Power Electronics Notebook

Dr. Mohamd Zaki Khader

By . Saeed Mustafa

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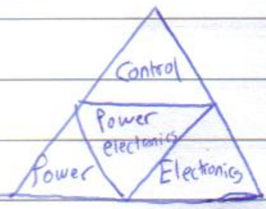
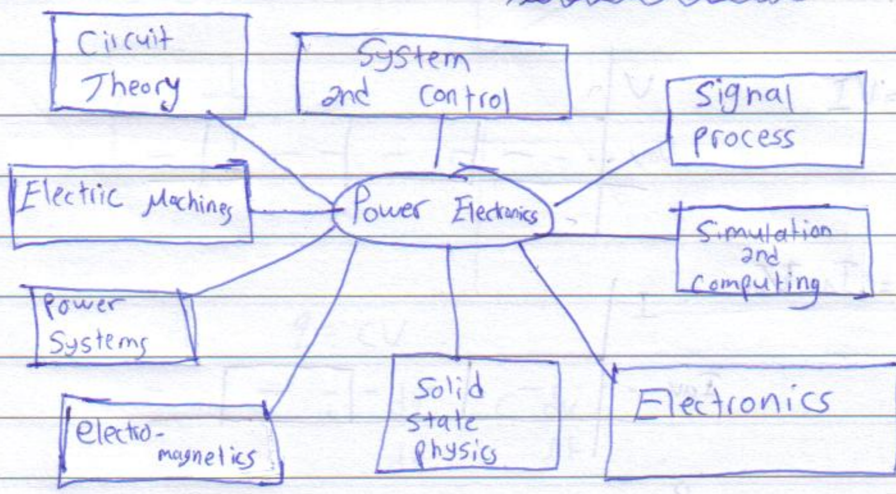
1st & 2nd week

14/9/2014

Power Electronics :-

Lecture 1





Converters

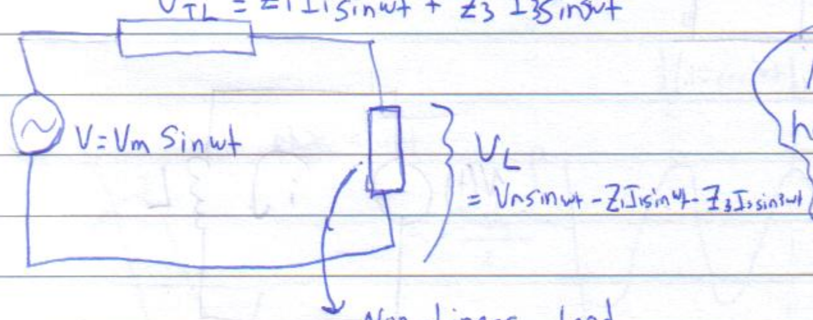
AC $\longrightarrow$ DC : rectifiers

AC $\longrightarrow$ AC : Controllers

DC $\longrightarrow$ AC : Invertors

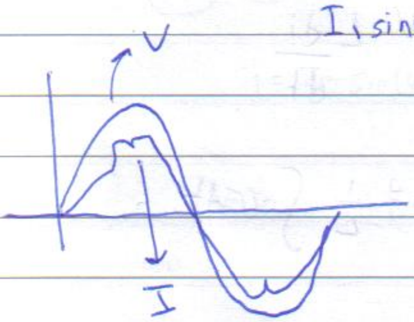
DC $\longrightarrow$ DC : DC Choppers

$V_{TL} = Z_1 I_1 \sin\omega t + Z_3 I_3 \sin 3\omega t$



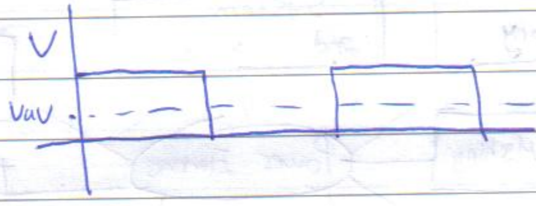
Non-linear loads injects harmonics to the rest of the system.

$I_1 \sin\omega t + I_3 \sin 3\omega t$

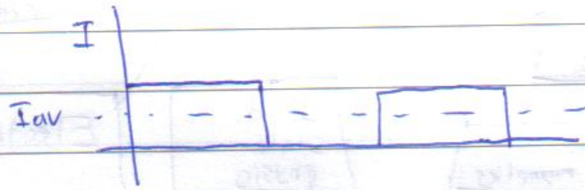


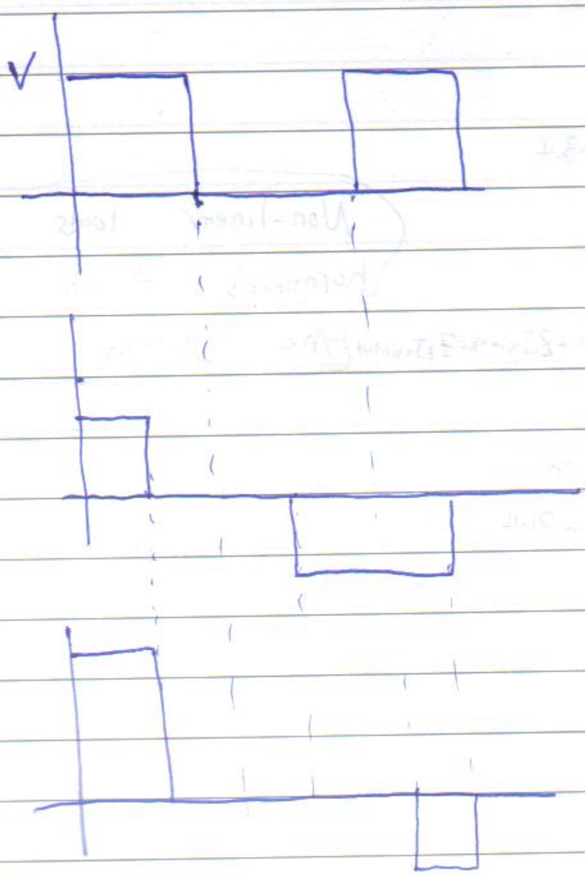
Power

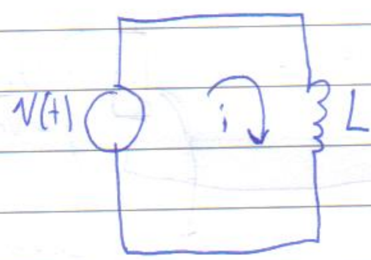
$P = VI$



$P_{av} = I_{av} V_{av}$





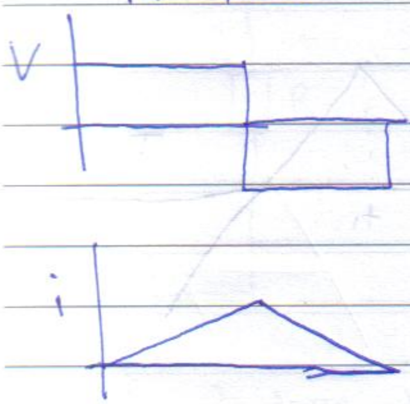


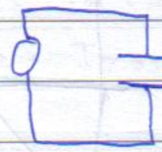
$V = L \frac{di}{dt}$

$i = \frac{1}{L} \int v \, dt$

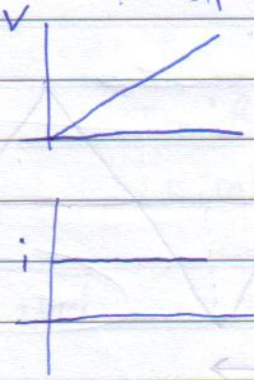
[redacted]

For inductor



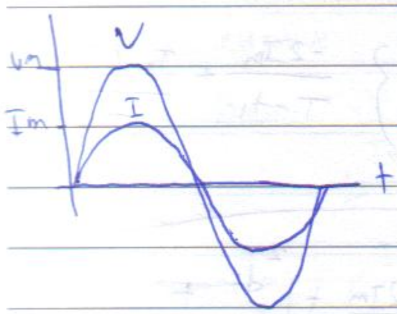


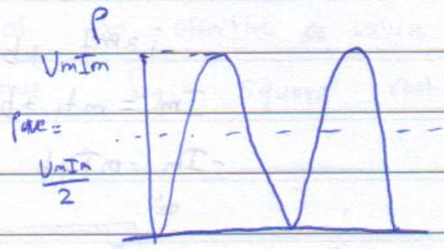
For capacitance



$$q = CV$$

$$i = \frac{dq}{dt} = C\frac{dv}{dt}$$





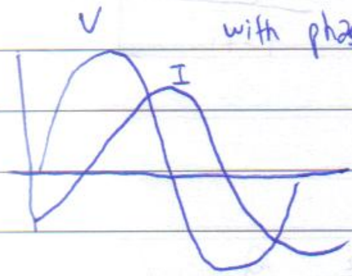
$$V_m \sin\omega t \cdot I_m \sin\omega t = V_m I_m \sin^2\omega t$$

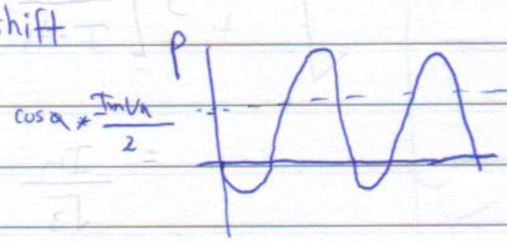
$$P_{ave} = \frac{1}{2\pi}\int_0^{2\pi} V_m I_m \sin^2\omega t \, d\omega t = \frac{1}{2} V_m I_m$$

$$\downarrow$$

$$\frac{1}{2}(1 - \cos^2\omega t)$$

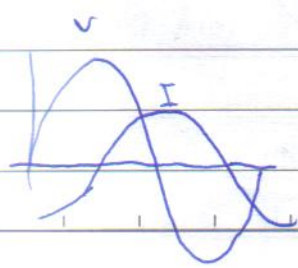
with phase shift

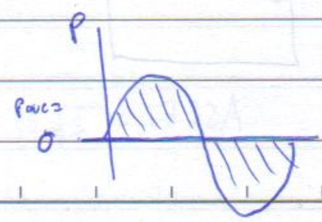


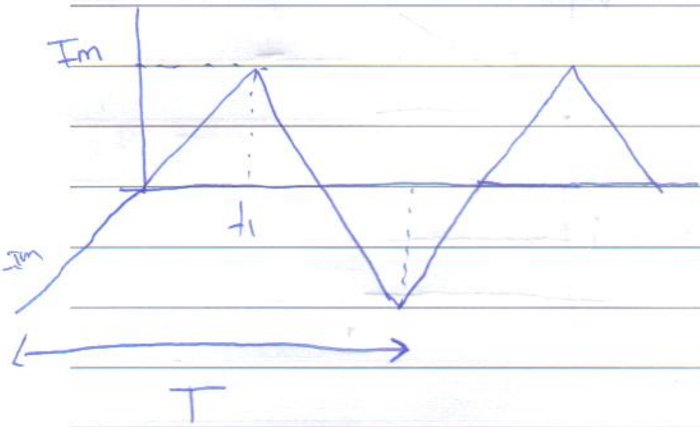


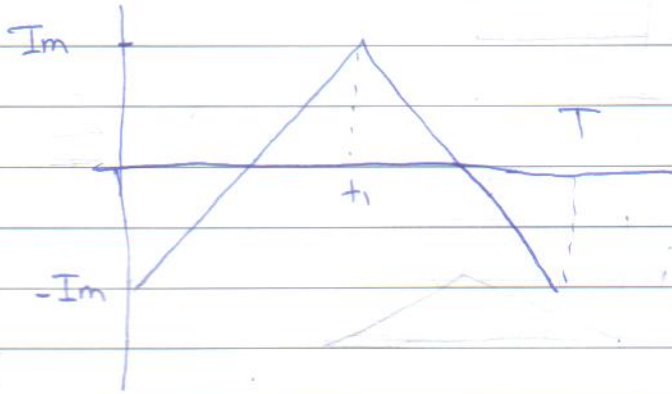
$V = V_m \sin\omega t$ $\quad i = I_m \sin(\omega t - \theta)$

$$P_{ave} = \frac{1}{2\pi}\int_0^{2\pi} V_m I_m \sin\omega t\left(\sin\omega t\cos\theta - \cos\omega t\sin\theta\right) = \frac{I_m V_m}{2}\cos\theta$$









$$m = \frac{I_m}{t_1}$$

$$m = \frac{2I_m}{t_1} \qquad i = -I_m + \frac{2I_m}{t_1}t$$

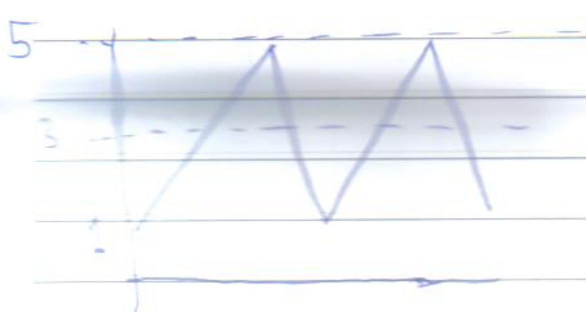
$$i = mt + b$$

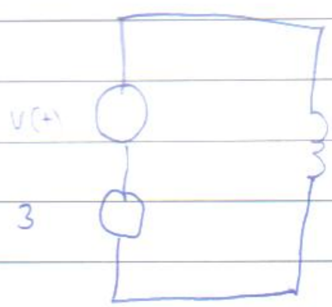
$$\left.\begin{aligned} I_m &= mt_1 + b \\ -I_m &= mT + b \end{aligned}\right\} \quad \frac{-2I_m}{T-t_1}$$

$$I_{rms} = \sqrt{\frac{1}{T}\int_0^T i^2(t)\,dt} = \sqrt{\frac{1}{T}\left\{\int_0^{t}\left(-I_m + \ldots\right) \ldots \int_{t_1} \left[\frac{\ldots}{T-t_1} \ldots \frac{\ldots}{T-t_1}\right]\right\}}$$

$$= \frac{I_m}{\sqrt{3}}$$

$$P = (rms)^2 = \frac{I_m^2}{3} = \frac{4}{3}$$



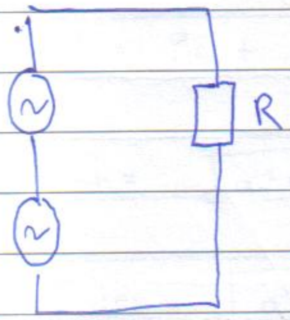


$I_m = 2$

$P_{dc} = 9$

$P_{TOT} = 9 + \frac{4}{3} =$

$V_{rms} = 3.22$

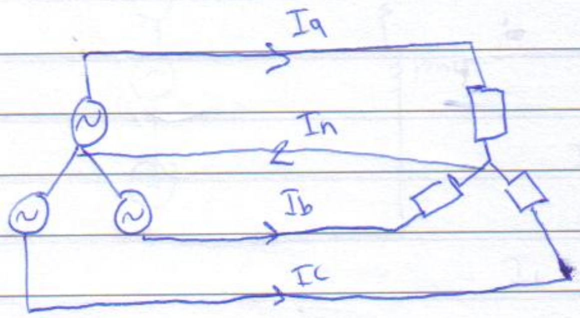


$I_1 = I_m \sin \omega_1 t$ $\qquad I_{rms}^2 R = P_1$

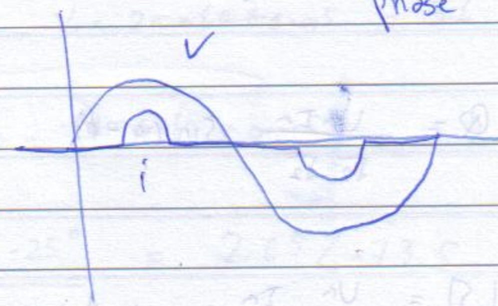
$I_2 = I_m \sin \omega_2 t$ $\qquad I_{2rms}^2 R = P_2$

$$I_{eff} = \sqrt{I_{1rms}^2 + I_{2rms}^2}$$

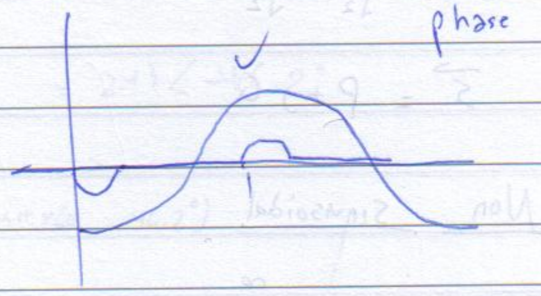
* If 2 sources have no ~~[illegible]~~ phase shift and same frequency then we add the effective values
* If 2 sources have different frequencies then we add the power of the 2 seperate values of the effective values then we return it to the effective value by square root.



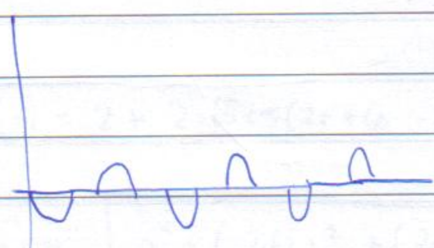
phase a



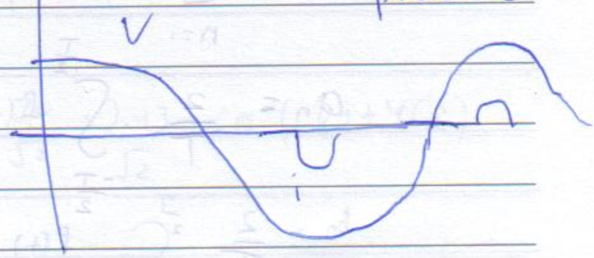
phase b



iN



phase c



$I_a = 10\ A_{rms}$

$I_b = 10\ A_{rms}$

$I_c = 10\ A_{rms}$

$$I_N = \sqrt{10^2 + 10^2 + 10^2} = 10\sqrt{3} = 17.32A$$

$V(t) = 4 + 8\sin(\omega_1 t + 10^\circ) + 5\sin(\omega_2 t + 50^\circ)$

$\omega_1 = 2\omega_2$

$V_{rms} = \sqrt{4^2 + \left(\frac{8}{\sqrt{2}}\right)^2 + \left(\frac{5}{\sqrt{2}}\right)^2} = 7.78$

if $\omega_1 = \omega_2$

$8\angle 10 + 5\angle 50 = 12.3\angle 25.2$

$V_{rms} = \sqrt{4^2 + \left(\frac{12.3}{\sqrt{2}}\right)^2} = 9.57$

$V(t) = V_m \cos(\omega t + \alpha)$

$i(t) = I_m \cos(\omega t + \phi)$ $\quad p(t) = V_m I_m \cos(\omega t + \alpha)\cos(\omega t + \phi)$

$P_{ave} = \frac{1}{T}\int_0^T p(t)\,dt = \frac{V_m I_m}{\sqrt{2}\sqrt{2}}\cos(\alpha - \phi)$ W

$Q = \frac{V_m I_m}{\sqrt{2}\sqrt{2}}\sin(\alpha - \phi)$ VAR

$|S| = \frac{V_m}{\sqrt{2}}\frac{I_m}{\sqrt{2}}$ VA

$\vec{S} = P + jQ$

Non Sinusoidal

$f(t) = a_0 + \sum_{n=1}^{\infty} a_n \cos n\omega t + b_n \sin n\omega t$

$a_n = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)\cos n\omega t \, d\omega t$

$b_n = \frac{2}{T}\int_{-\frac{T}{2}}^{\frac{T}{2}} f(t)\sin n\omega t \, d\omega t$

$$f(t) = a_0 + \sum_{n=1}^{\infty} C_n \cos(n\omega t + \phi_n) = a_n + \sum_{n=1}^{\infty} C_n \sin(\omega t + \theta_n)$$

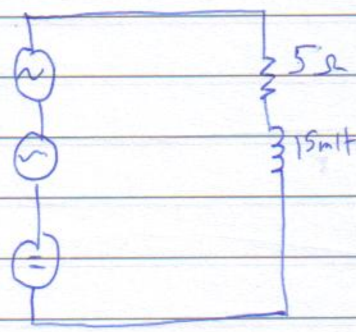
$$C_n = \sqrt{a_n^2 + b_n^2} \qquad \phi_n = \tan^{-1} \frac{-b_n}{a_n}$$

$$F_{rms} = \sqrt{a_0^2 + \sum_{n=1}^{\infty} \left(\frac{C_n}{\sqrt{2}}\right)^2}$$

$$V(t) = 10 + 20 \cos(2\pi 60 t - 25^\circ) + 30 \cos(4\pi 60 t + 20^\circ)$$

5Ω

$15mH$



$$I_0 = \frac{10}{5} = 2A$$

I_1 :- $X_1 = 2\pi * 60 * 0.015 = 5.6$

I_2 :- $X_2 = 4\pi * 60 * 0.015 = 11.2$

$$I_1 = \frac{20 \angle -25^\circ}{5 + j5.6} = 2.65 \angle -73.5$$

$$I_2 = \frac{30 \angle 20}{5 + j11.2} = 2.43 \angle -46.2^\circ$$

$$i(t) = 2 + 2.65 \cos(2\pi * 60 - 73.5^\circ) + 2.43 \cos(4\pi * 60 - 46.2^\circ)$$

$$I_{rms} = \sqrt{2^2 + \left(\frac{2.65}{\sqrt{2}}\right)^2 + \left(\frac{2.43}{\sqrt{2}}\right)^2} = 3.2 A$$

① $P = 2 * 10 + \frac{20}{\sqrt{2}} \cdot \frac{2.65}{\sqrt{2}} \cos(73.5 - 25) + \frac{30}{\sqrt{2}} \cdot \frac{2.43}{\sqrt{2}} \cos(20 + 46.2)$

$= 52.2 \ W$

② $P = 3.2^2 * 5 = 52.2 \ W$

③ $P = 2^2 * 5 + \left(\frac{2.65}{\sqrt{2}}\right)^2 * 5 + \left(\frac{2.43}{\sqrt{2}}\right)^2 * 5 = 52.2 \ W$

Sinusoidal source non linear load

$$V(t) = V_1 \sin(\omega t + \theta)$$

$$i(t) = I_0 + \sum_{n=1}^{\infty} I_n \sin(n\omega t + \phi_n)$$

$$P_0 = 0$$

$$P_n = 0 \quad n \neq 1$$

$$P_1 = \frac{V_1 I_1}{\sqrt{2}\sqrt{2}} \cos(\theta - \phi)$$

$$V_{rms} = \frac{V_1}{\sqrt{2}}$$

$$I_{rms} = \sqrt{I_0^2 + \sum_{n=1}^{\infty} \left(\frac{I_n}{\sqrt{2}}\right)^2}$$

$$|S| = V_{rms} I_{rms} \qquad Q_1 = \frac{V_1 I_1}{\sqrt{2}\sqrt{2}} \sin(\theta - \phi)$$

$$\sqrt{P^2 + Q^2} = \frac{V_1 I_1}{\sqrt{2}\sqrt{2}} \neq |S|$$

$$S^2 = P^2 + Q^2 + D^2 \leftarrow$$ distortion volt-ampere "VAD"

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3rd week

$$PF = \frac{I_{1rms}}{I_{rms}} \cos(\theta_1 - \phi_1) = \text{displacement Factor} \times \text{Distortion Factor}$$

Total harmonic distortion

$$= \frac{\sqrt{\sum_{n \neq 1} I_{n\,rms}^2}}{I_{1rms}} = \frac{\sqrt{I_{rms}^2 - I_{1rms}^2}}{I_{1rms}} = \sqrt{\left(\frac{I_{rms}}{I_{1rms}}\right)^2 - 1}$$

$$= \sqrt{\left(\frac{1}{DF}\right)^2 - 1} \qquad DF = \sqrt{\frac{1}{(THD)^2 + 1}}$$

$$D = V_{1rms} \sqrt{\sum_{n \neq 1} I_{n\,rms}^2}$$

$$v(t) = 100 \cos 377t \ \ V$$

$$i(t) = 8 + 15 \cos(377t + 30^\circ) + 6 \cos(2 * 377t + 45^\circ) + 2 \cos(3 * 377t + 60^\circ)$$

$$V_{rms} = \frac{100}{\sqrt{2}}$$

$$I_{rms} = \sqrt{8^2 + \left(\frac{15}{\sqrt{2}}\right)^2 + \left(\frac{6}{\sqrt{2}}\right)^2 + \left(\frac{2}{\sqrt{2}}\right)^2} = 14A$$

$$P = \frac{100}{\sqrt{2}} \cdot \frac{15}{\sqrt{2}} \cos 30 = 650 \ W$$

$$Q = \frac{100}{\sqrt{2}} \cdot \frac{15}{\sqrt{2}} \sin -30 = -375 \ VAR$$

$$S = V_{rms} I_{rms} = \frac{100}{\sqrt{2}} * 14 = 990 \ VA$$

$$D = \sqrt{S^2 - P^2 - Q^2} = +\sqrt{990^2 - 650^2 - 375^2} = 648 \ VAD$$

displacement factor $= \cos 30 = 0.866$

distortion factor $= \frac{10.6}{14} = 0.758$

$PF = 0.758 \times 0.866 = 0.66$

$$THD = \frac{\sqrt{8^2 + \left(\frac{6}{\sqrt{2}}\right)^2 + \left(\frac{2}{\sqrt{2}}\right)^2}}{10.6} = 0.86$$

$$THD = \sqrt{\left(\frac{1}{0.758}\right)^2 - 1} = 0.86$$

$$D = \frac{100}{\sqrt{2}} \sqrt{8^2 + \left(\frac{6}{\sqrt{2}}\right)^2 + \left(\frac{2}{\sqrt{2}}\right)^2} = 648 \text{ VAD}$$

* Form factor $= \frac{I_{rms}}{I_{av}}$

* crest factor $= \frac{I_{peak}}{I_{rms}}$

Com 2

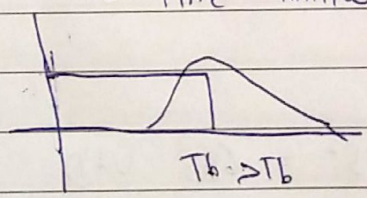
Base band binary Tx:-

$S_0(t) \longrightarrow$ "0"

$S_1(t) \longrightarrow$ "1"

Conditions:- In order to seperate two signals.

1. Time limited (T_b)



$T_b \rightarrow T_b$

· Orthoganal signals can be separated, detected.

$L_m = 250\ \mu H$

$N_1 = 10$

$N_2 = \cancel{220}\ 100$

$V_s = 220\ V$

$t_1 = 50\ \mu s$

$a = \frac{N_2}{N_1} = 10$

$V_p = (1+a)V_s = (1+10)*220 = 24,200\ V$

$I_o = \frac{V_s * t_1}{L_m} = 220 * \frac{50*10^{-6}}{250*10^{-6}} = 44\ A$

$I_o' = \frac{44}{10} = 4.4\ A$

$t_2 = 250 * 44 * \frac{10}{220} = 500\ \mu s = a t_1$

$W = \frac{1}{2} \frac{V_s^2}{L_m} t_1^2 = \frac{1}{2} L_m I_o^2 = \frac{1}{2} * 250*10^{-6} * 44^2 = 0.242\ J$

Five Apple