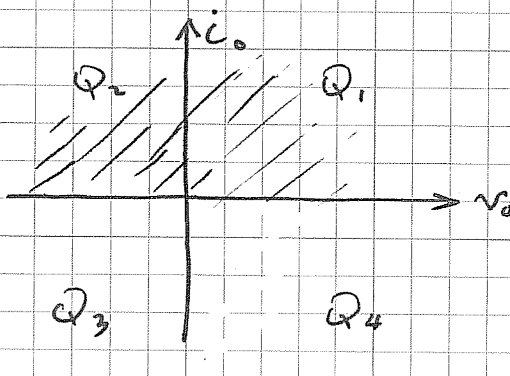
Problem 1:

a) When T_1 is triggered T_2 is reverse biased and I_o circulates in source and T_1. The output voltag v_o is nearly equal to the supply voltage. When T_2 is triggered in the negative half-cycle T_1 becomes reverse biased and turns off the curre I_o circulates in T_2 and v_o is $\simeq 0$. When $\alpha < 9$ $V_o > 0$ and the converter operates as a controlled rectifier and when $\alpha > 90°$ the converter operates in inverter mode with $V_o < 0$. The operating quadrants are Q_1 and Q_2 as shown below.



b) See plots on Question sheet. (attached

c) $$I_1 = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi+\alpha} I_o^2\, d\omega t} = \frac{I_o}{\sqrt{2}}$$

$$V_o = \frac{1}{2\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin\omega t\, d\omega$$

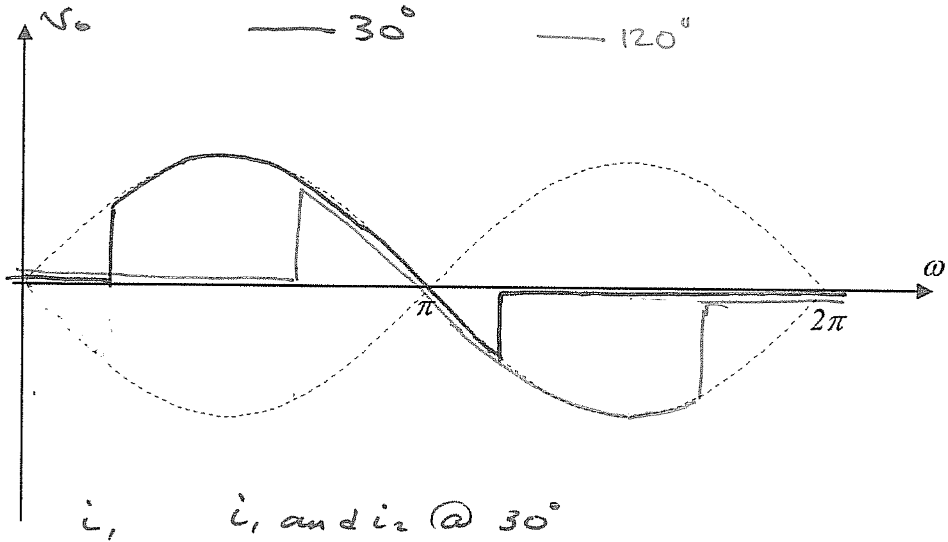
$$= \frac{V_m}{\pi}\cos\alpha$$

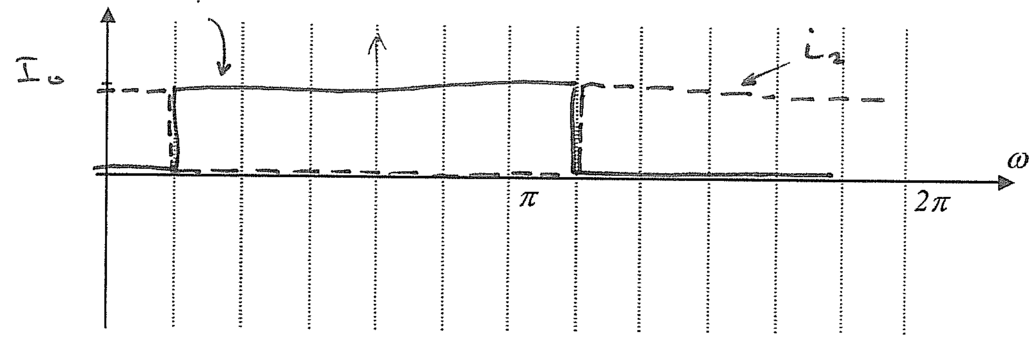
d) $$PF = \frac{V_s I_{s1} \cos\phi_1}{V_s I_s}$$

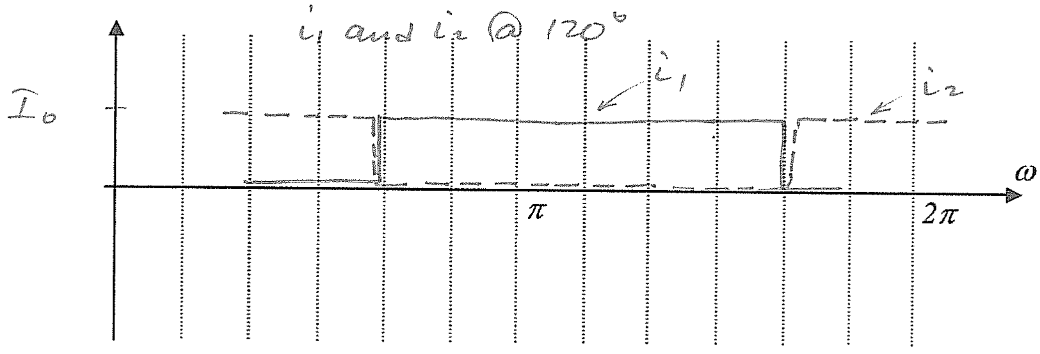
$I_s = \frac{I_o}{\sqrt{2}}$ and $I_{s1} = \frac{4 I_o}{2\sqrt{2}\pi}$ from Fourier Series Analy

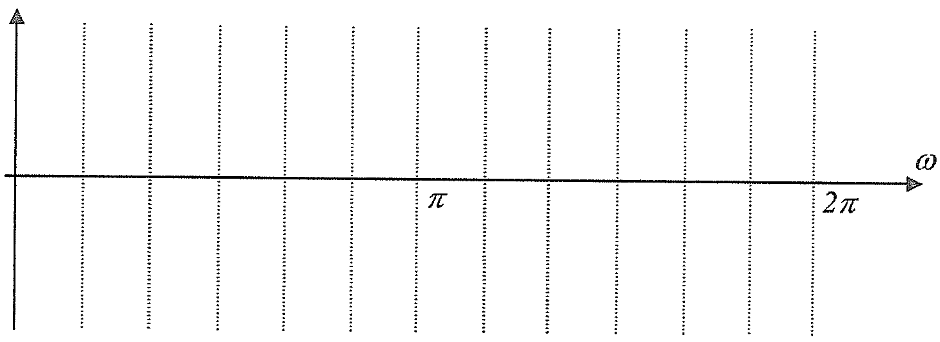
$\phi = \alpha$ ∴ $PF = \frac{2}{}\cos\alpha$

PLOT SHEET 1


v_o
30°
120°
ωt
π
2π

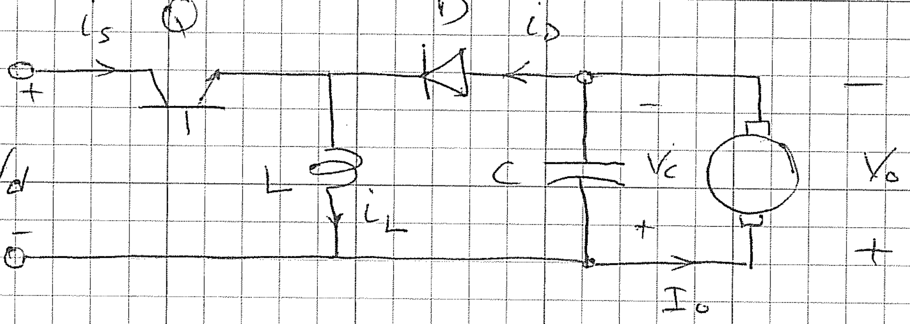

i_1
i_1 and i_2 @ 30°
i_2
I_o
ωt
π
2π


i_1 and i_2 @ 120°
i_1
i_2
I_o
ωt
π
2π

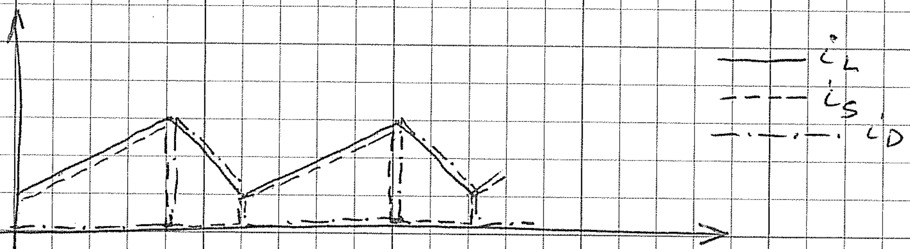

ωt
π
2π

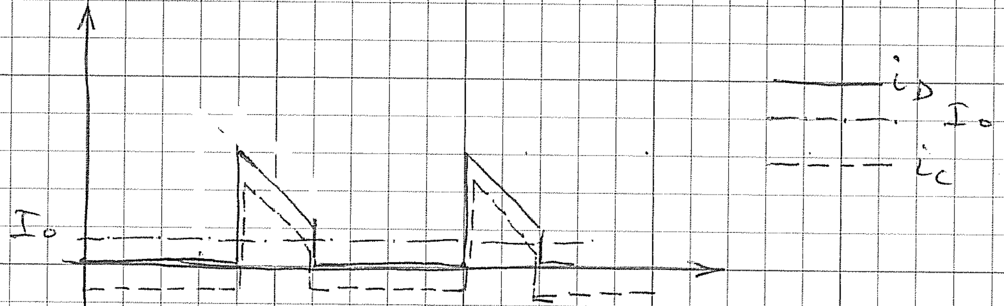
Problem 2.

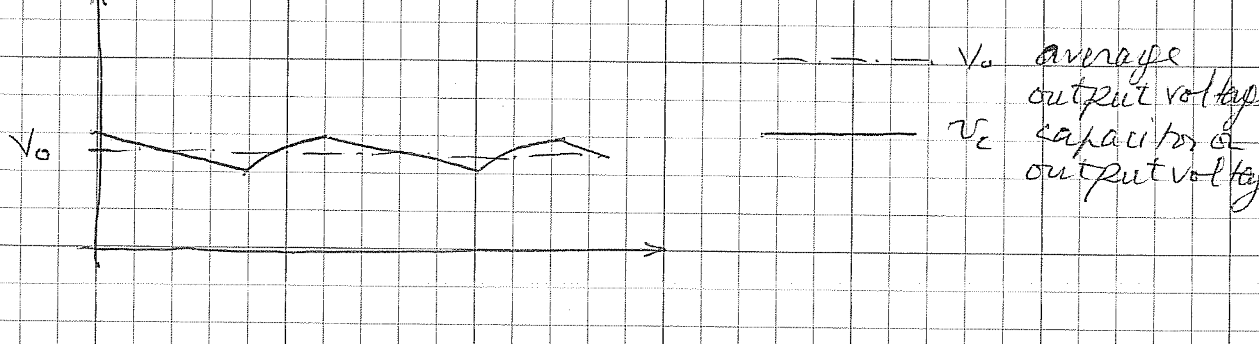
a)



To modes of operation: Mode M_1 the transistor Q is on, L is charged at a rate V_d/L and the energy in C is discharge to the load. In mode M_2, Q is off and energy in L charges capacitor and load.







b) Buck boost regulator is nec
because output voltage can b
higher or lower than supply V_d

$V_o = \frac{D\,V_d}{1-D} \Rightarrow V_o = 24^V \Rightarrow D = 0.33$

and at $V_o = 72V \Rightarrow D = 0.6$.

c) $I_{LB} = I_S + I_o$

but $I_S = I_o \frac{D}{1-D}$

at $D_1 = 0.33 \Rightarrow I_S = 7.39\,A$

$D_2 = 0.6 \Rightarrow I_S = 22.5\,A$.

$\therefore$ I_{LB_1} calculated at $D_1 = 0.33$ is $22.4\,A$

I_{LB_2} calculated at $D_2 = 0.6$ is $37.5\,A$.

$$L > \frac{V_d D_1}{2 f_s I_{LB_1}} = 14.1\,\mu H$$

$$L > \frac{V_d D_2}{2 f_s I_{LB_2}} = 15.4\,\mu H$$

Select $L = 20\,\mu H$.

$$C = \frac{I_o D}{f_s \Delta V_o} = \frac{15 \times 0.6}{25 \times 10^3 \times 0.1} = 3600\,\mu F.$$

d) Peak transistor current is $I_2 = I_L + \frac{\Delta I}{2}$

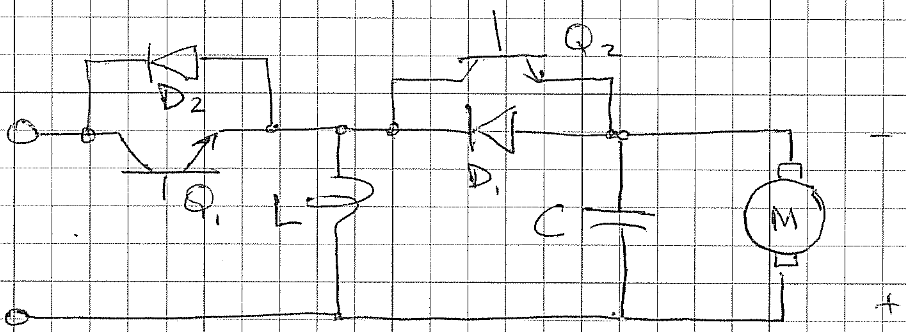
$$I_L = I_o + I_s = \frac{I_o}{1-D} \Rightarrow I_2 = \frac{I_o}{1-D} + \frac{V_d D}{2 f_s L} \Rightarrow$$

$$D = 0.33 \Rightarrow I_2 = \frac{15}{0.67} + \frac{48 \times 0.33}{2 \times 25 \times 10^3 \times 20 \times 10^{-6}} = 38.23\,A$$

$$D = 0.6 \Rightarrow I_2 = \frac{15}{0.4} + 48 \times 0.6 \quad = \underline{66.3\,A}$$

The peak transistor current is mainly determined by the load current and the maximum duty cycle allowed. The higher the duty cycle, the higher the peak transistor current. The effect of frequency on the peak transistor current is secondary in comparison, but a higher frequency will allow a smaller inductance L, which makes it easier to construct.

e) A diode and transistor are added as shown:



To drive the motor Q_2 is turned off and Q_1 is switched (on-off) with a variable duty cycle. To br. the motor, Q_1 is turned off and Q_2 is switched on-off.

Date : June 6, 2005	Name : Final Exam 2005	Course : EECE 473

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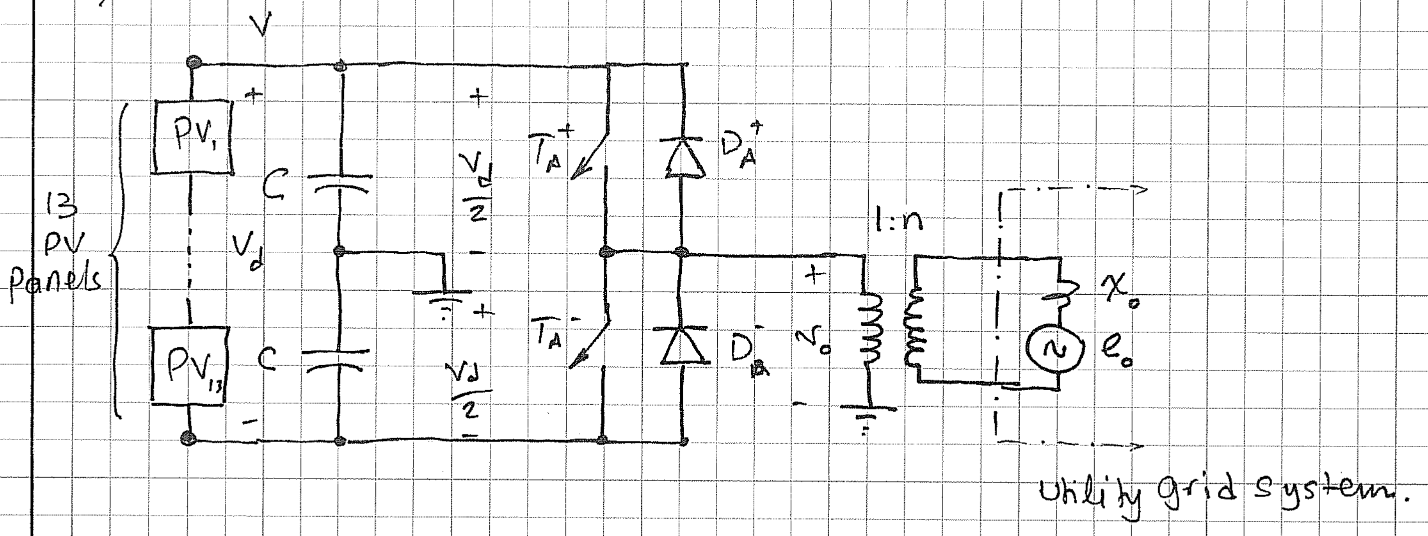
Signature: ____________________

Problem 3:

a)



The connection diagram is as shown above. The switches T_A^+ and T_A^- are turned on and off in a complementary way using a trigger signal derived from the comparison of a control signal (v_c) and a triangular signal (v_t) as shown on the plot sheet (2). When $v_c > v_t$ T_A^+ is on (T_A^- is off) and vice versa when $v_c < v_t$ T_A^+ is off and T_A^- is on. When T_A^+ is on v_o is $\frac{V_d}{2}$ and when T_A^- is on $v_o = -\frac{V_d}{2}$.

b) Let us try the middle end transformer, i.e. 1:3 (= 1:n)
The output voltage inverter (fundamental component) is given by:

$$\hat{V}_{o1} = \frac{\sqrt{2}E_o}{n}$$

For the half-bridge inverter:

$$\hat{V}_{o1} = m_a \frac{V_d}{2}$$

where $V_d = \{ 13 \times 18 = 234V ;\ 13 \times 9V = 117V \}$

As V_d avaries m_a will be varied to match the fundamental of the inverter output with that of the utility:

$$m_a = \frac{2\hat{V}_{o1}}{V_d}$$

For $V_d = 117V$ $m_a = 1.77$

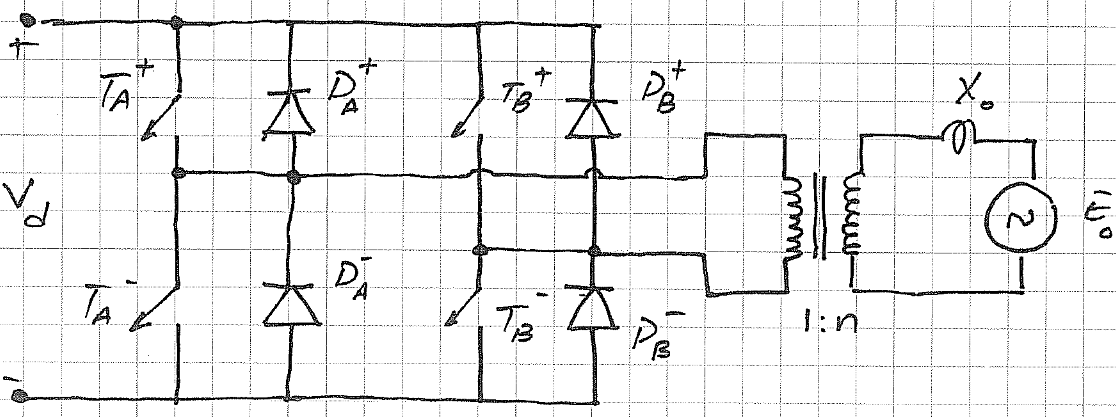
$V_d = 234V$ $m_a = 0.886$.

Since $m_a > \frac{4}{\pi} = 1.273$ we need to go to a higher n.

At $n = 4$ $\hat{V}_{o1} = 77.77V$ $m_a = \{ 1.329 ; 0.665 \}$

$m_a > 1.273$

Discussion: If m_a is limited to 1.0, for the purpose of cont the harmonics, then the minimum voltage that can be accomodated is $V_d = 2\hat{V}_{o1}/m_a = 155.5V$ or $11.96V$(155. per panel. If the full range is strictly needed then a full bridge inverter can be used as follows:



In this case with $n=3$ as transformer ratio:

$$\hat{V}_{01} = m_a V_d \Rightarrow m_a = \frac{\hat{V}_{01}}{V_d}$$

but $\hat{V}_{01} = \frac{\sqrt{2}\,220}{3} = \frac{311.1}{3} = 103.7V$

In this case as V_d changes from 117 to 234V, the range of m_a is $\{0.886 ; 0.443\}$. The system in this case would be able to sustain a lower voltge per panel for a $m_a = 1$: $V_d = 103.7 = 13 \times 7.8V$. So the inverter would be able to supply power dow to a lower panel voltage of 7.8V.

c) The five most dominant harmonics are at: (for $\frac{1}{2}$ bridge).

$$f_1 m_f,\ f_1(m_f+2),\ f_1(m_f-2),\ f_1(2m_f+1),\ f_1(2m_f-1)$$

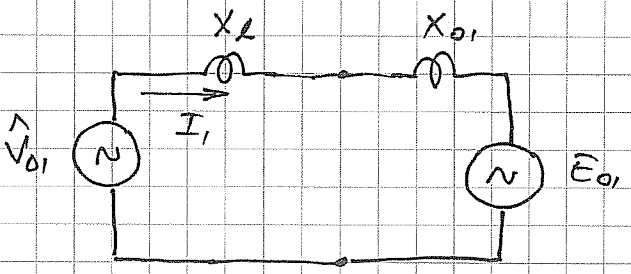
$f_{21} = 1050$, $f_{23} = 1150$, $f_{19} = 950$ $f_{43} = 2150$ $f_{41} = 2050$ rad/

The corresponding harmonic voltages at $m_a = 1$ are:

$$V_{0h} = \frac{1}{\sqrt{2}} \frac{V_d}{2} \left(\frac{\hat{V}_{0h}}{V_d/2}\right) = \frac{1}{\sqrt{2}} \frac{155.5}{2} \left(\frac{\hat{V}_{0h}}{V_d/2}\right) = 55\left(\frac{V_{0h}}{V_d/2}\right)$$

d) Equivalent circuits

* At fundamental frequency:



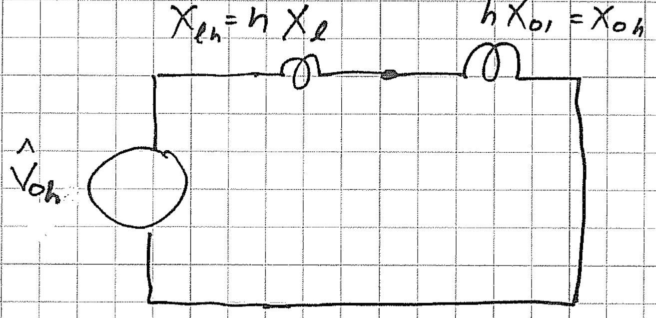
X_{01} and E_{01} are the reflected values of X_0 and E_0.

$$X_{01} = \frac{1}{n^2} X_0 = \frac{1}{4^2} \times 1.4\times10^{-3} \times 314 = 0.0275\ \Omega$$

$$\bar{E}_{01} = \frac{1}{n} \bar{E}_0 = \frac{220}{4} = 55\,V \quad \text{rms.} \Rightarrow \hat{E}_{01} = 55 \times \sqrt{2} = 77.8V.$$

$$\hat{V}_{01} = 77.8V. \qquad X_l = \frac{1\times10\times10^{-3}}{4^2} \times 314 = 0.196\ \Omega$$

* At the harmonic frequencies:



As illustrated in the plots of Plotsheet 2, the maximu current ripple occurs around the zero crossing of the fun mental. Using the i_{ripple} integral, the peak-to-peak curren ripple ΔI_r is given by:

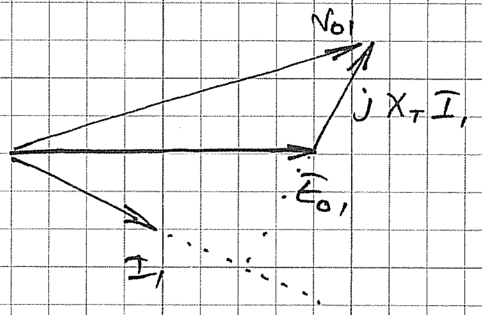
$$\Delta I_r \simeq \frac{1}{L}\int_{t_1}^{t_2} V_d \, dt = \frac{V_d}{L}(t_2 - t_1) = \frac{V_d}{L}\Delta t$$

$\Delta t = t_2 - t_1$ is nearly equal to a half a period of the triangul

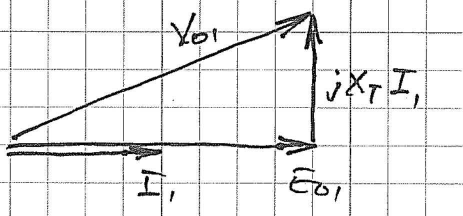
carrier wave: $\Delta t = \frac{T_s}{2} = \frac{1}{2f_s} = \frac{1}{2 \times m_f \times f_1} = \frac{1}{2 \times 21 \times 50} = 4.76 \times 10^{-4}$

$$\therefore \ \Delta I_r = \frac{155.5}{\frac{(10+1.4)}{4^2}} \times 4.76 \times 10^{-4} = 0.104 \text{ A}.$$

e) phasor diagram and Power:



This is the phasor diagram of the fundamental in ge

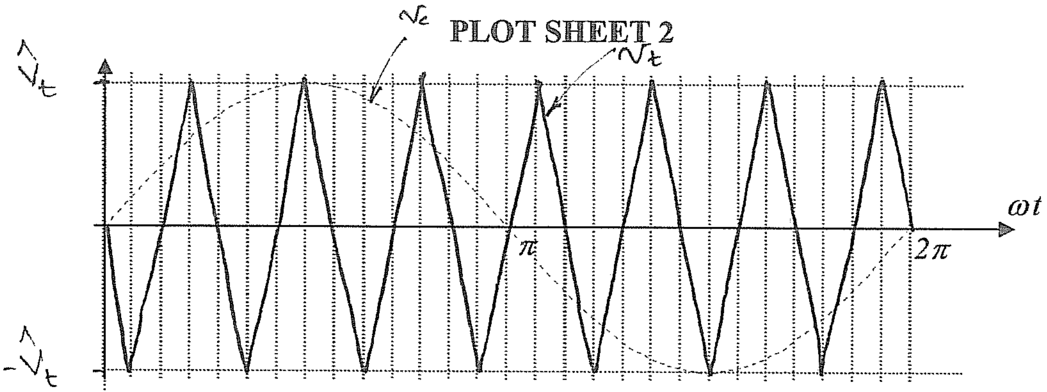


Phasor diagram when current is in phase with utility voltage.

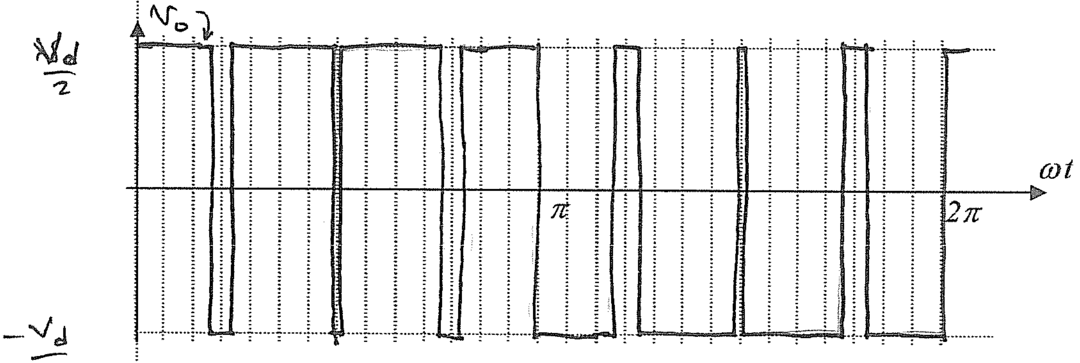
Consider the Cell operating at rated insolation i.e. providing a power of $120W \times 13 = 1560W$. About 15% is lost in the inverter-transformer set-up, so 1326 W is reach the utility. Therefore the rms of the current $I_1 = \frac{1326}{55} = 24$

From the phasor diagram: $E_{o1}^2 + (X_T I_1)^2 = V_{o1}^2 \Rightarrow$

PLOT SHEET 2



(a)



(b)