Emnekode : ENE 505

Kandidatnr. : 730

Dato : 29.11.17

Ark nr. : 1 av 11

1

$V_d = 14V$

$V_o = 42V$

$P_o = 21W$

$f_s = 200kHz$

$\Delta i_L = 1.8A$

$$T_s = \frac{1}{f_s} = \frac{1}{200kHz} = \underline{5\mu s}$$

$$V_o = V_d\left(\frac{D}{1-D}\right)$$

$$42 = 14 \cdot \left(\frac{D}{1-D}\right)$$

$42 - 42D = 14D$

$\underline{D = 0.75}$

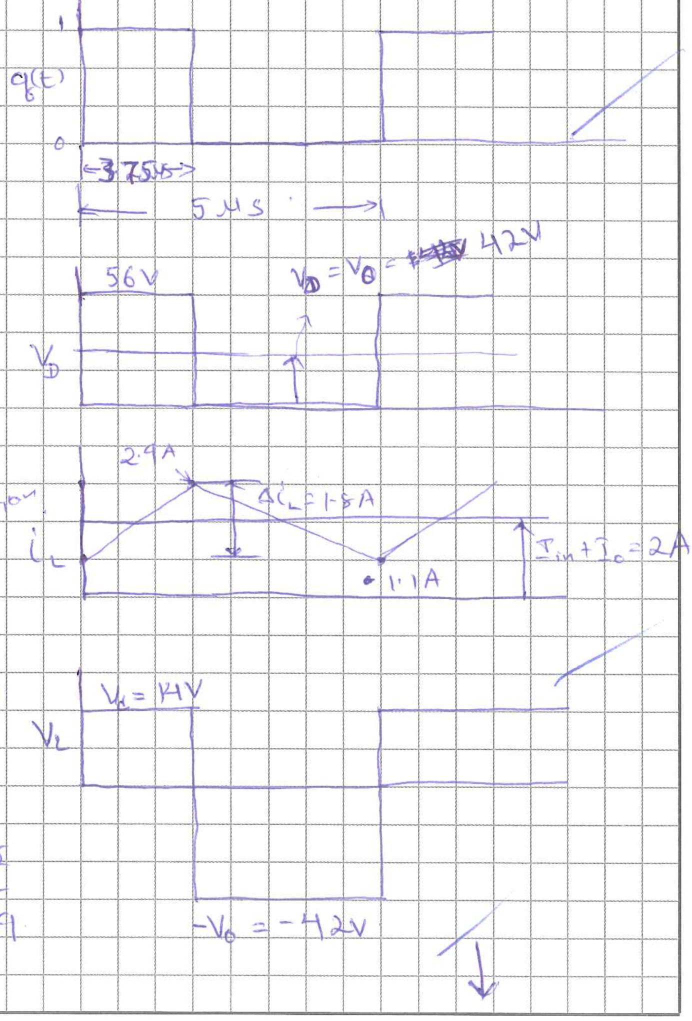
$DT = 3.75\mu s$

i)

$$\Delta i_L = \frac{V_d DT}{L}$$

$$L = \frac{14 \times 3.75\mu}{1.8}$$

$$\underline{\underline{L = 29.17\mu H}}$$



$V_{D_{on}} = V_d + V_o$

$V_{D_{on}} = 56V$

$V_{D_{off}} = 0$

As per question order

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

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

$I_L = I_{in} + I_o$

$$I_L = \frac{P_o}{V_{in}} + \frac{P_o}{V_o} = \underline{\underline{2A}}$$

$$\frac{\Delta i_L}{2} = \frac{1.8}{2} = 0.9$$

Emnekode : ENE 505

Kandidatnr. : 730

Dato : 29.11.17

Ark nr. : 2 av 11

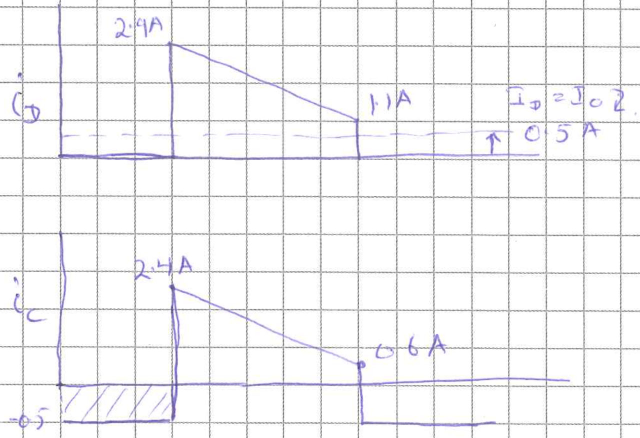
$V_{L_{on}} = V_d = 14V$

$V_{L_{off}} = -V_o = -42V$

$i_{D_{on}} = 0$

$i_{D_{off}} = i_L$

$I_D = I_o = \frac{P_o}{V_o} = \frac{21}{42} = 0.5A$



$I_C \neq I_D = I_o$

(ii) $I_L = \frac{\Delta i_L}{2}$

$I_L = I_o + I_{in}$ | $\Delta i_L = \frac{V_{in} DT}{2L}$

$$\frac{P_{ocrit}}{V_o} + \frac{P_{ocrit}}{V_{in}} = \frac{V_d DT}{2L}$$

$$\frac{P_{ocrit}}{42} + \frac{P_{ocrit}}{14} = \frac{14 \cdot 3.75\mu}{2 \times 29.17\mu}$$

$$9.5 \times 10^{-2} P_{ocrit} = \cancel{0.8997}\ 0.899$$

$\cancel{P_{oc}}$

$$\boxed{P_{ocrit} = 9.43W}$$

UNIVERSITETET I AGDER

Emnekode : ENE 505

Kandidatnr. : 730

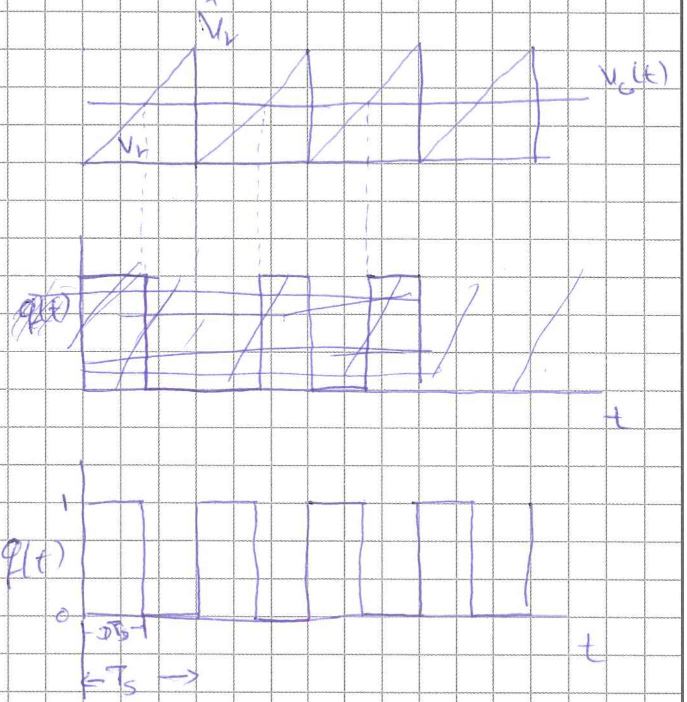
Dato : 29.11.17

Ark nr. : 3 av 11

2

2.1

$T_s = \frac{1}{f_s}$.



When $V_c(t) > V_r \Rightarrow q(t) = 1$

When $V_c(t) < V_r \Rightarrow q(t) = 0$

$$d(t) = \frac{V_c(t)}{\hat{V}_r}$$

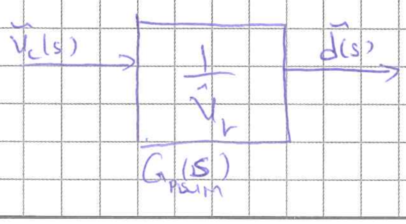
Linearizing around ~~around~~ DC steady state adding small disturbance

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

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

$$d(t) = \underbrace{\frac{V_c}{\hat{V}_r}}_{D} + \underbrace{\frac{\tilde{V}_c(t)}{\hat{V}_r}}_{\tilde{d}(t)}$$

Taking transfer function of the small perturbation:



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

UNIVERSITETET I AGDER

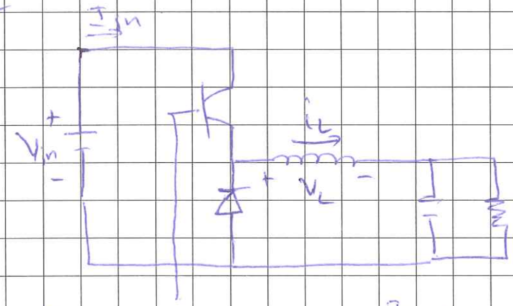
Emnekode : ENE 505

Kandidatnr. : 730

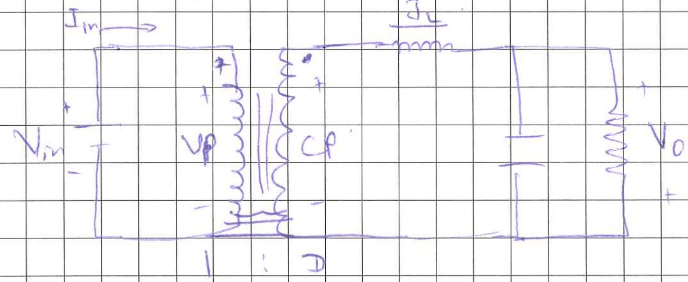
Dato : 29.11.7

Ark nr. : 4 av 11

2.2



Buck converter



Average model representation of Buck Converter steady state

from simplified buck converter output voltage is given as

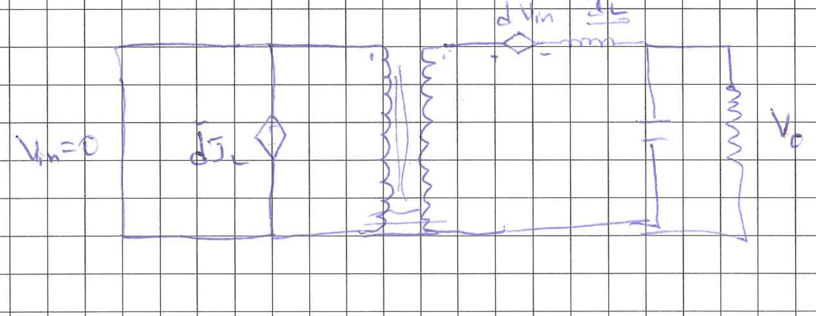
$$V_o = V_{in} D \quad \text{--- (i)}$$

Current is given by

$$I_{in} = I_o D \quad \text{--- (ii)}$$

from page 5

for small perturbation a single pole representation of buck converter.



UNIVERSITETET I AGDER

Emnekode : ENE 505

Kandidatnr. : 730

Dato : 29.11.17

Ark nr. : ~~4~~ 5 av 11

2.2 taking voltage component of average model

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

neglected

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

$$\tilde{v}_{cp}(t) = \tilde{d}(t)V_{vp} + D\tilde{v}_{vp}(t) \quad \text{--} (1)$$

Taking current

neglected

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

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

$D\,\tilde{i}_{cp}(t)$

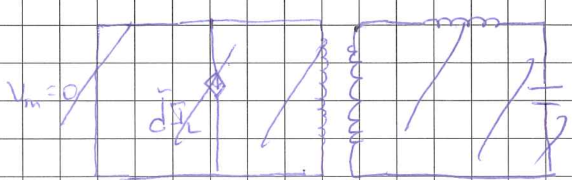
$$I_{vp} = DI_{cp}$$

$$\tilde{i}_{vp}(t) = I_{cp}\tilde{d}(t) + D\,\tilde{i}_{cp}(t) \quad \text{--} (2)$$

Taking fig (3) ~~eq~~ ⇒ eq (1) & (2) are derive for small perturbation signals

by using eq (1) & (2) small signal around a steady state operating point given by D, V_{vp}, I_{cp} can be represented as fig (4)

please see (*) page 4



UNIVERSITETET I AGDER

Emnekode : ENE 505

Kandidatnr. : 730

Dato : 29.11.17

Ark nr. : 6 av 11

3.

3.1

$V_s = 120V$ (rms)

$P = 0.95kW$

$I_{s_1} = 10A$ (rms)

$THD = 75\%$.

a)

$DPF = ?$

$P = V_s I_{s_1} \cos\phi_1$

$\cos\phi_1 = DPF$.

$DPF = \frac{950}{120 \times 10}$

$\underline{DPF = 0.79}$

b)

$I_{distortion} = ?$

$\%THD = \frac{I_{dist}}{I_{s_1}} \times 100$

$I_{distortion} = \frac{75\% \times 10}{100}$

$\underline{I_{dist} = 7.5A \text{ (rms)}}$

c) $PF = ?$

$PF = \frac{1}{\sqrt{1 + \left(\frac{\%THD}{100}\right)^2}} \cdot DPF$

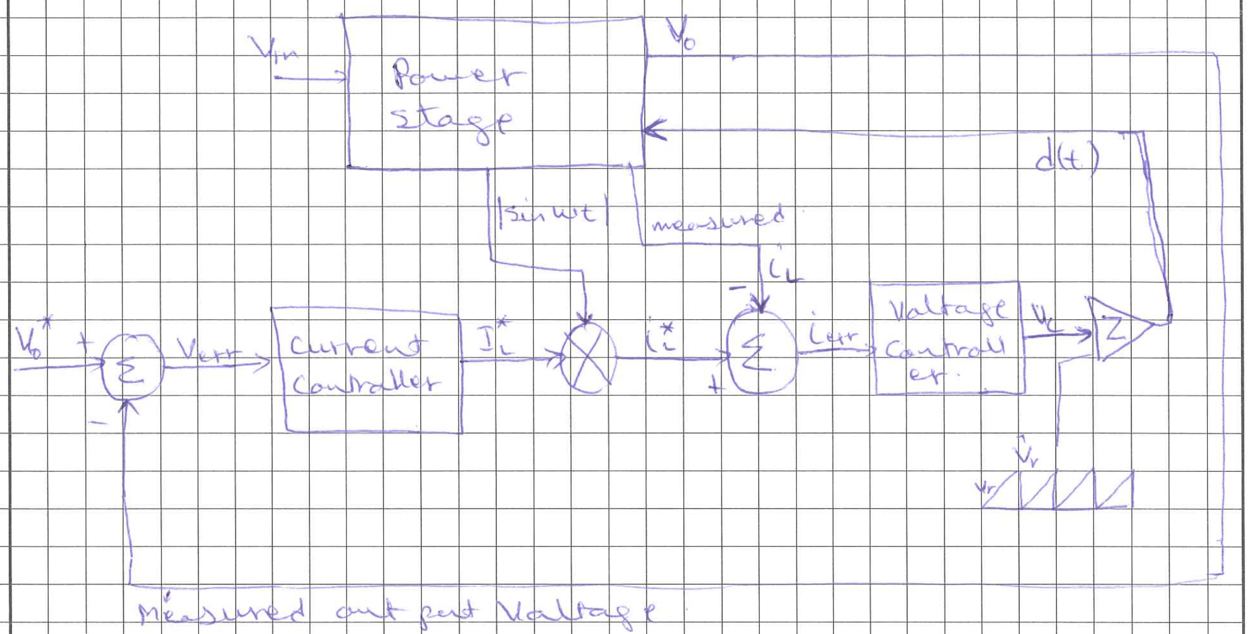
$PF = \frac{1}{\sqrt{1 + \left(\frac{75}{100}\right)^2}} \cdot 0.79$

$\underline{PF = 0.632}$

The power factor is bellow the acceptable limit, the limit is 0.707, so there must be ~~some~~ power factor correction done.

Emnekode	: ENE 505
Kandidatnr.	: 730
Dato	: 29.11.17
Ark nr.	: ~~8~~ 7 av 11

3.2



→ Measured ~~out~~ put Voltage Compared with reference Voltage.

→ The error Voltage feed to current Controler & Current Controller gives out amplitude of inductur current (reference)

→ To the reference ~~~~ amplitud of the current (I_L^*). Sinusidal wave is meltiplid from the circuit Sin wave

→ The reference ~~~~ Sin wave (i_L^*) Compared with mesured actual inducter current & the error feeds to Voltage Controller, the Voltage Controller gives out Control Voltage (V_c)

→ Using PWM, ~~~~ V_c with V_r formes a switching paterns of q(t)

* Current controller is fast responding relative to Voltage controller.

UNIVERSITETET I AGDER

Emnekode : ENE 505

Kandidatnr. : 730

Dato : 29.11.17

Ark nr. : 8 av 11

4 4.1

$f = 60Hz$ $T = \frac{1}{60} = 16 ms$

$V_{in} = 120V(rms)$

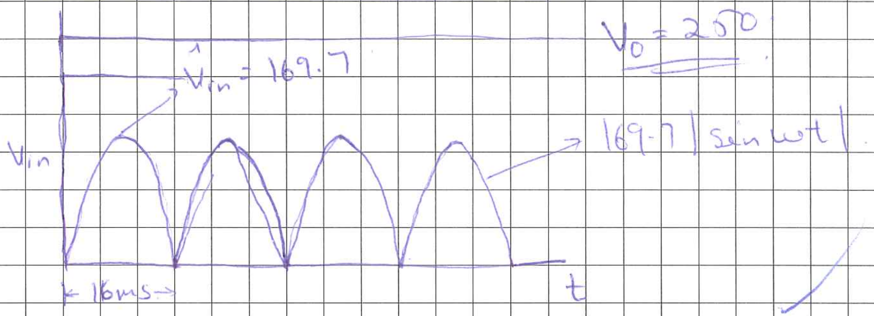
$V_o = 250V$

$P_o = 250W$

$V_{in}(t) = \hat{V}_{in}|\sin\omega t|$

$\hat{V}_{in} = V_{in}(rms) \cdot \sqrt{2}$ $\hat{V}_{in} = 169.7$

$V_{in}(t) = 169.7|\sin(\omega t)|$



(2)

$i_L(t) = i_{in}(t) = \hat{I}_{in}|\sin\omega t|$

$\hat{I}_{in} = \sqrt{2} \cdot I_{in}(rms)$

$I_{in} = \frac{P_o}{V_{in}} = \frac{250}{120} = 2.08A(rms)$

$\hat{I}_{in} = \sqrt{2} \cdot 2.08A(rms)$

$\hat{I}_{in} = 2.95A$

$i_L(t) = 2.95|\sin\omega t|$

Emnekode : EME 505

Kandidatnr. : 730

Dato : 29.11.17

Ark nr. : 9 av 11

(*) $d(t)$?

$$V_o = \hat{V}_{in}|\sin \omega t| \cdot \frac{1}{1-d(t)}$$

$$1-d(t) = \frac{\hat{V}_{in}|\sin \omega t|}{V_o}$$

$$d(t) = 1 - \frac{\hat{V}_{in}}{V_o}|\sin \omega t|$$

$$d(t) = 1 - \frac{169.7}{250}|\sin \omega t|$$

$$d(t) = 1 - 0.6788|\sin \omega t|$$

(*) $P_{in} = P_o$

$$\hat{I}_{in}|\sin \omega t| \cdot \hat{V}_{in}|\sin \omega t| = V_o \, i_d$$

current through diode $= i_d = \frac{\hat{V}_{in}\hat{I}_{in}}{V_o}|\sin \omega t|^2$

$$\boxed{2\sin^2\theta = 1-\cos 2\theta}$$

$$i_d = \underbrace{\frac{\hat{V}_{in}\hat{I}_{in}}{2V_o}}_{I_o} - \underbrace{\frac{\hat{V}_{in}\hat{I}_{in}}{2V_o}\cos(2\omega t)}_{i_{d2}}$$

→ Let us assume the second harmonic current fully passes through capacitor

current through the load is I_o

$$I_o = \frac{\hat{V}_{in}\hat{I}_{in}}{2V_o}$$

UNIVERSITETET I AGDER

Emnekode : ENE 505

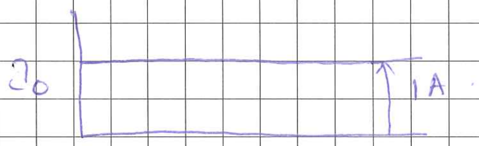
Kandidatnr. : 730

Dato : 29.11.17

Ark nr. : ~~9~~ 10 av 11

$$I_o = \frac{169.7 \times 2.95}{2 \times 250}$$

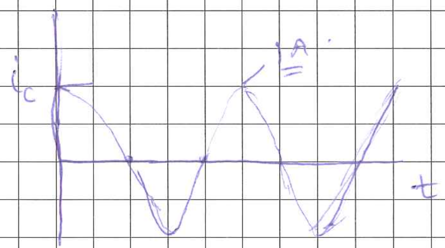
$$\underline{I_o = 1A}$$



$i_c = ?$

$$i_c \simeq \frac{V_{in} I_{in}}{2V_o} \cdot (\cos 2\omega t)$$

$$\underline{i_c = 1 \cos 2\omega t}$$



UNIVERSITETET I AGDER

Emnekode : ENE 505

Kandidatnr. : 730

Dato : 29.11.17

Ark nr. : ~~10~~ 11 av 11

4.2

$$\Delta V = \frac{1}{2\omega C} \cdot \hat{I}_d$$

$$\Delta V = \frac{1}{2\omega C} \cdot \frac{1}{2} \cdot \frac{\hat{V}_{in}}{V_0} \cdot \hat{I}_L \cancel{\cos 2\omega t}$$

$$\Delta V = \frac{1}{2\pi f C} \cdot \frac{1}{2} \cdot \frac{\hat{V}_{in}}{V_0} \cdot \hat{I}_L \qquad \hat{I}_L = \hat{I}_{in}.$$

$\omega = 2\pi f$.

$$\Delta V = \frac{1}{4\pi \cdot 60 \times 220 \mu F} \cdot \frac{169.7}{250} \cdot 2.95$$

$$\Delta V = 12 V$$