CHALMERS	Anonymous code / Anonym kod: ENM061, Aug 2018	Points for question (to be filled in by teacher) / Poäng på uppgiften (ifylles av lärare)	Consecutive page no. / Löpande sid nr: 1 — Question no. / Uppgift nr: 1,2

1. (a) & (b) check lecture handouts (2 pts each part)

2. $V_0 = 12V$ $P_0 = 48W$, $V_d = 18V$, $f_{sw} = 20kHz$

2(a) Boundary condition $\Rightarrow$ CCM and $I_L = \frac{1}{2}\Delta \hat{i}_L$

$I_0 = P_0/V_0 = \underline{\underline{4A}} \Rightarrow R = V_0/I_0 = \underline{\underline{3\Omega}}$

During off-period, $V_L = -V_0$
During on-period, $V_L = V_d$
$\Rightarrow V_{L=0} = V_d \cdot D - V_0(1-D) = 0$

$\Rightarrow \frac{V_0}{V_d} = \frac{D}{1-D} \Rightarrow D = \underline{\underline{0.4}}$

$P_0 = P_{in} \Rightarrow V_d I_d = P_0 \Rightarrow I_d = \underline{\underline{2.67A}}$ (1)

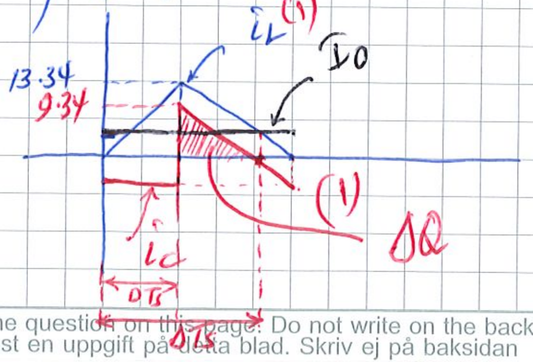
using $i_L = i_d + i_{Diode} \Rightarrow I_L = I_d + I_{Diode} = I_d + I_0 = \underline{\underline{6.67A}}$

$\Rightarrow \Delta \hat{i}_L = 2I_L = \underline{\underline{13.34A}}$ (1)

during on period, $V_L = V_d$: $\frac{L\Delta \hat{i}_L}{DT_s} = \frac{Lf_{sw} \cdot \Delta \hat{i}_L}{D}$

$\Rightarrow L = \frac{DV_d}{f_{sw} \cdot \Delta \hat{i}_L} = \underline{\underline{27\mu H}}$ (2)

2(b) During on period, $i_c = -I_0$; During off period, $i_c = i_L - I_0$



the time $i_c = 0$ is calculated when $i_L = I_0$

$\Rightarrow \frac{\Delta - D}{\Delta \hat{i}_L - I_0} = \frac{1-D}{\Delta \hat{i}_L}$

$\Rightarrow \Delta = \underline{\underline{0.82}}$

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			Question no. / Uppgift nr: 2,3

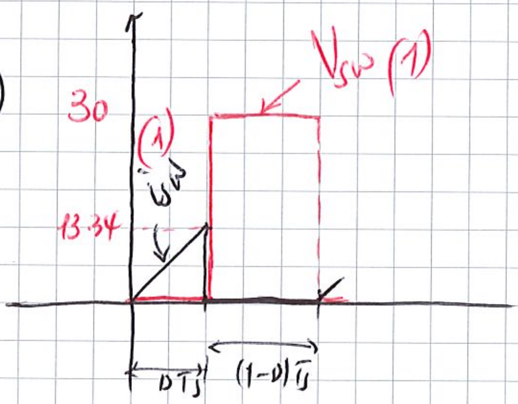
2(c) $\Delta Q = \frac{1}{2}(\Delta - D)T_s \cdot \hat{i}_c$ (1)

$$\Rightarrow \Delta V_o = \Delta Q / C = \frac{(\Delta - D)\hat{i}_c}{2 f_{sw} \cdot C}$$

$$\Rightarrow C_{min} = \frac{(\Delta - D)\hat{i}_c}{2 f_{sw} \cdot \Delta V_o} = \begin{cases} 40.9\,\mu F & \text{for } 10\% \text{ ripple} \\ 409\,\mu F & \text{for } 1\% \text{ ripple} \end{cases}$$

(1)

2(d)



$i_{sw} = i_d = i_L$ during on, 0 during off

$V_{sw} = 0$ during on

$V_{sw} = V_d - V_L = V_d + V_o = 30V$

3. $N_1 : N_2 : N_3 = 1:2:2$; $V_d = 20V$, $f_{sw} = 20$ kHz, $D = 0.3$, $L_m = 100\mu H$

3(a). $R_{load} = 20\Omega$, $V_o = ?$

Assume CCM $\Rightarrow$ $V_o = \frac{N_3}{N_1}\frac{D}{1-D} V_d = \frac{2}{1} \cdot \frac{0.3}{1-0.3} \cdot 20V = \underline{\underline{17.143V}}$

$V_{o,max} = \frac{N_3}{N_2} V_d = 20V > V_o$ (N_2 winding not used) (1)

$I_D = I_O = \frac{V_o}{R_{load}} A = \frac{17.143}{20} A = \underline{\underline{0.858A}}$

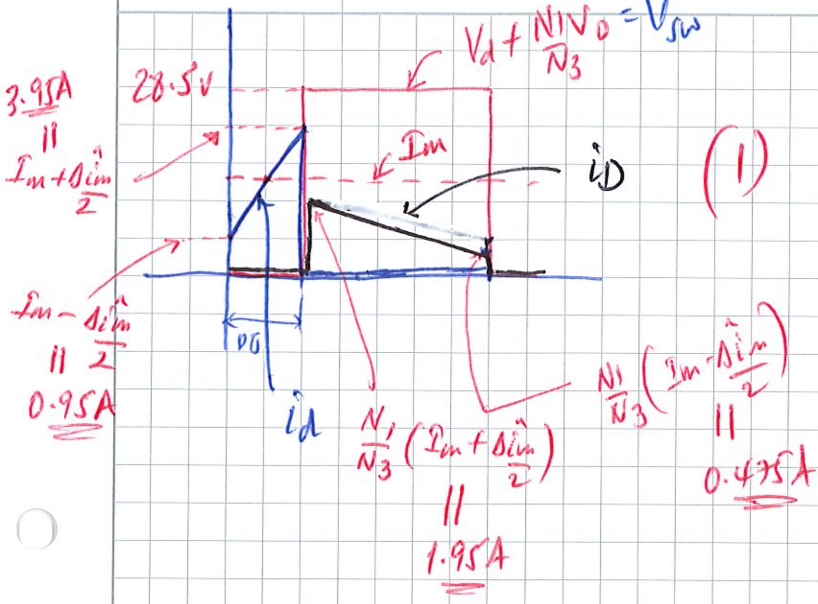
$I_d = P_o / V_d = V_o I_o / V_d = \underline{0.7354A}$

(1)

$\Rightarrow I_m = I_d + \frac{N_3}{N_1} I_D = (0.735 + 2(0.858))A = \underline{\underline{2.4514A}}$

During on-period, $L_m \frac{\Delta i_m}{DT_s} = V_d \Rightarrow \Delta \hat{i}_m = \frac{DV_d}{L_m f_{sw}} A = 3A$

$\frac{\Delta i_m}{2} = 1.5A < I_m = 2.45A \Rightarrow$ Converter in CCM. (1)



2(b) $R_{load,min}$ is the value where the converter operates at the boundary condition

$\Rightarrow I_m = \frac{\Delta \hat{i}_m}{2}$ & $V_0 = \frac{N_3}{N_1} \cdot \frac{D}{1-D} V_d = 17.143V < V_{0,max} = 20V.$

$\Rightarrow I_m = 1.5A$ from previous task

$\Rightarrow I_d = I_m \cdot D$ (CCM mode)

$\Rightarrow I_d = 0.45A$ (1)

$\Rightarrow I_0 : I_0 = V_d I_d / V_0 = 20(0.45)/17.13 A = \underline{0.5254A}$ (1)

$\Rightarrow R_{load} = \frac{V_0}{I_0} \Omega = \underline{32.6 \Omega}$ (1)

2(c) if R increases further from 2(b), converter goes to DCM and the output voltage increases. When $V_0 = V_{0,max} = \frac{N_3}{N_2} V_d = 20V$, N_2 starts to conduct. (1)

$\Rightarrow V_0 = V_{0,max} = 20V$

$= D \sqrt{\frac{R_{load}}{2 L_m f_{sw}}} \cdot V_d$ (DCM)

$\Rightarrow R_{load} = \underline{44.4 \Omega}$ (2)

2

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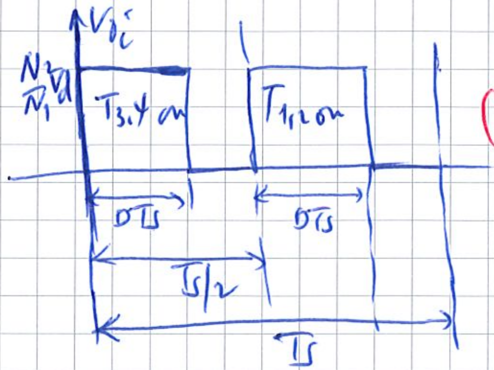
4.(a) $V_1 = -V_d$ (1)

$V_{D1} = -2N_2/N_1 \, V_d$ (1) (D_1 : off)

$V_{D2} = 0$ (1) (D_2 : on)

4(b)



(1)

$$V_0 = \frac{1}{T_s}\int_0^{T_s} V_{0i}\,dt = 2\left(\frac{N_2}{N_1}\right)\frac{DT_s \cdot V_d}{T_s}$$

$$V_0 = 2\frac{N_2}{N_1}D \cdot V_d$$

$$\frac{V_0}{V_d} = 2\frac{N_2}{N_1}D \quad (1)$$

5.(a) check lecture notes for V_{N0} (1) and V_A. (1)

for resistive load, $i_A = V_A/R_{load} = V_A/30\Omega$ (1)

5(b) $I_d = P_0/V_d$ where $P_0 = 3\frac{1}{T_s}\int_0^{T_s} V_A \cdot i_A\,dt$

$$= 3 \cdot \frac{1}{2\pi}\int_0^{2\pi} V_A^2/30 \, d\theta$$

$$\Rightarrow I_d = \frac{3}{2\pi V_d}\int_0^{2\pi} V_A^2(t)\,dt \quad (1)$$

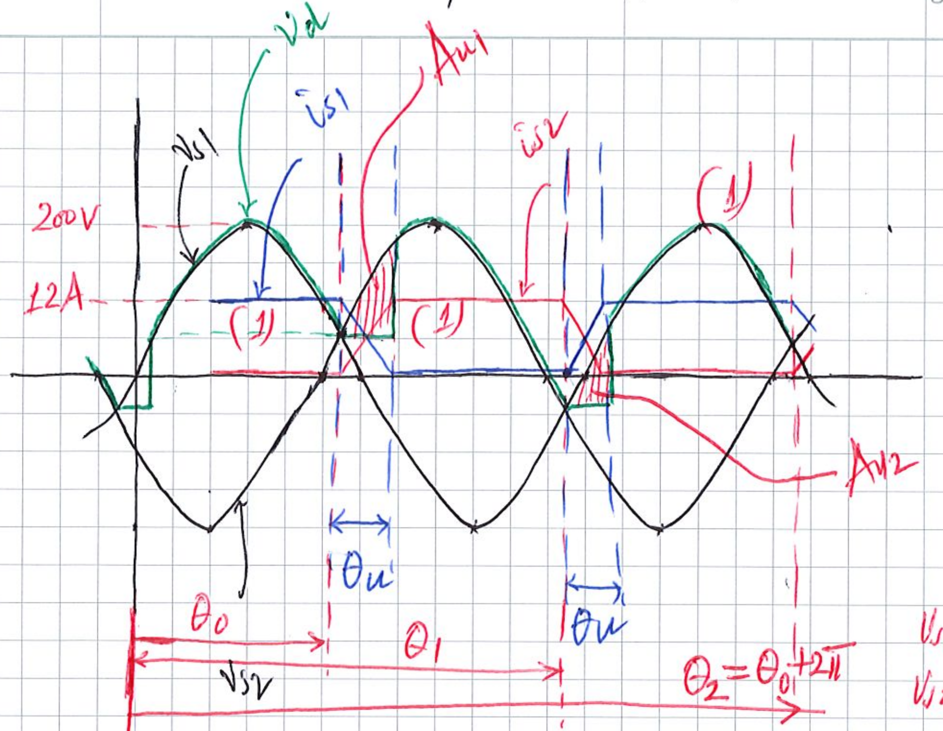
dc harmonics : square wave → low order (1)
PWM → high order harmonics (1)

5.(c) PWM. $\hat{V}_{A(1)} = m_a \cdot V_d/2 = V_d/2 \; V = 150V$ (1)

square wave $\hat{V}_{A(1)} = \frac{4}{\pi}\frac{V_d}{2} V = 191V$ (using Fourier) (2)

Answer only one question on this page. Do not write on the back of this paper
Behandla endast en uppgift på detta blad. Skriv ej på baksidan.

6.(a)



50Hz. system

$V_{s1} = 200 \sin(\omega t)$

$V_{s2} = 200 \sin(\omega t - 5/6\pi)$

at θ_0 : $v_{s1} = v_{s2}$ ⇒ $200 \sin(\theta_0) = 200 \sin(\theta_0 - 5/6\pi)$

⇒ $\sin(\theta_0) = \sin(\theta_0 - 5/6\pi)$, $\pi/2 < \theta_0 < \pi$

⇒ $\theta_0 = ?$

Find also θ_1 where $\sin(\theta_1) = \sin(\theta_1 - 5/6\pi)$

$3/2\pi < \theta_1 < 2\pi$

(1)

6(b) look 6(a) for plot of V_d

Find θ_0 and θ_1 and show V_d calculation

then $$V_d = \frac{1}{2\pi}\int_{\theta_0}^{\theta_0+2\pi} v_d \cdot dt = \frac{1}{2\pi}\left[\int_{\theta_0+\theta_u}^{\theta_1} v_{s1} dt + \int_{\theta_1+\theta_u}^{\theta_1+2\pi} v_{s2} dt - A_{u1} - A_{u2}\right]$$ (1)

$\theta_u = ?$ and then $v_d = ?$ during commutation

⇓

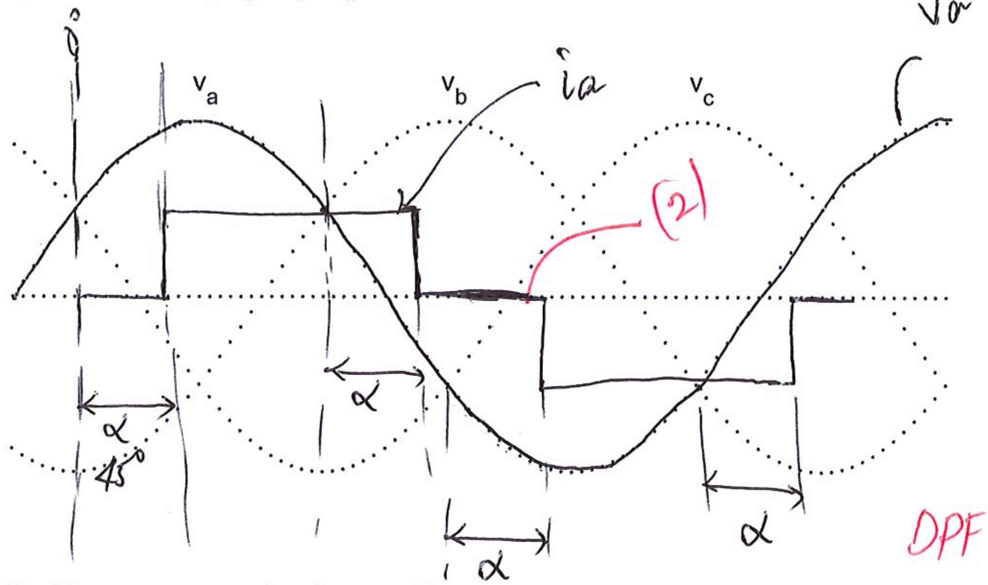
$$v_d = v_{s1} - L_s \frac{di_{s1}}{dt} = v_{s2} - L_s \frac{di_{s2}}{dt} \quad \Big| \; i_{s2} = I_d - i_{s1}$$

$$\Rightarrow v_{s1} - v_{s2} = 2L_s \frac{di_{s1}}{dt} \Rightarrow L_s \frac{di_{s1}}{dt} = \frac{v_{s1} - v_{s2}}{2} \Rightarrow v_d = \frac{v_{s1} + v_{s2}}{2}$$ (1)

θ_u is calculated from i_{s1} goes from I_d to 0

Dot paper for Question 7 (*give a page number and put this paper together with your answer sheets if you use it for your answers. The distance between the dots in the voltage plots is 5°.*)

1) Phase-voltage plot for part 7.a.



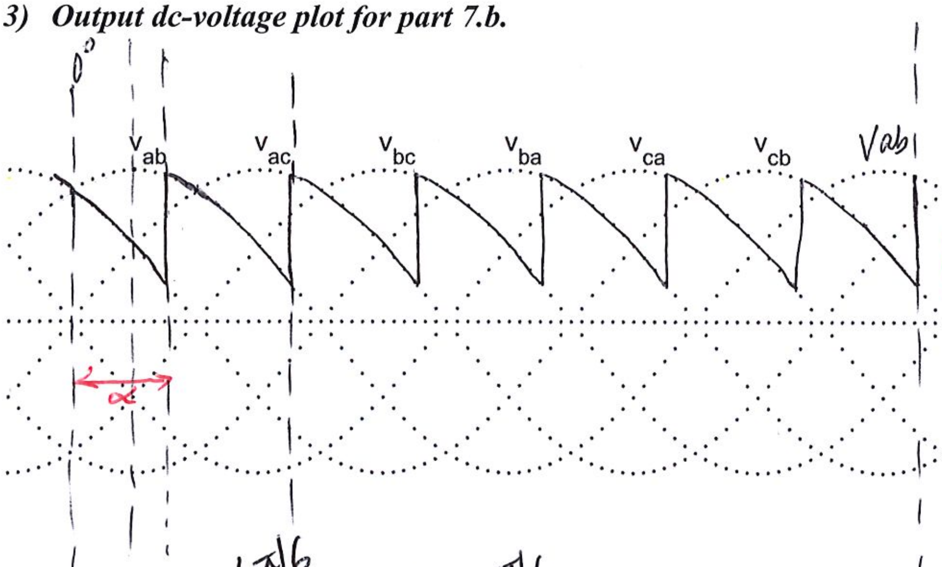
(1)

DPF = cos(α)

2) Phase-current plot for part 7.a.

See Fig. above

3) Output dc-voltage plot for part 7.b.



(2)

$\theta_1 = \alpha - \pi/6$

$\theta_1 + \pi/3 = \alpha + \pi/6$

$\theta_1 + 2\pi$

(1)

$\theta_{ref} = 0 \Rightarrow V_{ab} = \sqrt{2} \cdot V_{LL} \cos\theta, \Rightarrow V_{dc} = \frac{1}{\pi/3} \int_{\alpha-\pi/6}^{\alpha+\pi/6} \sqrt{2} V_{LL} \cos\theta \cdot d\theta = \frac{3\sqrt{2}}{\pi} V_{LL} \cos\alpha$