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Emnekode : ENE505

Kandidatnr. : 212

Dato : 13/12/16

Ark nr. : 01 av 13

P1

(i)

$V_d = 12V$ $\quad D = 0.6 \quad P_o = 36W \quad L = 25\mu H$

$$\frac{V_o}{V_d} = \frac{D}{1-D}$$

$$V_o = \frac{D}{1-D} V_d = \frac{0.6}{1-0.6} \times 12 = 18V$$

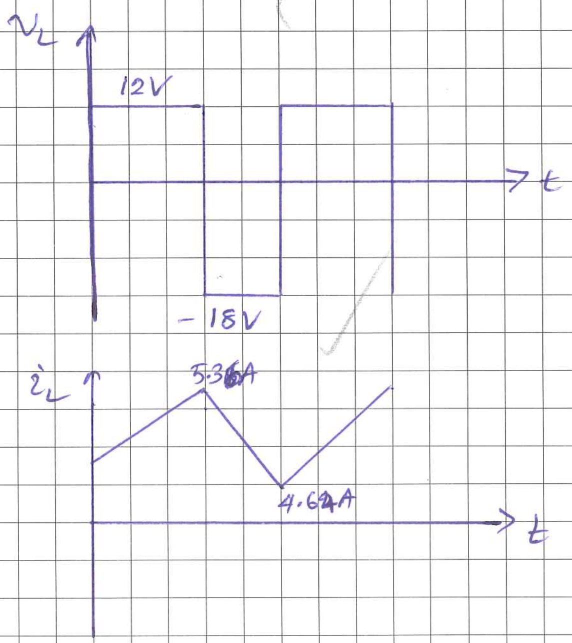
$$I_o = \frac{P_o}{V_o} = \frac{36}{18} = 2A$$

$$I_{in} = \frac{P_o}{V_{in}} = \frac{36}{12} = 3A$$

$$I_L = I_{in} + I_o = 2+3 = 5A$$

$$\Delta i_L = \frac{V_{in} D T_s}{L} = \frac{12 \times 0.6}{25 \times 10^{-6} \times 400 \times 10^3}$$

$$\Delta i_L = 0.72 A$$



$$i_{L max} = I_L + \frac{\Delta i_L}{2}$$

$$= 5 + \frac{0.72}{2}$$

$$i_{L max} = 5.36A$$

$$i_{L min} = I_L - \frac{\Delta i_L}{2}$$

$$= 5 - 0.36$$

$$i_{L min} = 4.64 A$$

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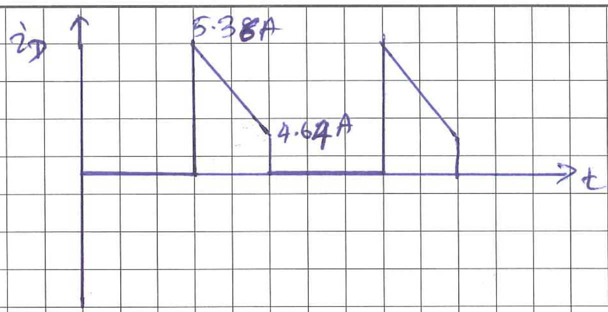
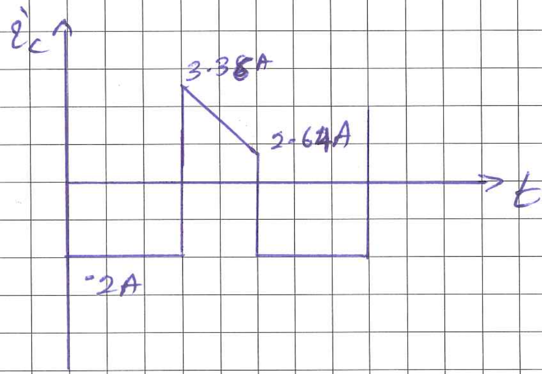
$i_D = 0 \rightarrow t_{on}$

$i_D = i_L \rightarrow t_{off}$



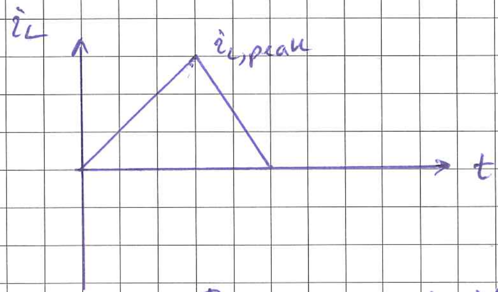
$i_C = -I_o \rightarrow t_{on}$

$i_C = i_D - I_o$



(ii) At Critical Conduction Mode

$$i_{L,peak} = \frac{V_{in} D T_s}{L} = I_{L,critical}$$



$$I_{L,criti} = \frac{1}{2} \frac{V_{in} D T_s}{L}$$

$$I_{L,crit} = \frac{12 \times 0.6}{2 \times 25 \times 10^{-6} \times 400 \times 10^{3}}$$

$$I_{L,crit} = 0.36 A$$

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$$I_L = I_{din} + I_o$$

$$= \frac{D I_o}{1-D} + I_o$$

$$I_L = \frac{I_o}{1-D}$$

$$\therefore \quad I_o = I_L (1-D)$$

$$I_{o_{crit}} = 0.36(1-0.6)$$

$$I_{o_{crit.}} = 0.144\,A$$

$$P_o = V_o I_o =$$

$$P_{o,crit} = V_o I_{o_{crit}} = 18 \times 0.144$$

$$P_{o_{crit}} = 2.592\,W$$

Critical value of P_o

(iii)

$$P_o = 5\,W$$

$$I_o = \frac{5}{18} = 0.278\,A = I_{o_{crit.}}$$

$$I_{L,crit} = \frac{V_{in} D T_s}{2L} = \frac{V_o (1-D) T_s}{2L}$$

$$L_{crit} = \frac{V_o}{\left(\frac{I_{o,crit}}{1-D}\right)} \frac{(1-D) T_s}{2}$$

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$$L_{crit} = \frac{V_o}{I_{o,crit}} \frac{(1-D)^2}{2f_s}$$

$$= \frac{18}{0.278} \times \frac{(1-0.6)^2}{2 \times 400 \times 10^3}$$

$$L_{crit} = 12.96\mu H$$

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P2

2.2

For Buck Converter

$$V_o + \tilde{v}_o(t) = d(t)\left[V_{in} + \tilde{v}_{in}(t)\right]$$

$$V_o + \tilde{v}_o(t) = \left[D + \hat{d}(t)\right]\left[V_{in} + \tilde{v}_{in}(t)\right]$$

$$V_o + \tilde{v}_o(t) = DV_{in} + D\tilde{v}_{in}(t) + \hat{d}(t)V_{in} + \hat{d}(t)\cdot\tilde{v}_{in}(t)$$

($\hat{d}(t)\cdot\tilde{v}_{in}(t) \to 0$)

$$\tilde{v}_o(t) = D\tilde{v}_{in}(t) + \hat{d}(t)V_{in}$$

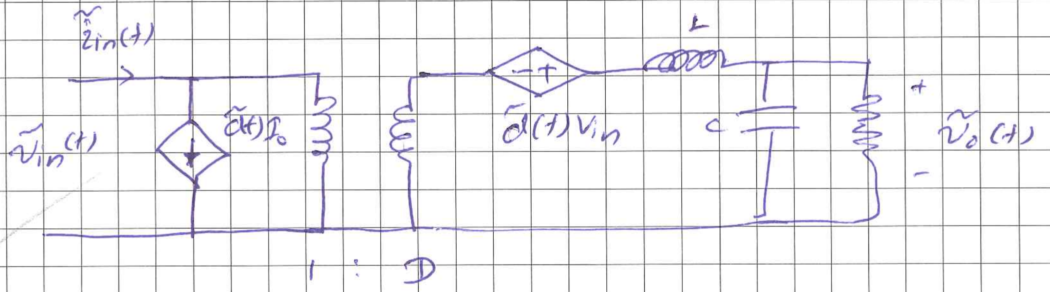
$$I_{in} + \hat{i}_{in}(t) = d(t)\left[I_o + \tilde{I}_o(t)\right]$$

$$I_{in} + \hat{i}_{in}(t) = \left(D + \hat{d}(t)\right)\left[I_o + \tilde{I}_o(t)\right]$$

$$I_{in} + \tilde{i}_{in}(t) = DI_o + D\tilde{I}_o(t) + \hat{d}(t)I_o + \hat{d}(t)\tilde{I}_o(t)$$

($\hat{d}(t)\tilde{I}_o(t) \to 0$)

$$\tilde{i}_{in}(t) = D\tilde{I}_o(t) + \hat{d}(t)I_o$$



small signal pertubation act

Considering steady state operating condition

$$\tilde{v}_{in}(t) = 0$$

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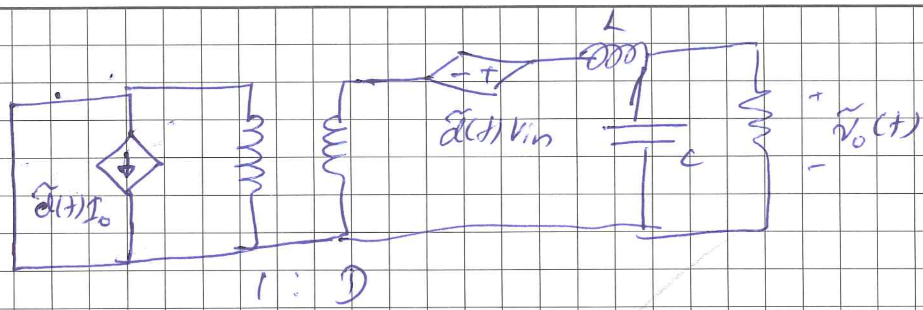
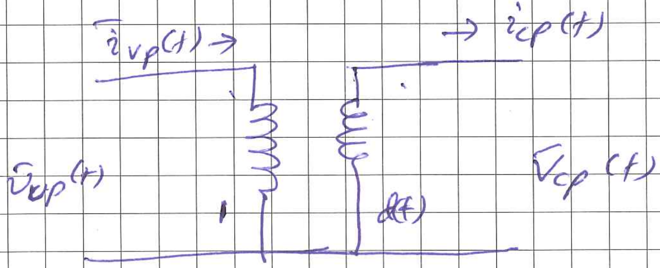


2.1



$$\hat{v}_{cp} = d(t)\, \tilde{v}_{vp}$$

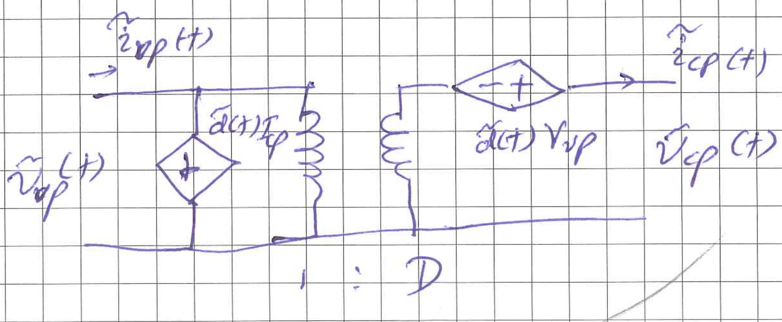
$$V_{cp} + \tilde{v}_{cp}(t) = [D + \hat{d}(t)][V_{vp} + \tilde{v}_{vp}(t)]$$

$$\hat{v}_{cp}(t) = D\tilde{v}_{vp} + \hat{d}(t)\, V_{vp}$$

$$\hat{i}_{vp}(t) = d(t)\, \tilde{i}_{cp}(t)$$

$$I_{vp} + \tilde{i}_{vp}(t) = [D + \tilde{d}(t)][I_{cp} + \hat{i}_{cp}(t)]$$

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



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P3

3.1

$I_s = 10A_{rms}$ $I_{s_1} = 8A_{rms}$ $DPF = 0.85$

(a) $I_s = \sqrt{I_{s_1}^2 + I_{dis}^2}$

$I_{dis} = \sqrt{I_s^2 - I_{s_1}^2}$

$= \sqrt{10^2 - 8^2}$

$I_{dis} = 6A$

(b) $THD\% = \frac{I_{dis}}{I_{s_1}} \times 100\%$

$= \frac{6}{8} \times 100\%$

$= 75\%$

(c) $PF = \frac{I_{s_1}}{I_s} \cdot DPF$

$= \frac{8}{10} \times 0.85$

$PF = 0.68$

The THD is equal to 75%. It is a higher range of distortion. It causes the system to have

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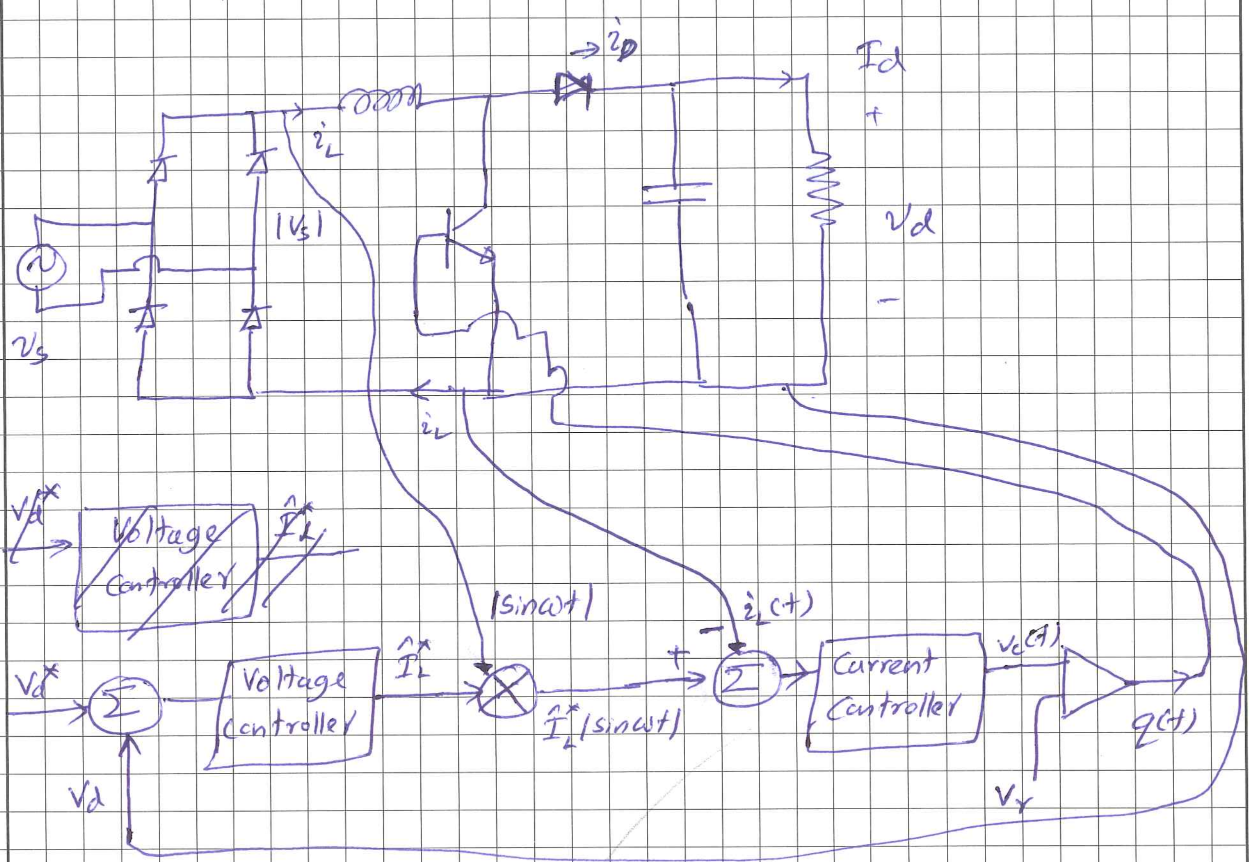
a low power factor. Need a Power Factor Correction system

3.2



The average inner current controller loop ensures the form $i_L^*(t)$ based on the template $|\sin\omega t|$ measured from $|V_s|$ o/p of voltage rectifier bridge. A control voltage $v_c(t)$ is generated and it compared with a ramp signal v_r to generate a switching signal for boost converter switch.

The voltage control loop determines the peak amplitude of $\hat{I}_L^*$ of inductor current based on o/p voltage feedback. If inductor current is insufficient for a given load supplied by PFC, the o/p

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voltage drops below it's preselected referrence value. By measuring O/P voltage & using it as feedback signal, voltage controller adjust the induct current amplitude to maintain O/P voltage at referrence value Vd.

Voltage controller acts to regulate O/P voltage to referrence value Vd in addition to determine the inductor peak amplitude.

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P4

4.1

$V_{in} = v_s = 120 V_{rms}$ $f = 60 Hz$

$V_d = 250 V$ $P_o = 300 W$

lossless ckt

$$\frac{V_d}{|V_s|} = \frac{1}{1-d(t)}$$

$$I_s = \frac{P_o}{V_s}$$

$$I_s = \frac{300}{120} = 2.5 A$$

$$1 - d(t) = \frac{|V_s|}{V_d}$$

~~$i_L = \sqrt{2} \times 25 \sin(120\pi)t$~~

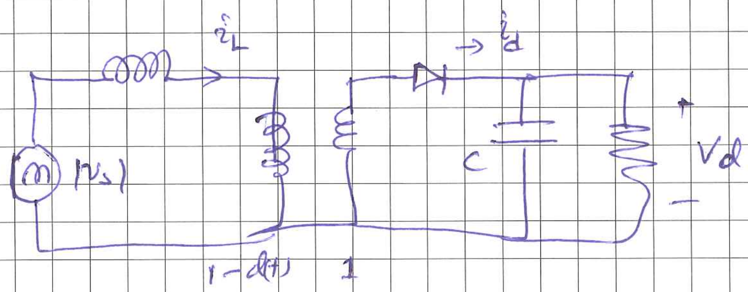
~~$i_L = 25\sqrt{2} |\sin(120\pi)t|$~~

$$i_L = 2.5\sqrt{2} |\sin(120\pi)t|$$

$$d(t) = 1 - \frac{|V_s|}{V_d}$$

$$d(t) = 1 - \frac{\sqrt{2} \times 120 |\sin(2\pi \times 60)t|}{250}$$

$$d(t) = 1 - 0.68 \sin((120\pi)t)$$



$$i_d(t) = [1 - d(t)]\, i_L(t)$$

$$= \frac{|V_s|}{V_d} \cdot |I_s| = \frac{\hat{V}_s \hat{I}_L}{V_d} \sin^2 \omega t$$

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$$i_d(t) = \frac{1}{2}\frac{\hat{V}_{in}\hat{I}_L}{V_d} - \frac{1}{2}\frac{\hat{V}_{in}\hat{I}_L}{V_d}\cos 2\omega t$$

$$= \frac{1}{2} \times \frac{120\sqrt{2} \times 2.5 \times \sqrt{2}}{250} - \frac{1}{2}\frac{120\sqrt{2} \times 2.5 \times \sqrt{2}}{250}\cos(4\pi \times 60)t$$

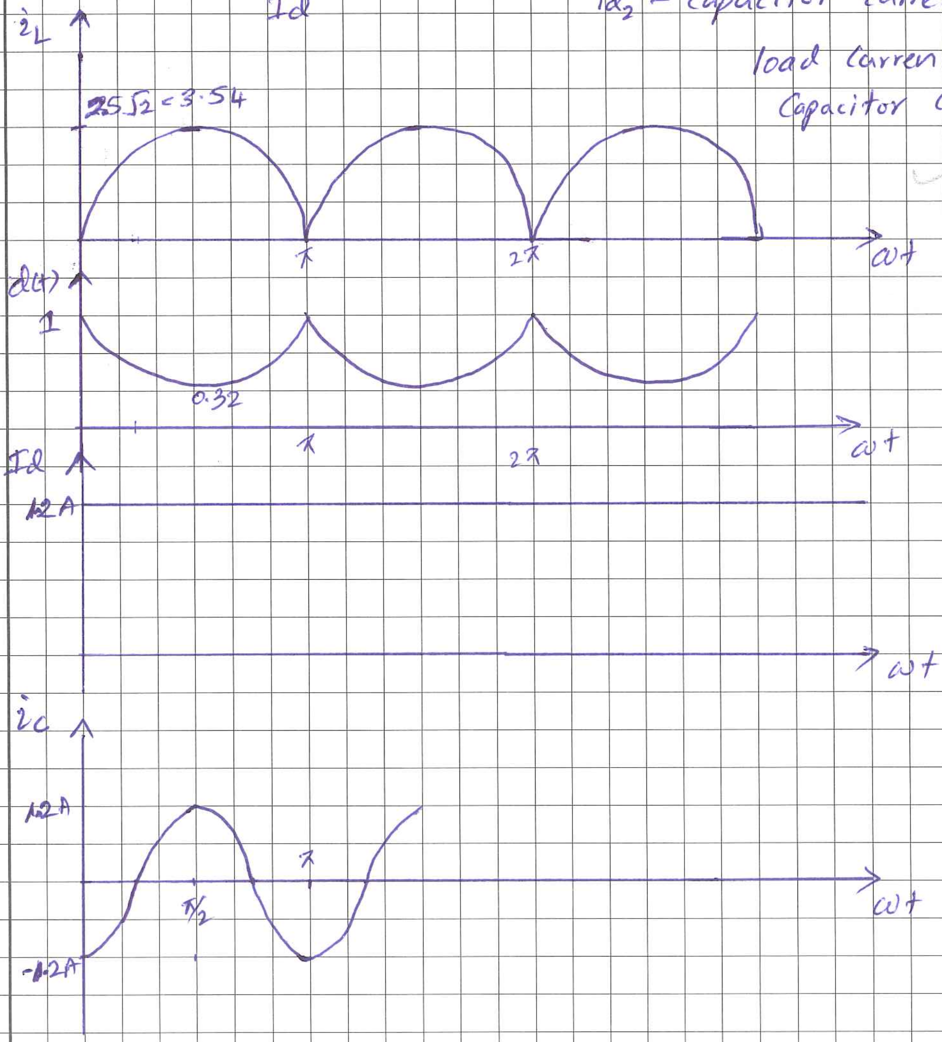
$$i_d(t) = 1.2 - 1.2\cos[(240\pi)t]$$

1.2 → I_d

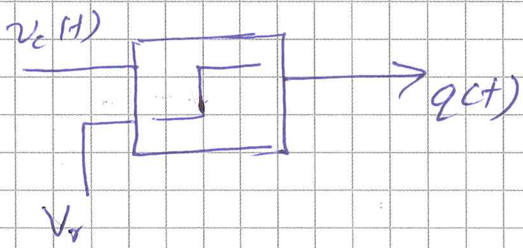
i_{d_2} – capacitor current

load current = 1.2 A

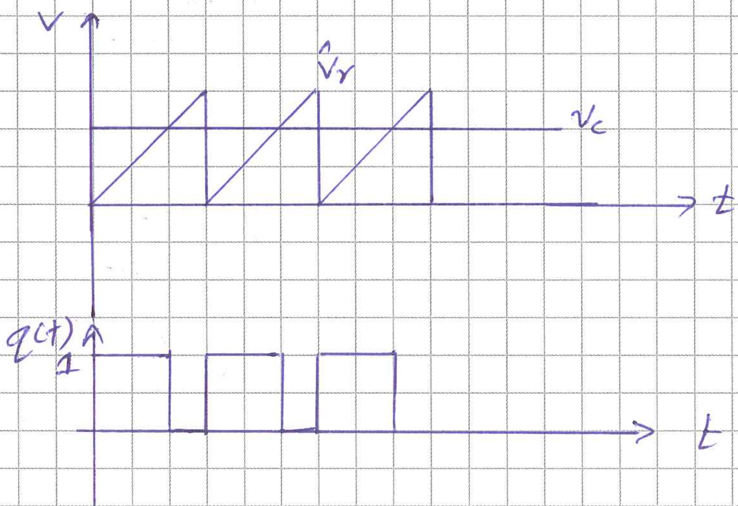
Capacitor current = 1.2 cos2ωt



4.2



$$G_{pwm} = \frac{\hat{d}(s)}{\tilde{v}_c(t)}$$



The control voltage $v_c(t)$ is generated by the error amplifier and compared with a ramp signal

$$v_c(t) = V_c + \tilde{v}_c(t)$$

The o/p switching signal is represented by $q(t)$ which is equal to 1, if $v_c(t) \geq V_r$, otherwise 0. The duty ratio of switch signal is defined as below

$$\frac{v_c(t)}{\hat{V}_r} = \frac{V_c}{\hat{V}_r} + \frac{\tilde{v}_c(t)}{\hat{V}_r}$$

$$\downarrow$$

$$d(t) = D + \tilde{d}(t)$$

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

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

$$\left|G_{pwm}(s)\right| = \frac{\tilde{d}(s)}{\tilde{v}_c(s)} = \frac{1}{\hat{V}_r}$$