UNIVERSITETET I AGDER

Emnekode: ENE 505

Kandidatnr.: 731

Dato: 29.11.17

Ark nr.: 1 av 8

1. **Buck-Boost**

(i)

$V_d = V_{in} = 14V$

$V_o = 42V$

$P_o = 21W$

$\Delta i_L = 1{,}8A$

$f_s = 200\,kHz$

$$V_o = \frac{D}{1-D} \cdot V_{in} \rightarrow \frac{V_o}{V_{in}} = \frac{D}{1-D} \rightarrow \frac{42}{14} = \frac{D}{1-D} \rightarrow D = 0{,}75$$

$$T_s = 1/f_s = 1/200 \cdot 10^3 = 5\,\mu s$$

$$t_{on} = D \cdot T_s = 0{,}75 \cdot 5\mu s = 3{,}75\,\mu s$$

$$P_o = V_o \cdot I_o \rightarrow I_o = \frac{P_o}{V_o} = \frac{21W}{42V} = 0{,}5A$$

$$I_{in} = \frac{D}{1-D} \cdot I_o = \frac{0{,}75}{1-0{,}75} \cdot 0{,}5A = 1{,}5A$$

$$I_L = I_{in} + I_o = 1{,}5 + 0{,}5 = 2A$$

$$\Delta i_L = \frac{V_{in}(D \cdot T_s)}{L}$$

$$L = \frac{V_{in}(D \cdot T_s)}{\Delta i_L} = \frac{14(0{,}75 \cdot 5 \cdot 10^{-6})}{1{,}8A} = 29{,}17\,\mu H$$

$$\underline{\underline{\approx 29{,}2\,\mu H}}$$

$$i_{L,max} = I_L + \frac{\Delta i_L}{2} = 2 + \frac{1{,}8}{2} = 2{,}9A$$

$$i_{L,min} = I_L - \frac{\Delta i_L}{2} = 2 - \frac{1{,}8}{2} = 1{,}1A$$

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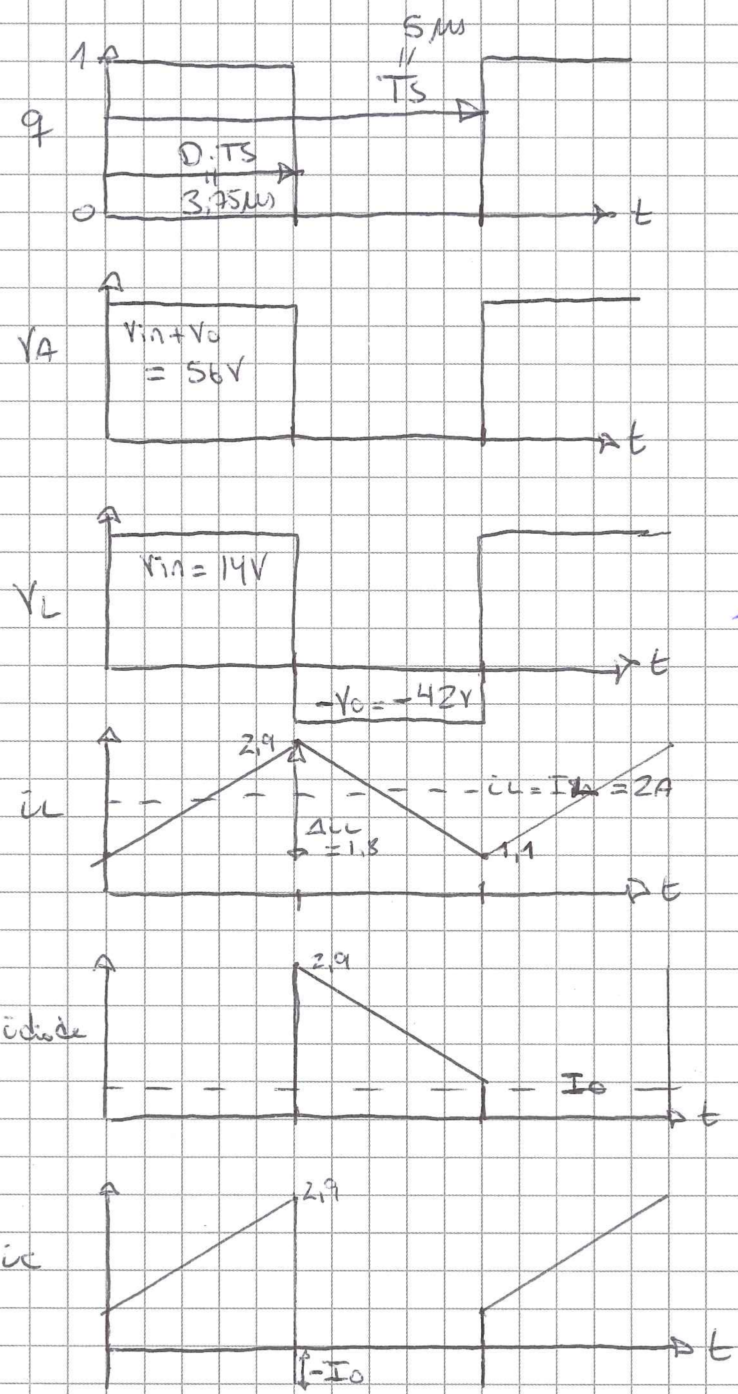
1.

(i) continue..



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1 (ii) Find $P_{o,crit}$

$$P_{o,crit} = V_o \cdot I_{o,crit}$$

$$I_{L,crit} = \frac{1}{1-D} I_{o,crit}$$

$$I_{o,crit} = I_{L,crit}(1-D)$$

$$\Delta i_L = 1{,}8\,A = \hat{I}_{L,crit}$$

$$I_{L,crit} = 0{,}5 \cdot \hat{I}_{L,crit} = 0{,}5 \cdot 1{,}8 = 0{,}9A$$

$$I_{o,crit} = 0{,}9(1-0{,}75) = 0{,}225\,A$$

$$V_o = 42\,V$$

$$P_{o,crit} = V_o \cdot I_{o,crit}$$

$$= 42V \cdot 0{,}225A = 9{,}45 \approx \underline{\underline{9{,}5\,W}}$$

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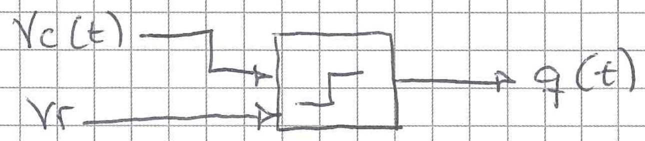
2.1

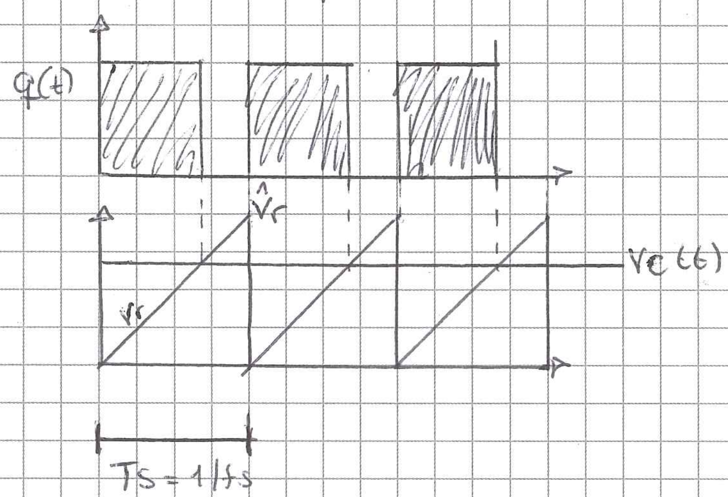


The output voltage Vo can be contolled by Pulse width modulating (PWM) the duty ratio d(t).

Vo is compared to it's reference value V_o^*, and the output is the contole voltage Vc(t). The contole voltage is then compared with a ramp voltage Vr, making the output q(t), which contols d(t).

q(t) = 1 when Vc(t) is greater than Vr, else 0.

vc(t) ranges between 0 and $\hat{V}_r$, which is the amplitude of vr.



Linearized transfer-function of PWM:

$$G_{PWM}(s) = \frac{1}{\hat{V}_r} = \frac{\tilde{d}(s)}{\tilde{v}_c(t)}$$

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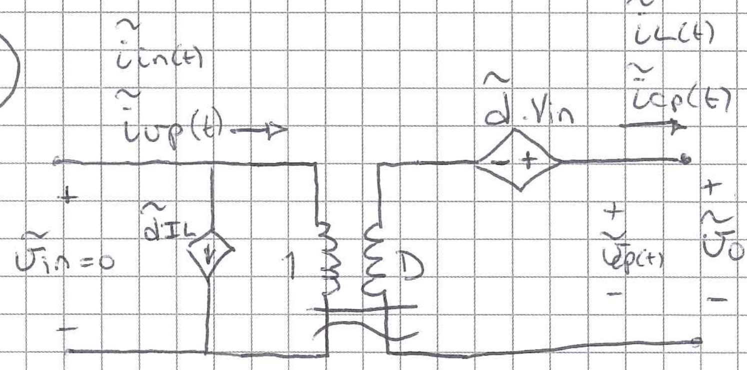
2.2



$$V_{cp} + \tilde{v}_{cp}(t) = (D + \tilde{d}(t))(V_{vp} + \tilde{v}_{vp}(t))$$
$$I_{vp} + \tilde{i}_{vp}(t) = (D \cdot \tilde{d}(t))(I_{cp} + \tilde{i}_{cp}(t))$$
$$\tilde{v}_{cp}(t) = (D \cdot \tilde{v}_{vp}(t)) + (\tilde{d}(t) \cdot V_{vp})$$
$$\tilde{i}_{vp}(t) = (D \cdot \tilde{i}_{cp}(t)) + (\tilde{d}(t) \cdot I_{cp})$$

3.1

$V_S = 120\,V\,(rms)$ $\quad I_{S1} = 10A\,(rms)$

$P = 0{,}95\ kW$ $\quad THD = 75\% \simeq 0{,}75$

a) $P = V_S \cdot I_{S1} \cdot DPF$

$\hookrightarrow DPF = \frac{P}{V_S \cdot I_{S1}} = \frac{0{,}95 \cdot 10^3}{\cancel{\sqrt{2}} \cdot 120 \cdot 10} = 0{,}5597 \approx \underline{\underline{0{,}56}}$
$\approx \underline{\underline{56\%}}$

b) $THD = \frac{I_{dist}}{I_{S1}} \rightarrow I_{dist} = THD \cdot I_{S1}$
$= 0{,}75 \cdot 10 = \underline{\underline{7{,}5A}}$

c) $PF = \frac{I_{S1}}{I_S} \cdot DPF = \frac{10}{12{,}5} \cdot 0{,}56 = 0{,}448$
$\approx \underline{\underline{0{,}45}}$

$I_S^2 = I_{S1}^2 + I_{dist}^2$

$I_S = \sqrt{I_{S1}^2 + I_{dist}^2} = \sqrt{10^2 + 7{,}5^2} = 12{,}5A$

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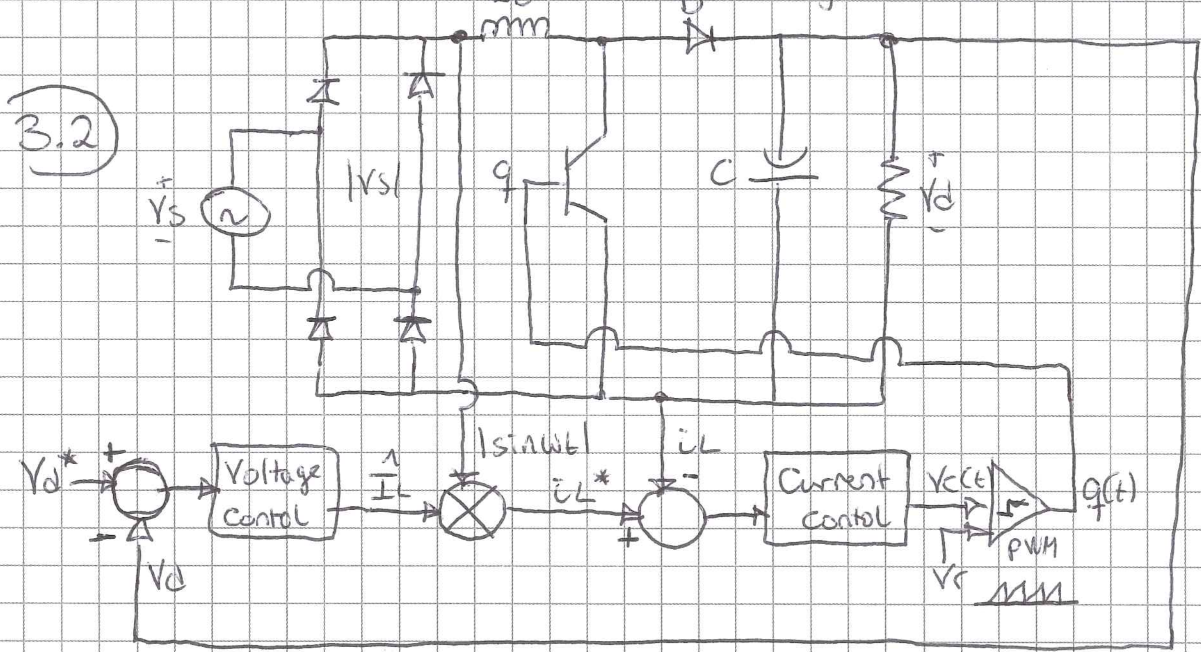
3.1 c) Comments: The ~~[illegible]~~ distortion component of I_s is 7,5A, which is 75% I_{s1}.
The distortion makes I_s less sinusoidal (due to noise/harmonics) making the overall PF low, and the circuit delivers less power. A voltage and curren contol circuit as drawn below can help with this by PWM to PFC.

3.2



The main objective is to draw the current in phase with the voltage.
The voltage and current contol loops are used to PWM the duty ratio d(t) to contol the output voltage Vd.
Vd is used in voltage contol to estimate the amplitude of i_L ($\hat{I}_L$), and |sinωt| is used to estimate the form of i_L.

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4.1 $P = \frac{1}{2} \cdot \hat{I}_s \cdot \hat{V}_s \rightarrow \hat{I}_s = \frac{P}{\sqrt{2} \cdot \hat{V}_s} = \frac{250W}{\sqrt{2} \cdot 120V} = \underline{1,47}$

$\hat{I}_L = \hat{I}_s$

$i_L(t) = \hat{I}_L |\sin wt| = 1,47 |\sin wt|$

$d(t) = 1 - \frac{\hat{V}_s |\sin wt|}{V_d} = 1 - \frac{\sqrt{2} \cdot 120}{250} \cdot |\sin wt|$

$= \underline{1 - 0,68 |\sin wt|}$

$\bar{i_d}(t) = \frac{1}{2} \cdot \frac{\hat{V}_s}{V_d} \cdot \hat{I}_L - \frac{1}{2} \frac{\hat{V}_s}{V_d} \cdot \hat{I}_L |\cos 2wt|$

$= \frac{1}{2} \cdot \frac{\sqrt{2} \cdot 120}{250} \cdot 1,47 - \frac{1}{2} \cdot \frac{\sqrt{2} \cdot 120}{250} \cdot |\cos 2wt|$

$= \underline{0,5 - 0,5 |\cos 2wt|}$

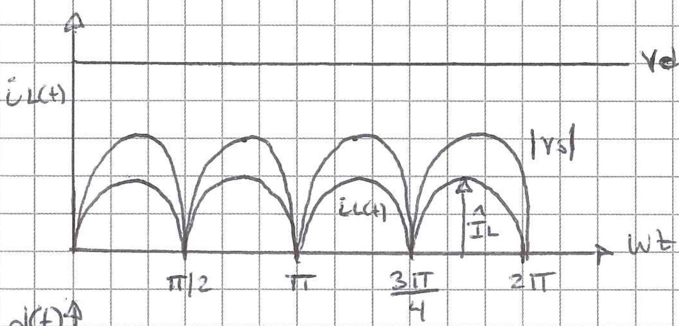
$\uparrow I_d$ $\quad\uparrow i_{d2}(t)$ second harmonic = current through the capacitor

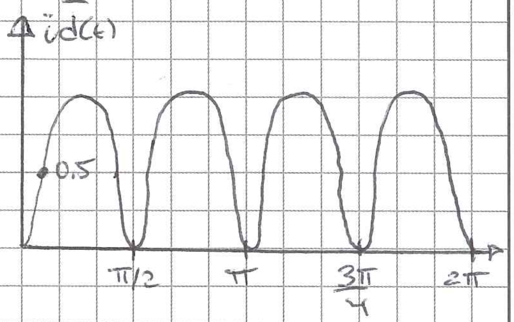
$w_s = 2 \cdot \pi \cdot f_s = 2 \cdot \pi \cdot 100 \cdot 10^3$

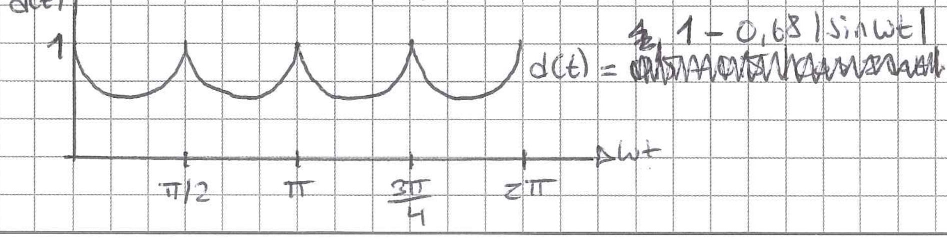
$i_C(t) = \left(\frac{1}{2wC}\right)\left(\frac{1}{2} \frac{\hat{V}_s}{V_d} \cdot \hat{I}_L \cdot |\cos 2wt|\right)$

$= \left(\frac{1}{4 \cdot 2 \cdot \pi \cdot 100 \cdot 10^3 \cdot 220 \cdot 10^{-6}}\right) \cdot \left(\frac{\sqrt{2} \cdot 120}{250} \cdot 1,47\right) \cdot |\cos 2wt|$

$= \underline{1,8 \cdot 10^{-3} |\cos 2wt|}$







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4.2 At full load:

$P = 250W \quad \hat{V}_s = \sqrt{2} \cdot 120 \quad \hat{I}_s = 1{,}47$

So $i_c = 1{,}8 \cdot 10^{-3} \, |\cos 2\omega t|$

$i_c = C \cdot \frac{dV_c}{dt}$ and since $V_o = V_c$

$i_c = C \cdot \frac{dV_o}{dt} \longrightarrow \frac{dV_o}{dt} = \frac{i_c}{C}$

$$\Delta V_o = \frac{dV_o}{dt} = \frac{1{,}8 \cdot 10^{-3} \cdot |\cos 2\omega t|}{220 \cdot 10^{-6}} = \underline{\underline{8{,}18 \cdot |\cos 2\omega t|}}$$

Boost: $V_o = \frac{1}{1-D} \cdot V_{in} \longrightarrow V_{in} = V_o(1-D)$

$\frac{V_o}{V_{in}} = \frac{1}{1-D}$

$\frac{250}{\sqrt{2} \cdot 120} = \frac{1}{1-D}$

$\hookrightarrow D = 0{,}32$

$\Delta V_{in} = 8{,}18 \, |\cos 2\omega t| \, (1 - 0{,}32)$

$= \underline{\underline{5{,}6 \cdot |\cos 2\omega t|}}$