 100 \cdot 10^3\,\Omega = \underline{\underline{100\,k\Omega}}$$

b) $20 = i_D \cdot R_D + v_{DS} = i_D \cdot 18 + v_{DS}$

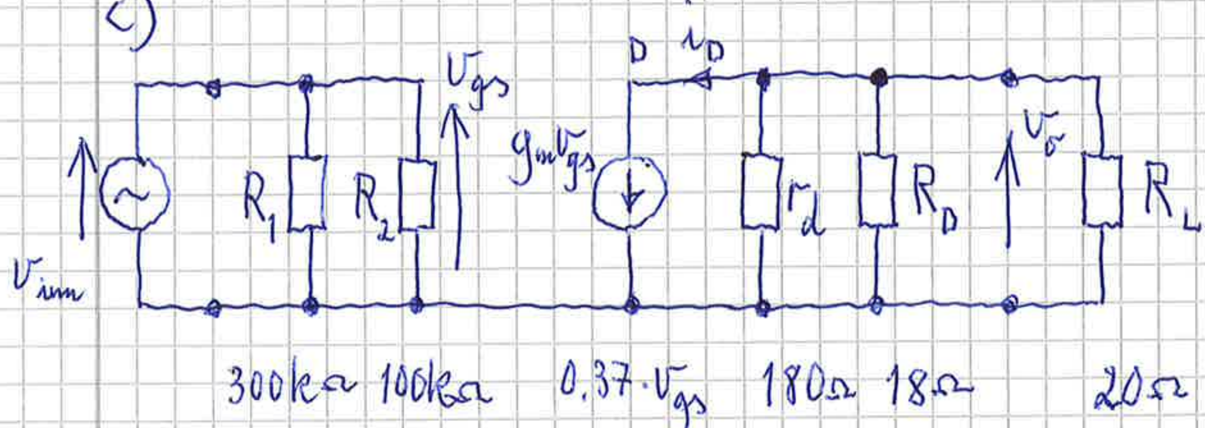
$i_D = 0$ gir $v_{DS} = 20\,V$

$v_{DS} = 0$ " $i_D = \dfrac{20}{18}\,A = 1.111\,A$

Arbeidslinje, se figur

$\underline{\underline{V_{DSQ} \approx 10\,V}}$, $\underline{\underline{I_{DQ} \approx 0.6\,A}}$

c)

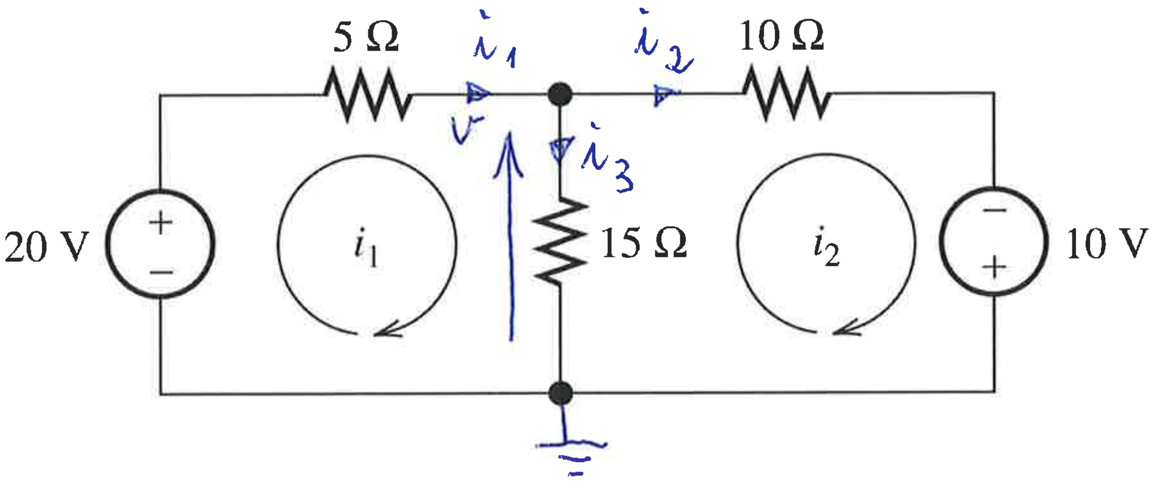


d) $R_L' = \left[\dfrac{1}{180} + \dfrac{1}{18} + \dfrac{1}{20}\right]^{-1}\Omega = 9.0\,\Omega$

$\underline{\underline{v_o}} = -g_m v_{gs} \cdot R_L' = -0.37 \cdot 9 \cdot v_{inn}$, $v_{gs} = v_{inn}$

$= -0.37 \cdot 9 \cdot 0.5 \sin(\omega t) = \underline{\underline{-1.665 \cdot \sin(\omega t)\,V}}$

Oppg. 7



$$i_1 = \frac{20-v}{5}, \quad i_2 = \frac{v+10}{10}, \quad i_3 = \frac{v}{15}$$

Knutepunktsanalyse:

$$i_1 - i_2 - i_3 = 0 \quad \text{(Kirchhoffs strømlov)}$$

$$\frac{20-v}{5} - \frac{v+10}{10} - \frac{v}{15} = 0 \quad \| \cdot 30$$

$$-(6+3+2)\cdot v + 6\cdot 20 - 3\cdot 10 = 0$$

$$\Rightarrow \quad v = \frac{90}{11}\,\text{V}$$

$$i_1 = \frac{20-\frac{90}{11}}{5} = \frac{26}{11}\,\text{A}, \quad i_2 = \frac{\frac{90}{11}+10}{10} = \frac{20}{11}\,\text{A}, \quad i_3 = \underbrace{\frac{6}{11}}_{\frac{90}{11\cdot 15}}\,\text{A}$$

Oppg. 8 a) $n_m = 0 \Rightarrow E_A = 0$

$$E_A = V_T - R_A \cdot I_A = 0 \rightarrow R_A = \frac{V_T}{I_A} = \frac{12}{24}\,\Omega = \underline{\underline{0.5\,\Omega}}$$

b) $P_{utv.} = E_A \cdot I_A = (V_T - R_A \cdot I_A) \cdot I_A = V_T \cdot I_A - R_A \cdot I_A^2$

$$\frac{dP_{utv}}{dI_A} = V_T - 2R_A I_A = 0 \rightarrow I_A^{max} = \frac{V_T}{2R_A} = \frac{12}{2 \cdot 0.5}\,A = 12\,A$$

$$\underline{\underline{P_{utv}^{max}}} = (\overbrace{12 - 0.5 \cdot 12}^{E_A = 6.0V})\,12\,W = \underline{\underline{72\,W}}$$

c) $E_A = V_T - I_A \cdot R_A = (12 - 6 \cdot 0.5)\,V = 9\,V$

$$E_A = K\Phi \cdot \omega_m = K\Phi\, n_m \cdot \frac{2\pi}{60} \Rightarrow$$

$$n_m = \frac{E_A \cdot 60}{K\Phi \cdot 2\pi} = \frac{9 \cdot 60}{(3/10\pi) \cdot 2\pi}\,°/min = \underline{\underline{900°/min}}$$