18th/11/2012

POWER ELECTRONICS AND DRIVES

INTRODUCTION.

(P.S. BIMBRA)
(&)
(N.P.T.E.L)

* RCT and Traic only do reverse conducting.

* Power diode :-

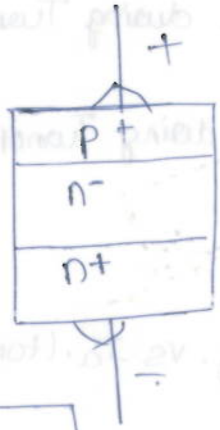


fig.(1.1)

* BJT

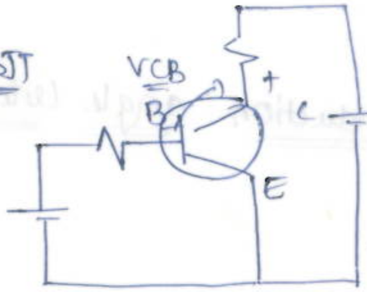


fig (1.2)

$I_C = \frac{V_{CC} - V_{CE}}{R_C}$

$\beta = I_C / I_B$

over drive the Base current.

$I_{C(sat)} = \frac{V_{CC} - V_{CE(s)}}{R_C}$

$I_{B(sat)} = I_{CS}/\beta$.

over drive factor $= \frac{I_B}{I_{BS}}$.

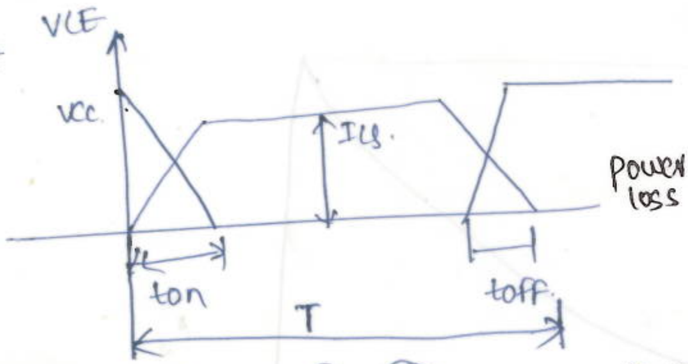
* 

fig (1.3)

* switch on energy loss $\Rightarrow \frac{V_{CC} \times I_{CS}}{6} t_{on}$

power loss = * average value of switch on loss $\Rightarrow \left(\frac{V_{CC} I_{CS}}{6} (t_{on})(F)\right)$

* switch off energy loss $\Rightarrow \left| \frac{V_{CC} I_{CS}}{6} t_{off}. \right|$

* average value of switch off loss $\rightarrow \frac{V_{CC} I_{CS}}{6} t_{off}.f.$

* Peak value of instantaneous power loss $\Rightarrow$

during switch on $\Rightarrow \frac{V_{CC} \cdot I_{CS}}{4}$

during switch off $\Rightarrow \frac{V_{CC} \cdot I_{CS}}{4}$

[Both are same]

power diode etc)

*.

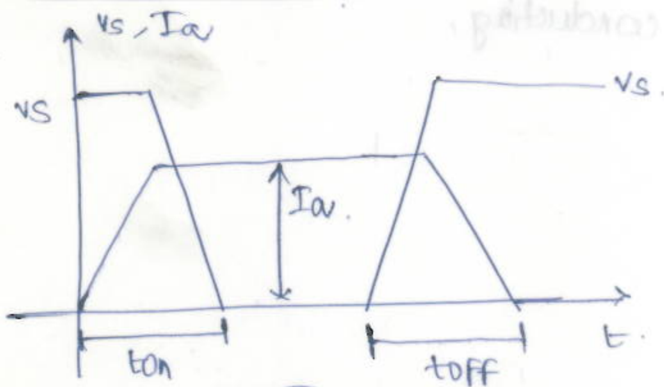


Fig (1.4)

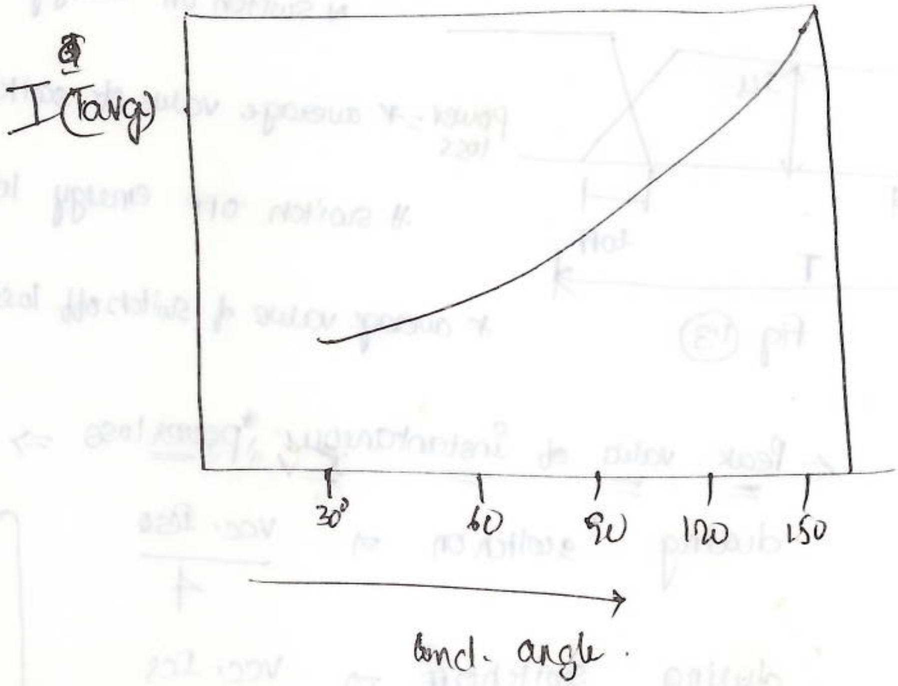
* Energy loss during Turnon → $\frac{1}{2} \cdot V_s \cdot I_a \cdot (t_{on})$

* Energy loss during Turnoff → $\frac{1}{2} \cdot V_s \cdot I_a (t_{off})$

* Average ~~Pow~~ Energy loss ⇒ $\frac{1}{2} \cdot V_s \cdot I_a \cdot (t_{on} + t_{off}) \cdot F$.

Form - factor and onstate current (through conduction angle criteria)

(next page fig 3.B onwards.



Diode – rectifiers

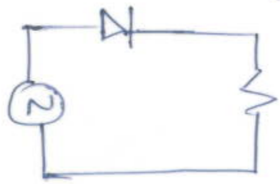


Fig (2.1)

$v_0 = \frac{v_m}{\pi}$

$v_{or} = \frac{v_m}{2}$

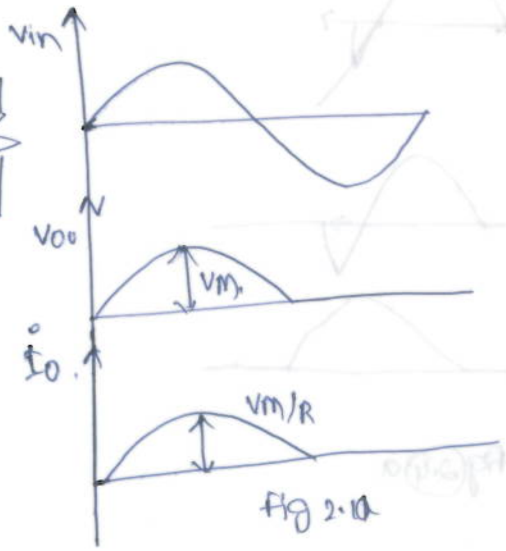


Fig 2.1a

$$v_{or} = \left[\frac{1}{2\pi}\int_0^{\pi} v_m \sin^2 \omega t\right]$$

$$v_m\left[\frac{1}{2\pi}\cdot\frac{\pi}{2}\right] = \frac{v_m}{2}$$

P.F ⇒ ≠ unity (0.707) (if T/F coupled)

close unity.

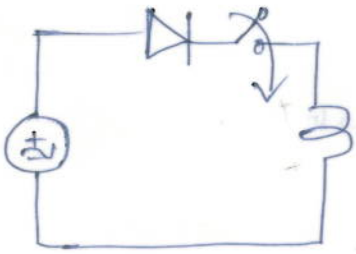


Fig (2.2)

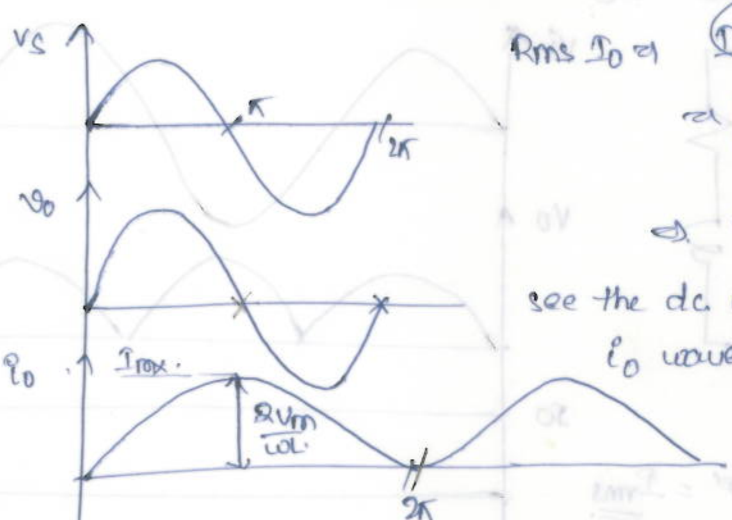


Fig (2.2a)

rms of th

$$\text{Rms } I_0 = I(1-\cos\omega t)$$

$$= \sqrt{\left(I_0^2 + I_0^2/2\right)}$$

$$\Rightarrow \sqrt{3/2}\, I_0 \Rightarrow 1.224\, I_0$$

see the dc component in i_0 waveform equation,

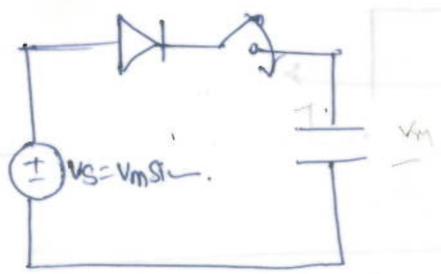


Fig (2.3)

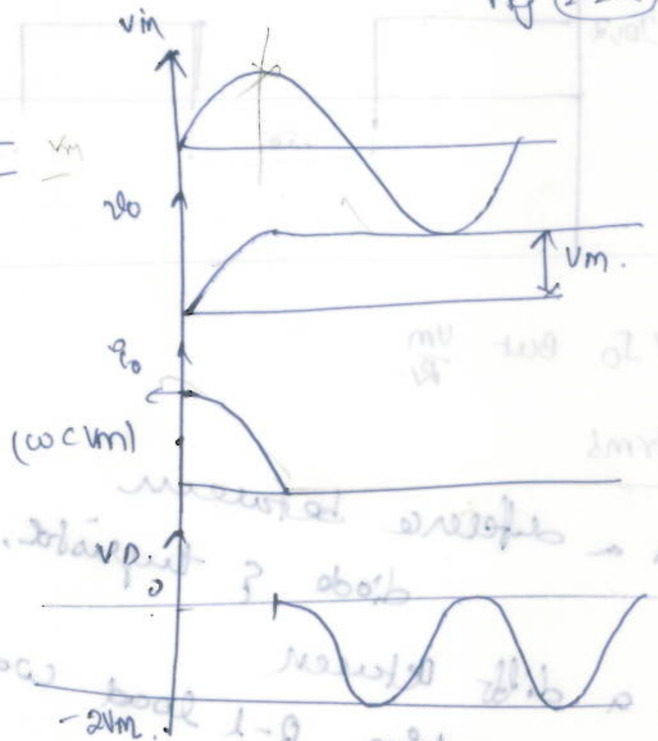


Fig (2.3a)

v_d $i_r = v_m(1-\cos\omega t)$

$= (1.225\, v_m)$

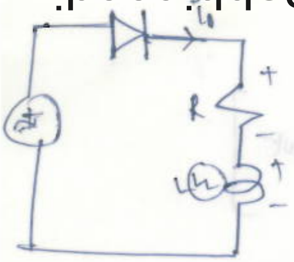
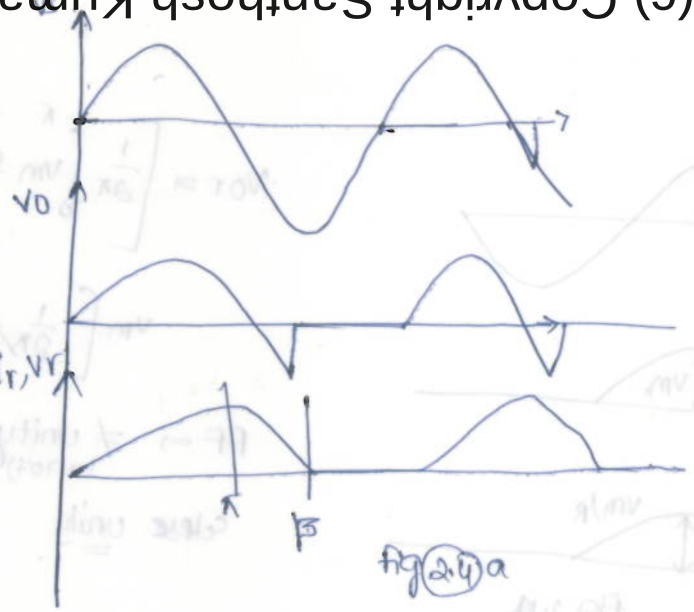


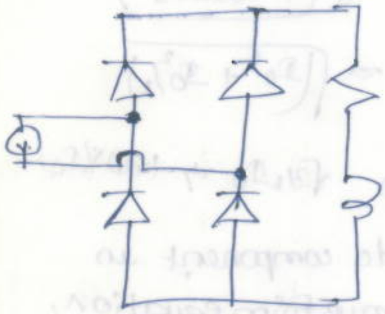
fig (2.4)

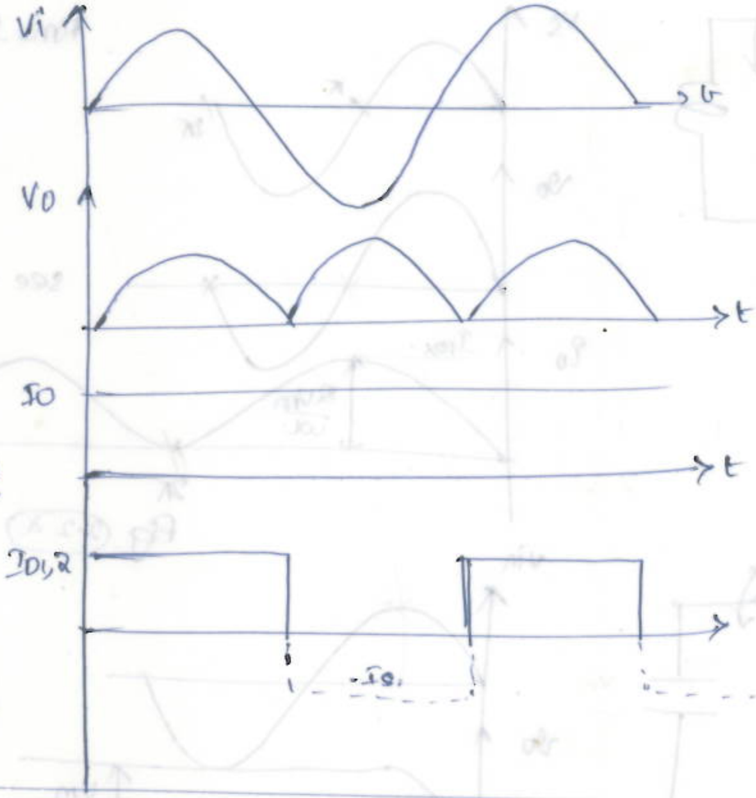


$V_0 \Rightarrow \frac{V_m}{2\pi}\left[1-\cos\beta\right]$.

fig (2.4) a

1φ full bridge - diode - I_0 const. - (RL).





Avg. $I_0 = \frac{V_0}{R} = \cancel{23'} = \underline{I_{rms}}$

$I_{max} = I_0$.

but for R-load

$I_m \cancel{=} \ne I_0$ But $\frac{V_m}{R_L}$.

$I_0 \ne I_{rms}$

Always there is a difference between diode & thyristor,

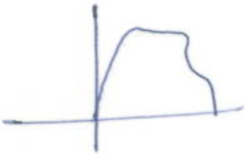
and there is a diff between R-load waveform, R-L load waveform in uncontrolled & controlled.

Thyristor gate characteristics.

$$\frac{1}{T} \cdot \int^{T_1} P_{g(max)} = P_g\,(avg).$$

$$\frac{T_1}{T}\,(P_{g\,max}) = P_g\,(avg)$$

$$\rightarrow \delta P_{g\,max} = P_g\,(avg).$$



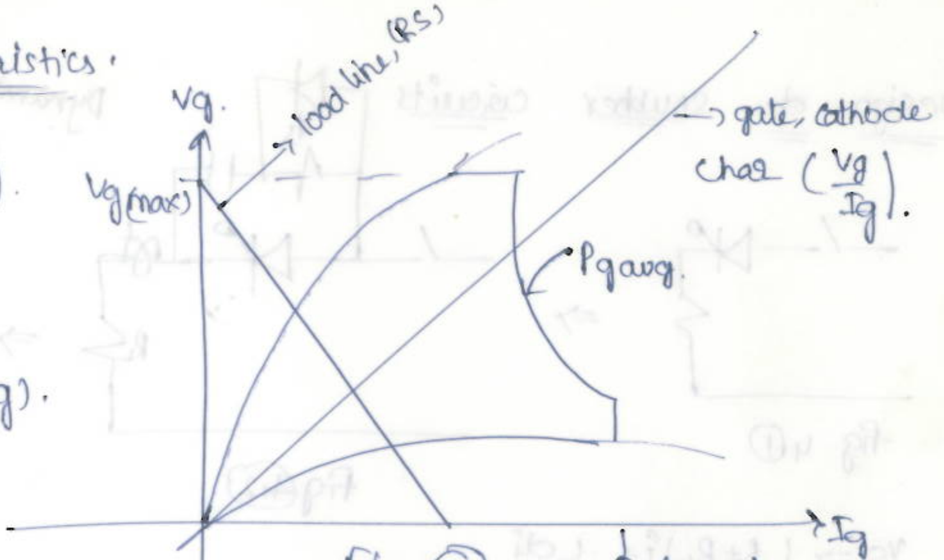


Fig (3.1).

* gate cathode characteristics means $\frac{V_g}{I_g}$; (usually given +ve).

Load line slope ⇒ R_s ⇒ (usually given −ve)

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* **SCR – derating phenomenon**
(Half-wave only)

Every manufacturer speifies the maximum (Rms) current handled by SCR. (fixed value)

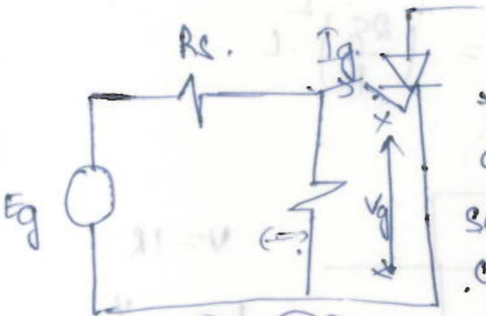


Fig (3.2).

* parallel (R) across gate–cath, ⇒ for supression of leakage currents and thermal stability.

Rms Because, (~~current~~ heat produced depends on rms, But not I_{avg})

so, $f.F \Rightarrow \frac{I_{rms}}{I_{avg}}$.

$$\text{form factor} \Rightarrow \frac{\left[\frac{1}{2\pi}\cdot\int_{\theta}^{\pi} I_m^2 \sin^2\theta\,)\right]^{1/2}}{\frac{I_m}{2\pi}\left[1+\cos\theta_1\right]}.$$

Visualization

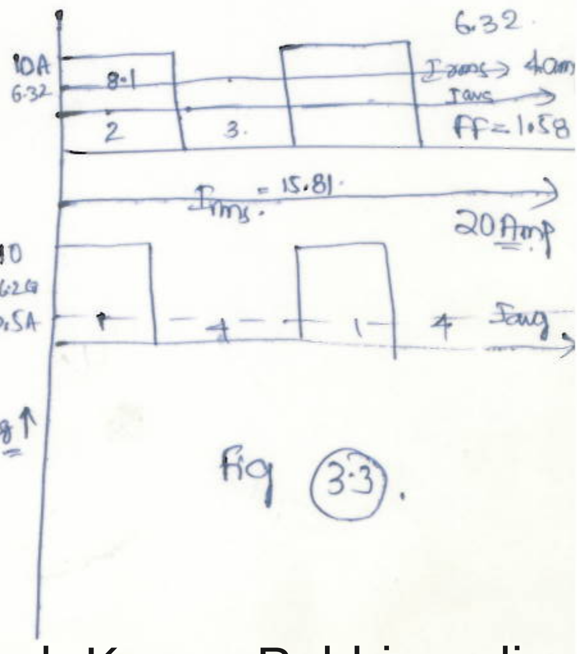
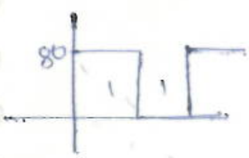


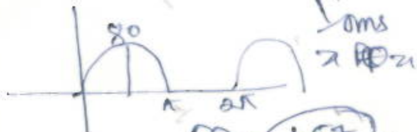
Fig (3.3).

* do prefer more conduction angle.

* prefer sine wave, not sq. wave.



→ FF ⇒ $\frac{80}{\sqrt{2}}$ ⇒ 56.577 ← Irms. (1.41) ff↓, Iavg↑
Iavg → 80 × ½ → 40 amp.



Irms
→ FF → $\frac{80}{2}$ → 40 Amp
FF ⇒ (1.57)

Design of snubber circuits

Dynamic equalizing circuit

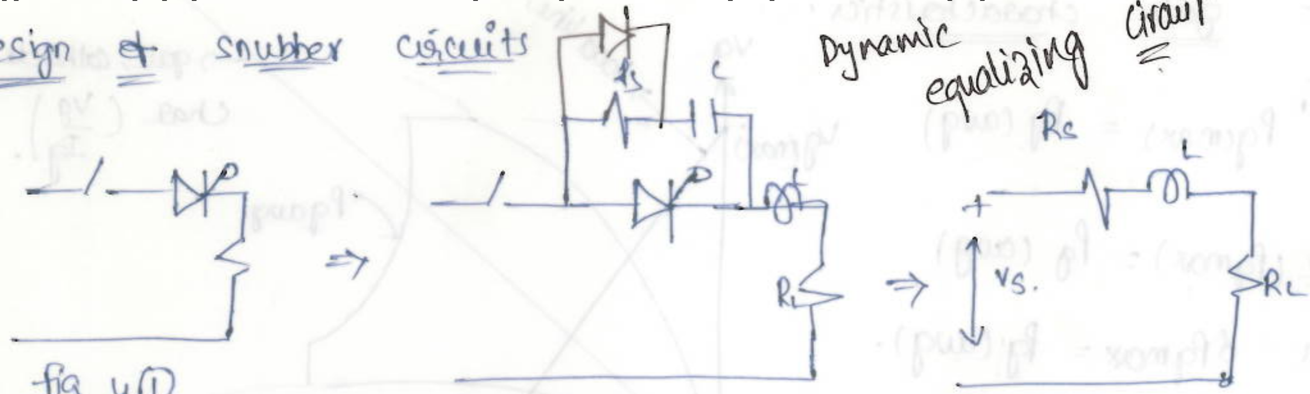


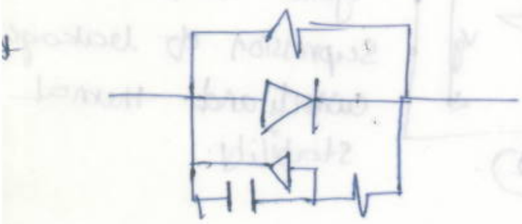
fig 4(1) fig(4.2) Fig. (4.3)

$V_S \Rightarrow (R_s + R_L) i + L\frac{di}{dt}$.

(1) $L = V_S / (di/dt) \Rightarrow 4.8\,\mu H$.

(2) next decide (R) Based on current carrying capacity of SCR

(3) $C = \left(\frac{2\xi}{R}\right)^2 \cdot L$ R.



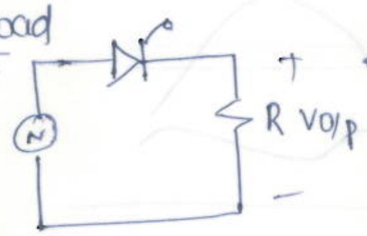
$V = IR$

$R = \frac{V}{I} \Rightarrow \frac{nV_{bm} - V_S}{(n-1)\Delta I_b}$.

$Q = CV \Rightarrow C = \frac{Q}{V} \Rightarrow \frac{\Delta Q (n-1)}{nV_{bm} - V_S}$.

Phase controlled rectifiers (Half wave).

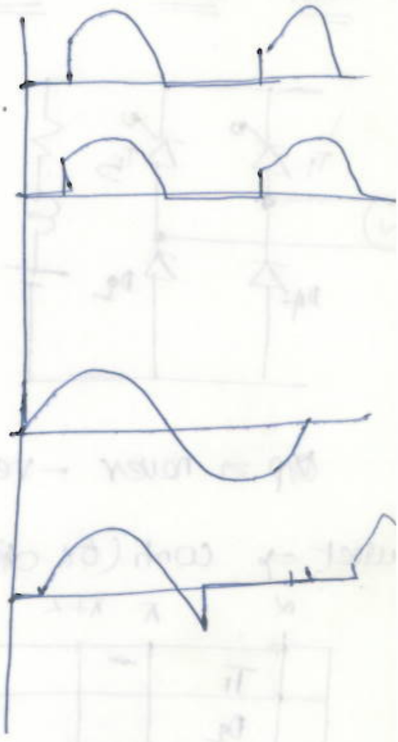
R- Load



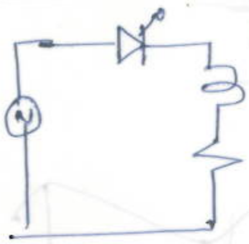
$\Rightarrow V_0 = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \sin\omega t \Rightarrow \frac{V_m}{2\pi}[1+\cos\alpha]$.

$V_{or} = \left[\frac{V_m^2}{2\pi}\left[(\pi-\alpha)+1/2 \sin 2\alpha\right]\right]^{1/2}$

$pf = \frac{V_{or}}{V_s}$.



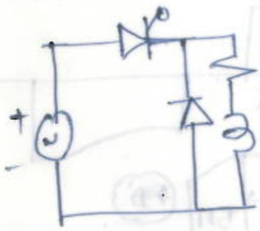
R-L load



$V_0 = \frac{V_m}{2\pi}\left[\cos\alpha-\cos\beta\right]$

$V_{or} = \left[\frac{V_m^2}{2\pi}\left(\beta-\alpha\right)+1/2\left(\sin 2\alpha-\sin 2\beta\right)\right]^{1/2}$.

R-L- F.Diode

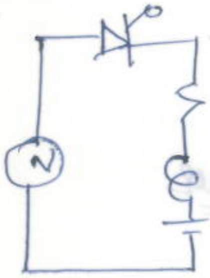


$\Rightarrow$ o/p looks like (R) load,

$\Rightarrow$ current can be continuous / discontinuous.

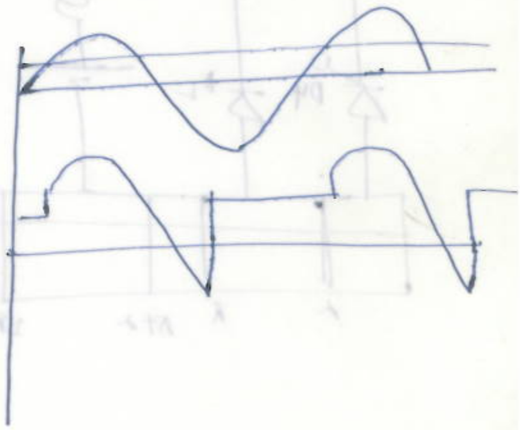
$\Rightarrow$ p.f improved.

R-L-E Load

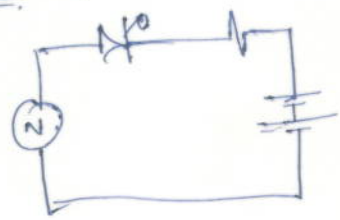


$\Rightarrow$ P.IV $\Rightarrow (E+V_m)$

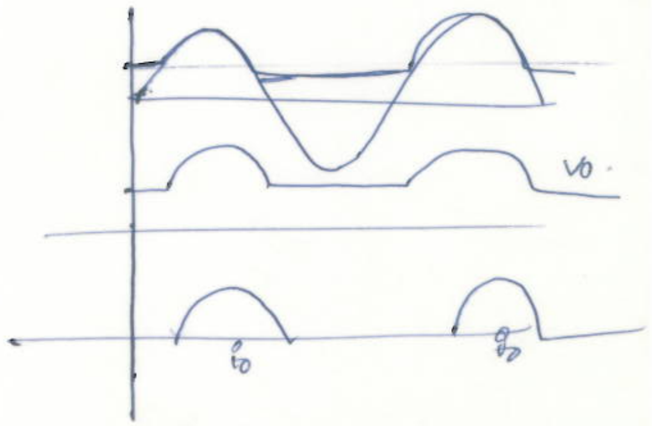
$I_0 = \frac{1}{2\pi R}\left[V_m(\cos\alpha-\cos\beta)-E(\beta-\alpha)\right]$



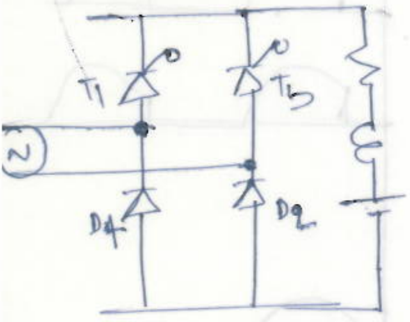
R- E load

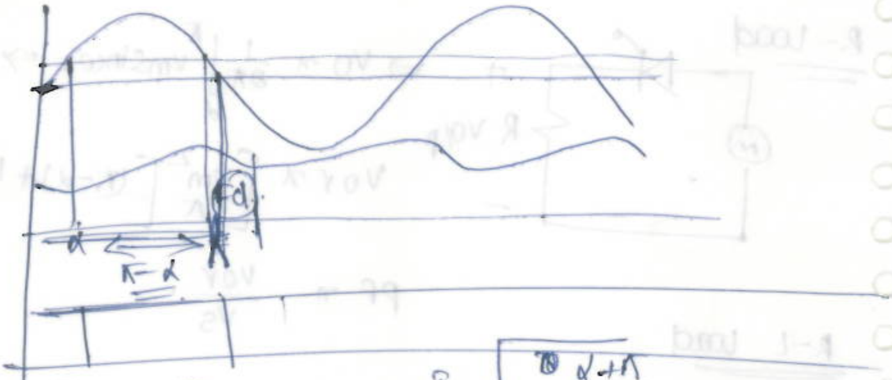


$i_0 = \frac{V_m \sin\omega t - E}{R}$.



Full wave rectifiers ⇒ Half controlled



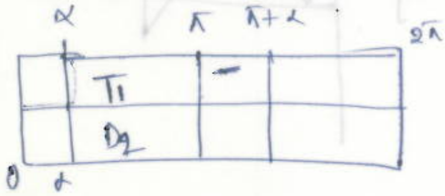


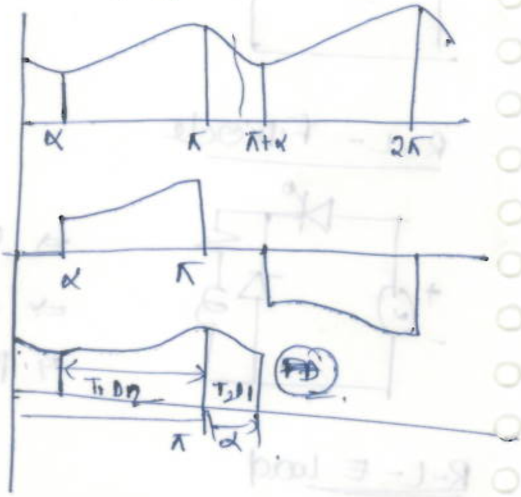
$I_{F.d}(rms) = I_0\sqrt{\frac{\alpha+\pi}{\pi}}$

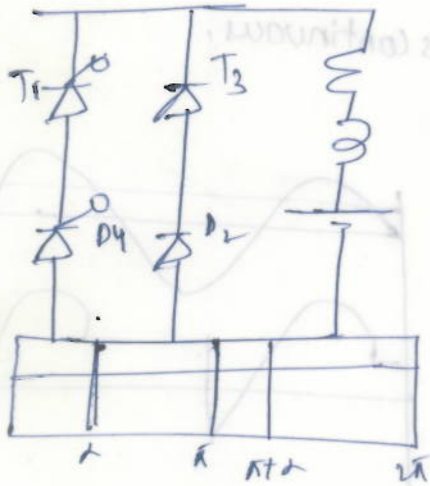
$I_{Thy} \Rightarrow I_0\sqrt{\frac{\pi-\alpha}{\pi}}$

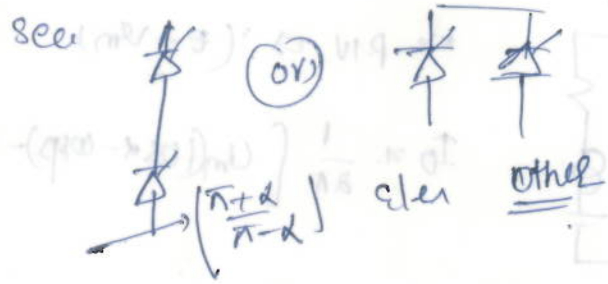
O/p ⇒ never −ve,

current ⇒ conti (or) dis-cont









1φ semi

Rms value of n^{th} Harmonic current, $\frac{2\sqrt{2}}{n\pi} I_0 \cdot \cos\frac{n\alpha}{2}$.

Rms fundamental ⇒ $\frac{2\sqrt{2}I_0}{\pi} \cos\alpha/2$.

Rms value of total input current, $I_0\left[\frac{\pi-\alpha}{\pi}\right]^{1/2}$.

displacement factor ⇒ $\cos\alpha/2$.

powerfactor ⇒ $(1+\cos\alpha) \cdot \sqrt{\frac{2}{\pi(\pi-\alpha)}}$ *

power input ⇒ $V_0 I_0$.

Reactive Power ⇒ $V_0 \cdot I_0 \cdot \tan\alpha/2$.

$\frac{2\sqrt{2}}{\pi} I_0 \cdot \cos\alpha/2$

$\frac{2\sqrt{2}}{n\pi} I_0 \cos(n\alpha/2)$.

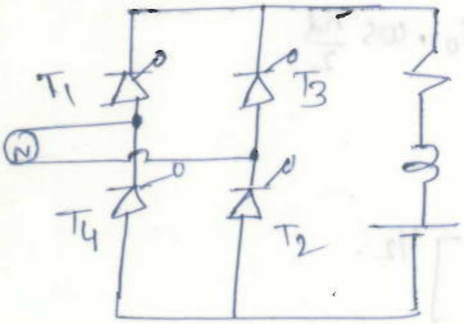
PF ⇒ $(1+\cos\alpha) \cdot \sqrt{\frac{2}{\pi(\pi-\alpha)}}$

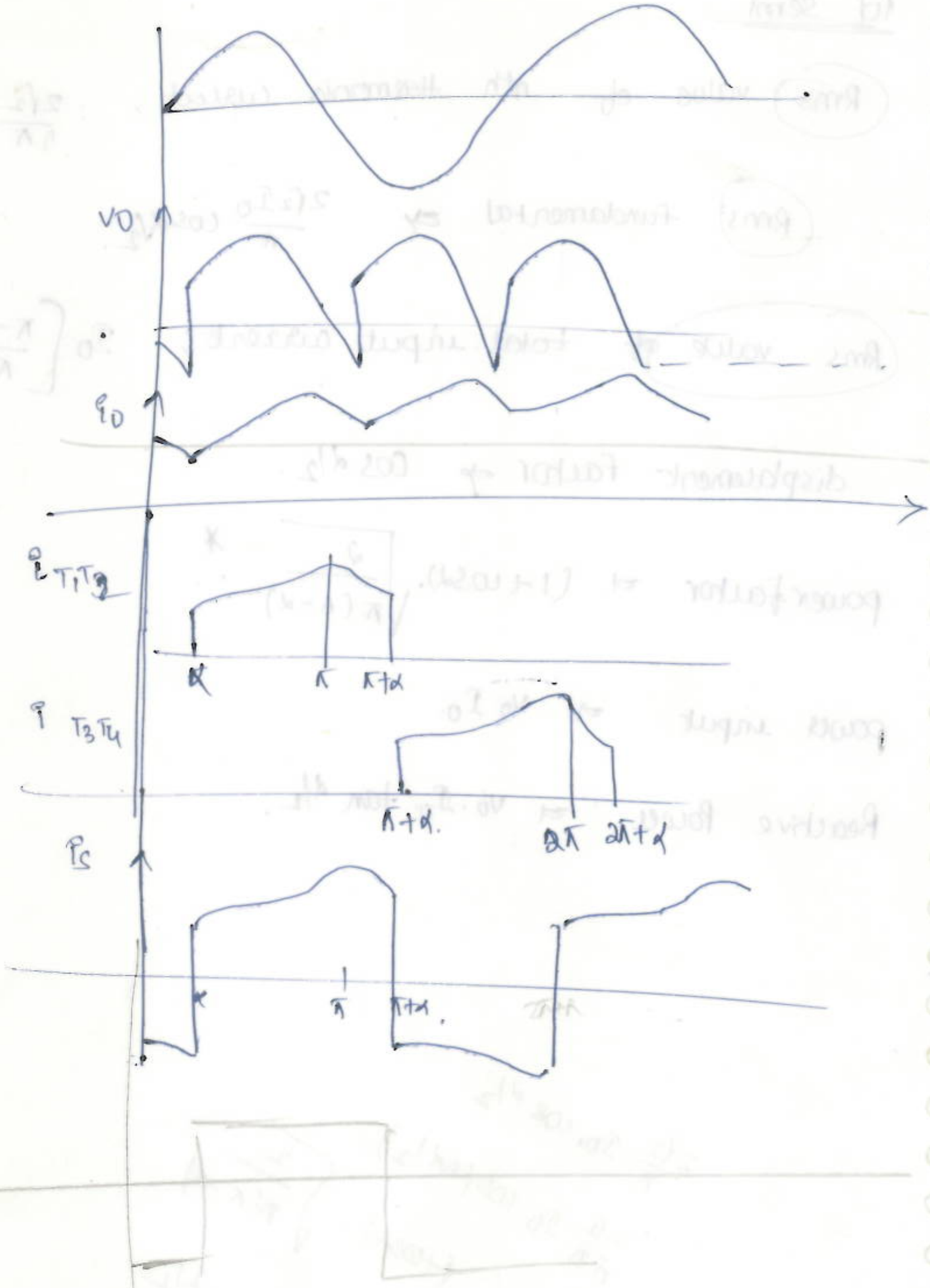
$V_0 I_0$,

R ⇒ $V_0 I_0 \tan\alpha/2$

$I_0\sqrt{\frac{\pi-\alpha}{\pi}}$

Full controlled





$\frac{2V_m}{\pi}\cos\alpha.$

$V_{or} = V_s.$

1ϕ full – fourier Analysis

rms value of nth Harmonic → $\frac{2\sqrt{2}}{n\pi} I_0$.

rms value of fund. comp → $\frac{2\sqrt{2}}{\pi} I_0$ → $0.90032 I_0$

rms value of total i/p current → $\left[\frac{I_0^2 \times \pi}{\pi}\right]$ → I_0.

displacement factor → $\cos\alpha$.

power factor → $\cos\alpha \cdot \frac{\sqrt{2} \cdot 2}{\pi}$

Active Power input → $V_0 \cdot I_0$.

Reactive Power input → $V_0 \cdot I_0 \cdot \tan\alpha$.

$\frac{2\sqrt{2}}{n\pi} I_0$.

$\frac{2\sqrt{2}}{\pi} I_0$

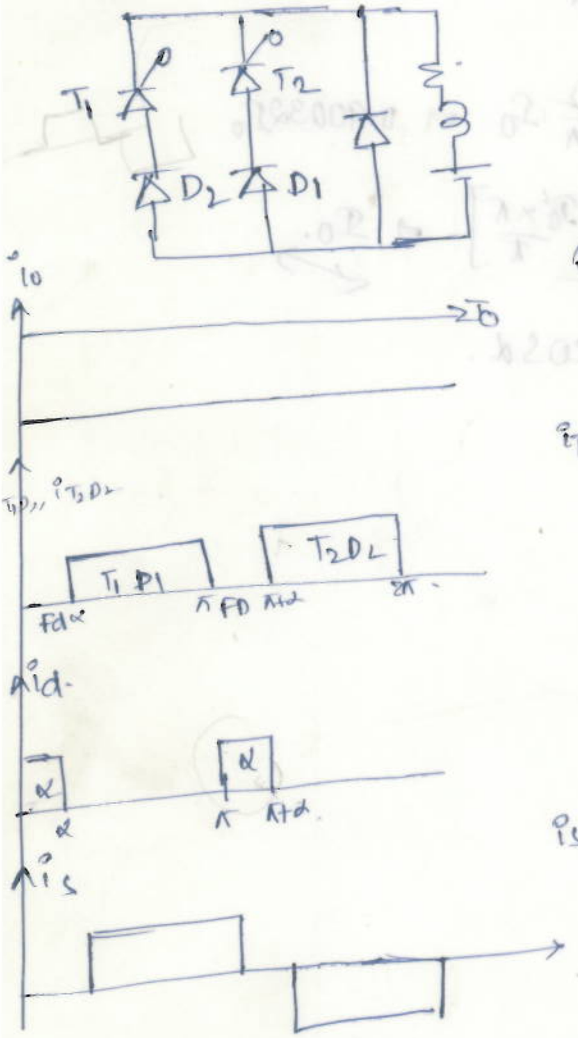
$I_0 = I_{rms}$ $\cos\alpha$ $\frac{2\sqrt{2}}{\pi}\cos\alpha$

$V_0 I_0$,

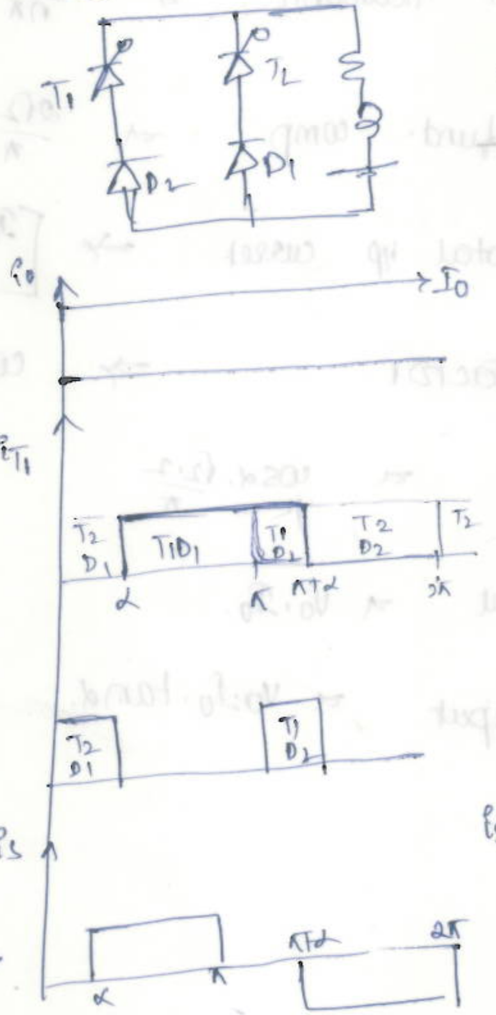
$V_0 I_0 \tan\alpha$

more on semi converters

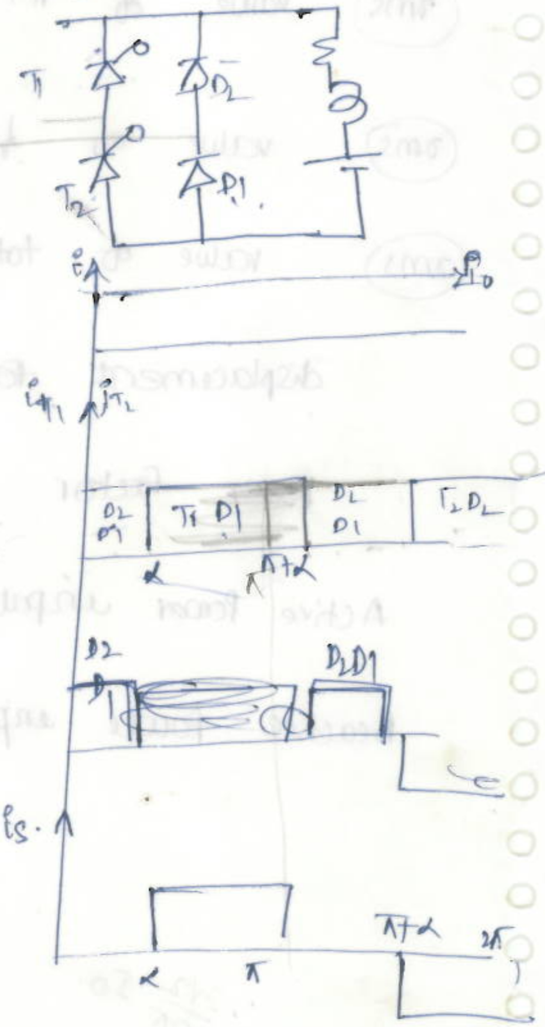
fig①



fig②



fig③



3φ - Rectifier circuits

(Quantitative Analysis only)

3φ - Half wave controlled, $\frac{3\sqrt{6}V_{ph}}{2\pi}\cos\alpha$. / Half controlled $\Rightarrow \frac{3\sqrt{6}V_{ph}}{2\pi}[1+\cos\alpha]$.

Avg. curr. rating of SCR $\Rightarrow I_0/3$.

rms. curr. rating of SCR $\Rightarrow I_0/\sqrt{3}$.

3φ - Full converters :-

rms value of source current, $I_0\sqrt{2/3}$. [120° of 180°].

rms value of thyrist. curr, $I_0\sqrt{1/3}$ (120° of 360°).

Analysis :-

Rms value of nth Har. curr $\sim \frac{2\sqrt{2}}{n\pi}\cdot\sin\left(\frac{n\pi}{3}\right)$

Rms value of fund. com. of $i \Rightarrow \frac{\sqrt{6}}{\pi}I_0$.

Rms. value of source current $\Rightarrow I_0\sqrt{2/3}$

Distortion factor $\Rightarrow \cos\alpha$.

power factor $\Rightarrow 3/\pi\cos\alpha$.

Active Power input $\Rightarrow V_0 \cdot I_0$.

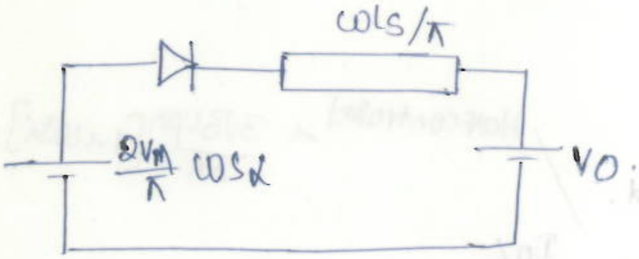
Reactive Power input $\Rightarrow V_0 I_0 \tan\alpha$.

source: $I_0\sqrt{2/3}$, SCR: $I_0\sqrt{1/3}$ $\quad$ $\alpha<60°$ $\quad$ $\alpha>60°$

$\sqrt{\frac{\pi-\alpha}{\pi}} \Rightarrow$ I source

$\sqrt{\frac{180-\alpha}{180}}$; $\sqrt{\frac{180-\alpha}{360}}$ $\quad$ $\sqrt{\frac{\pi-\alpha}{2\pi}}$

Single phase source inductance



$$I_O = \frac{V_m}{\omega L_s}\left[\cos\alpha - \cos(\alpha+\mu)\right]$$

$$V_{Ox} = \frac{V_m}{\pi}\left[\cos\alpha + \cos(\alpha+\mu)\right]$$

$$\cos(\alpha+\mu) = \left(-\frac{I_O \cdot \omega L_s}{V_m}\right) + \cos(\alpha).$$

Inductive voltage regulation $\Rightarrow \left[\frac{1-\cos\mu}{2}\right]$

3ϕ full converter

$$V_O = \frac{3 \cdot V_{mL}}{\pi}\cos\alpha \quad \text{for } 0<\alpha<\pi/3.$$

$$= \frac{3V_{mL}}{\pi}\left[1+\cos(\alpha+60)\right] \quad \text{for } \pi/3<\alpha<\frac{2\pi}{3};$$

3ϕ semi converter.

$$V_O = \frac{3V_{mL}}{2\pi}\left[1+\cos\alpha\right].$$

3ϕ mid point:-

$$V_O = \frac{3V_m}{2\pi}\cos\alpha:$$

~~3ϕ~~ - ~~source~~ ~~inductance~~

Dual converters

without circulating inductor ⇒ only (1) at a time in operation, another ideal,

with circulating inductor ⇒ Both are simultaneously operated,
$(\alpha_1 + \alpha_2 = 180^0)$

1ϕ phase

$$\boxed{\frac{V_m}{\omega L_0}[1 - \sin\alpha_1]}$$

3ϕ

$$\boxed{\frac{\sqrt{18}\,V_{ph}}{\omega L}(1 - \sin\alpha_1)}$$

*

peak ⇒ I_{cp} n $\frac{V_m}{\omega L}$.

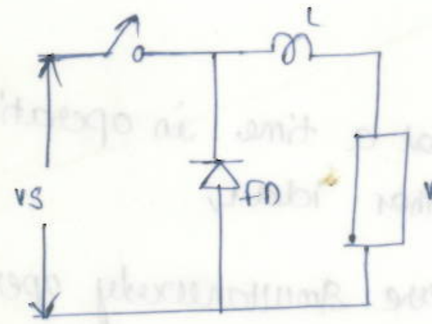
Peak I_{cp} n $\frac{\sqrt{18}\,(V_{ph})}{\omega L}$ V_{max} ?

α

d T. u f - m $\frac{5237}{67.83}$!

CHOPPERS

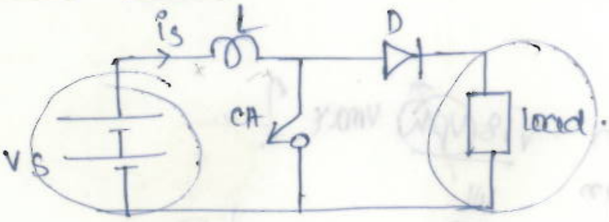
Basic

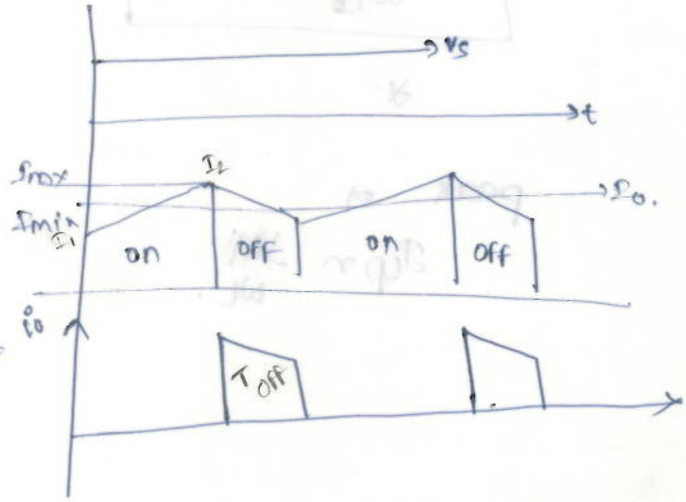


$V_0 = \alpha V_S$

* P.W.M technique fail if $\boxed{T_{ON} \simeq 0}$ (commutation scally fail).

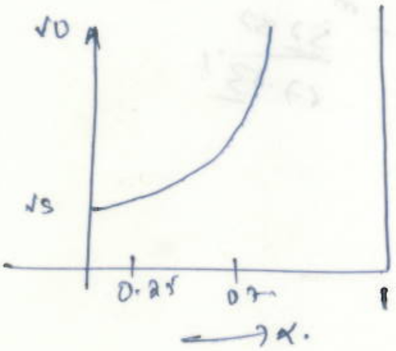
step-up chopper



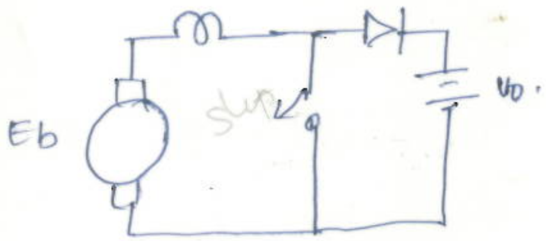


$V_S\left(\frac{I_1+I_2}{2}\right)T_{ON} = (V_0 - V_S)\left(\frac{I_1+I_2}{2}\right)T_{OFF}$

$$\left[V_0 = V_S/1-\alpha\right]$$



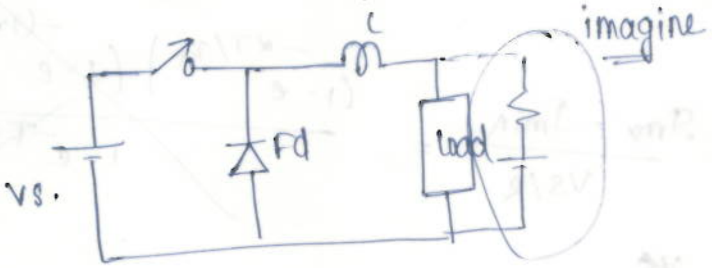
Regenerative Braking using Step-up



$do.\left(\frac{E_b}{1-\alpha} > V_0\right)$

Type (d) $V_0 = V_S\left(\frac{T_{ON} - T_{OFF}}{T_{ON} + T_{OFF}}\right)$.

Stepdown chopper Analysis



6

* average o/p voltage = αV_s
* average "output current" = $\frac{\alpha V_s}{R}$.
* R.m.s. value of o/p voltage = $\sqrt{\alpha} \cdot V_s$
* Rms value of o/p current = $\frac{\sqrt{\alpha} \cdot V_s}{R}$.

diode avg = $(1-\alpha) I_0$

rms → $\sqrt{(1-\alpha)}\, I_0$

* Rms thyristor current → $\frac{\sqrt{\alpha}(V_s - E)}{R}$
* average thyristor current → $\frac{\alpha (V_s - E)}{R}$.
* Eff. Resistance R_{eff} → $\frac{R}{\alpha}$.

* critical Inductance

$$v = L\frac{di}{dt}.$$

$$L = \frac{V \times t}{I}. \Rightarrow \frac{(V_s - V_0) \cdot T_{ON}}{2 I_0}.$$

(or)

$$\frac{(V_s - V_0)^2 \cdot V_0^2}{2f \cdot V_s \cdot P_0}.$$

αV_s,

$\alpha V_s / R$ $\quad \sqrt{\alpha} V_s$

$\frac{\sqrt{\alpha} V_s}{R}$

$\frac{\sqrt{\alpha}(V_s - E)}{R}$.

$\frac{\alpha (V_s - E)}{R}$, $\quad \frac{R}{\alpha}$ eff. step down

$(1-\alpha) I_0$, $\sqrt{(1-\alpha)}\, I_0$

Analysis of Type - A chopper

* per unit ripple → $\dfrac{I_{mx} - I_{min}}{V_S/R} = \cancel{\dfrac{(1-e^{-\alpha T/T_a})(1-e^{-(1-\alpha)T/T_a})}{1-e^{-T/T_a}}}$

$\Rightarrow \dfrac{\dfrac{V_S}{4fL}}{\dfrac{V_S}{R}}$

* δ dependent

$\boxed{\text{per unit ripple} \propto \dfrac{1}{4RfL}}$ [max when $\alpha = 0.5$]

* $\boxed{\text{ripple} \Rightarrow I_{mx} - I_{min} = \dfrac{V_S}{4fL}}$

δ independent

$\boxed{n\alpha}$ ^

$\boxed{n\alpha = 1}$

* ~~MAX~~ rms value of ~~fund~~. voltage $\propto \dfrac{0.45 V_S}{n}$ (or) $\dfrac{2V_S}{\pi\sqrt{2}} \cdot \sin(n\alpha\pi)$

rms

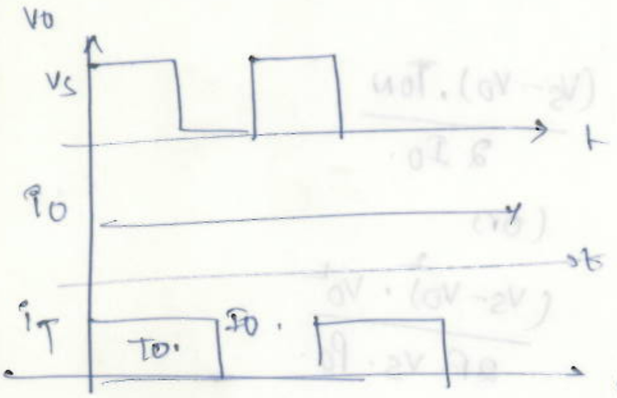
$\boxed{\alpha = 1}$

to eleminate nth Har

* $RF = \sqrt{\dfrac{1}{\alpha} - 1}$

* TYPE-A → RLE ⇒ $I_{T(av)} = \boxed{\dfrac{\alpha(V_S - E)}{R}} - \dfrac{L}{RT}(I_{mx} - I_{min})$

↑ incase ripple present



$I_T \Rightarrow I_0 \times \dfrac{T_0}{T} \Rightarrow \alpha\left(\dfrac{\alpha V_S - E}{R}\right) \propto \dfrac{\alpha^2 V_S - E\alpha}{R}$

$\alpha = \dfrac{E}{2V_S}$

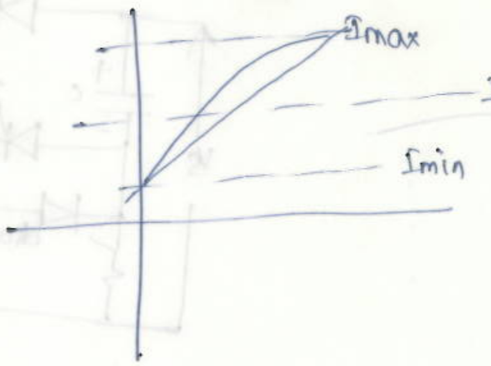
$I_{T(max)} \propto \dfrac{E^2}{4 V_S R}$

Process To find I_{max}, I_{min} in a chopper:-

find $I_0 = \frac{\alpha V_S - E}{R}$ (R L E)

find $\Delta I = I_{max} - I_{min} = \frac{V_S}{4fL}$

$I_0 = \frac{I_{max}+I_{min}}{2} = \frac{V_S}{4fL}$



$I_{max}+I_{min} = 2 I_0$

$I_{max} - I_{min} = \frac{V_S}{2fL}$

$\boxed{2I_{max} = (\quad)}$

A stepdown (Type-A) = $\boxed{\text{Inductance} \propto x(1-x)}$

x = duty cycle.

$\frac{2V_S}{\pi\sqrt{2}} \sin(n\alpha\delta)$

$\frac{2V_S}{\sqrt{2}\pi} \cdot \sin(n\alpha\delta)$

chopper RLE load:-

$$\boxed{\frac{e^{T_{ON}/L/R} - 1}{e^{T_{ON}+T_{OFF}/L/R} - 1} - \frac{E}{V_S} \geq 0.}$$

yes → conti

NO → Disc.

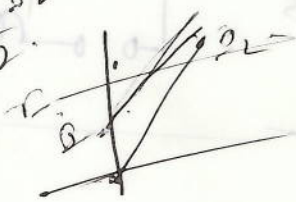
$\frac{2V_S}{\pi\sqrt{2}} \sin(n\pi\alpha)$

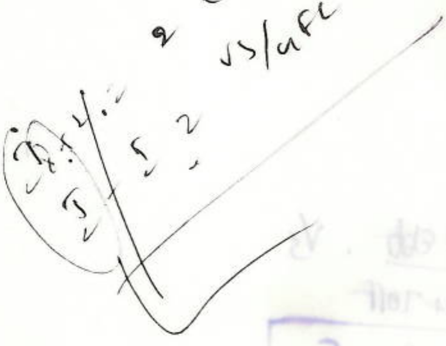
2 E.)

$V_S/4fL$

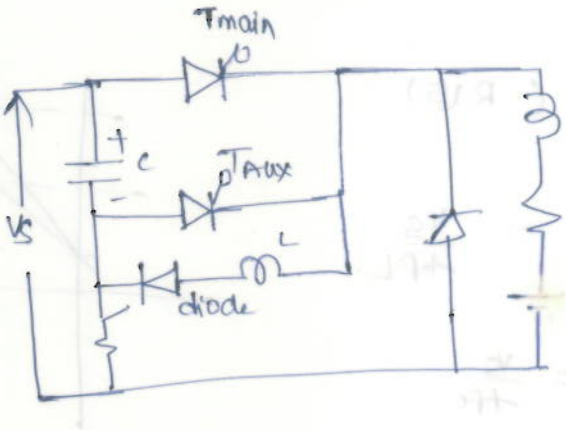
$\frac{V_0}{R}$

$\frac{I_1+I_2}{2}$

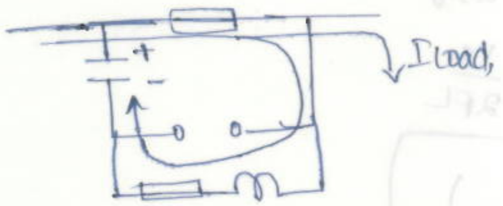




Voltage Commutated Chopper



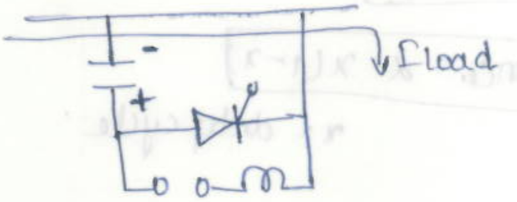
mode ①



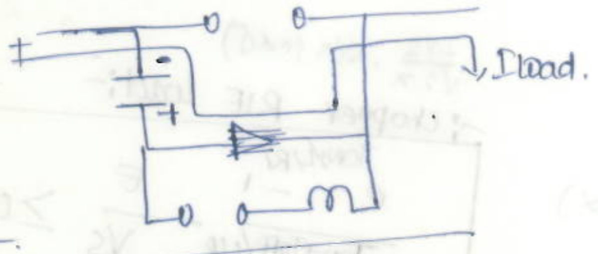
more current Handled, by main thyristor

$I_{total} = I_{load} + V_s\sqrt{C/L}$

mode ②

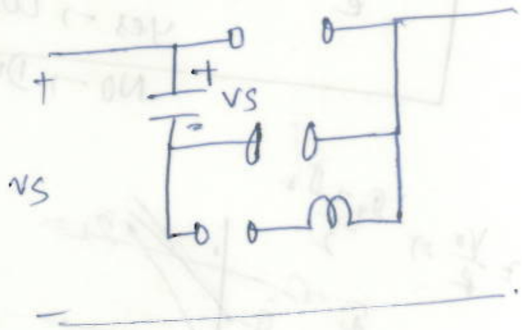


mode ③



voltage across load = 2VS

mode ④



no-load operation fails.

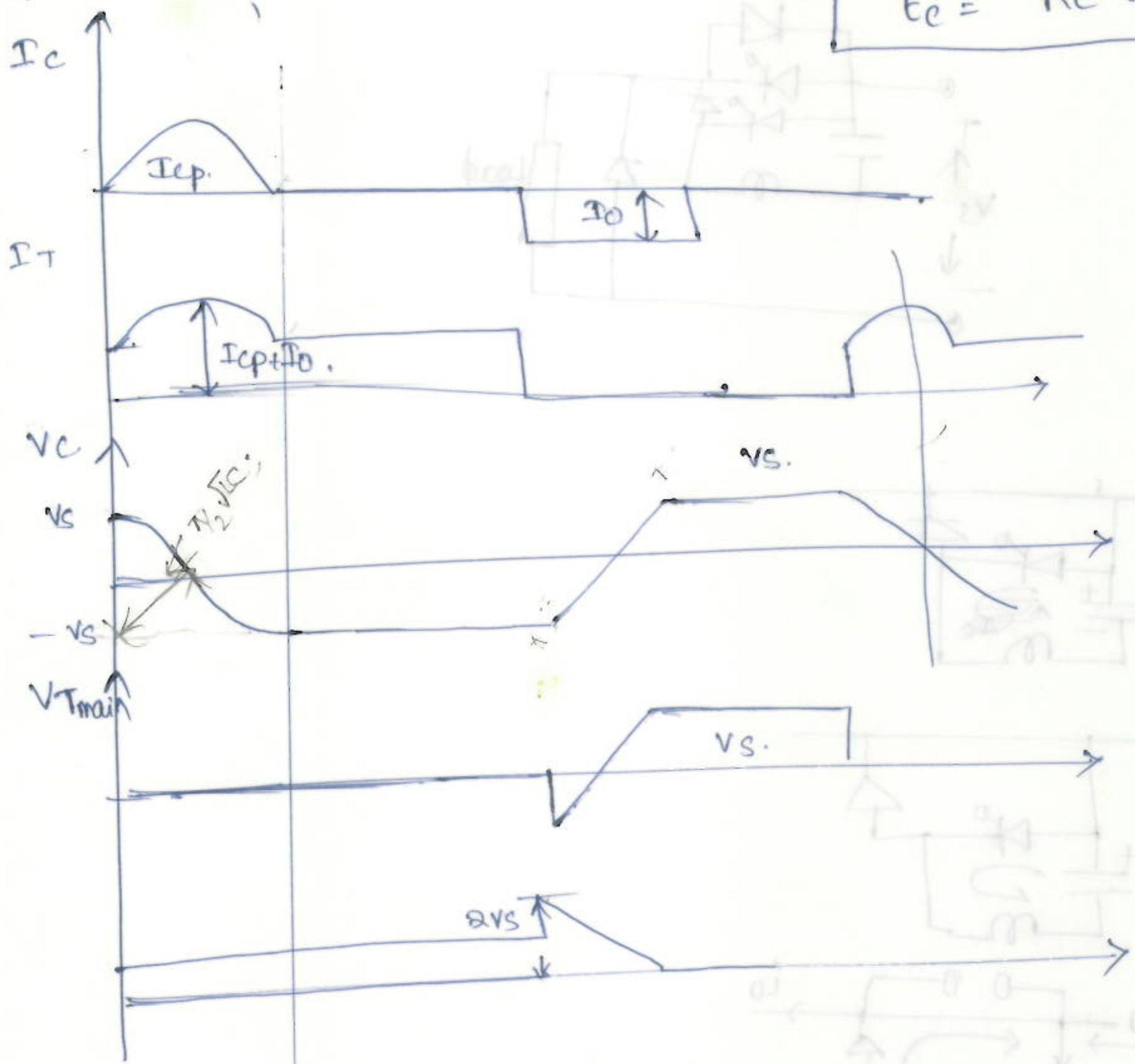
$T_{eff} = T_{ON} + \frac{2V_s \cdot C}{I_0}$; ⇒ makes.

$V_0 = \frac{T_{ON\,eff}}{T_{ON} + T_{off}} \cdot V_s$

$\boxed{V_0 = T_{ON\,eff} \cdot V_s \cdot F}$

Waveforms

$\boxed{t_c = RC \ln(2)}$



Eff on period: $T_{on} + \dfrac{2V_s \cdot C}{I_o}$.

(or) $T_{ON\,eff} = T_{ON} + \left(\dfrac{V_s + V_c}{I_o}\right) C$

Tmain off time:

TAUX

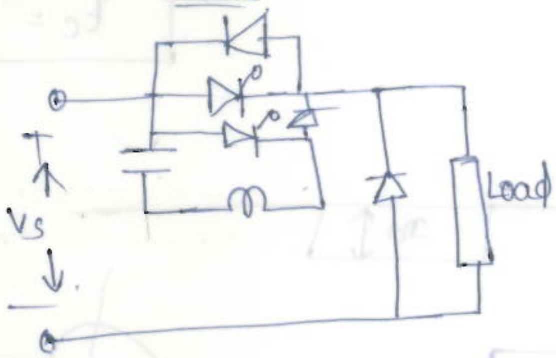
min

To

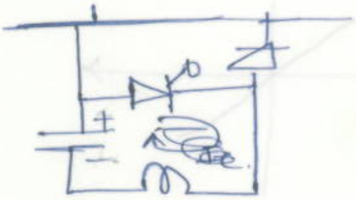
nges from

} like th

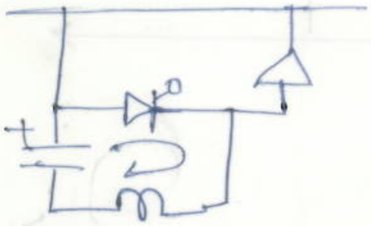
Current Commutated Chopper



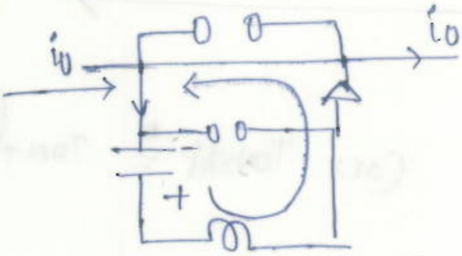
mode ①



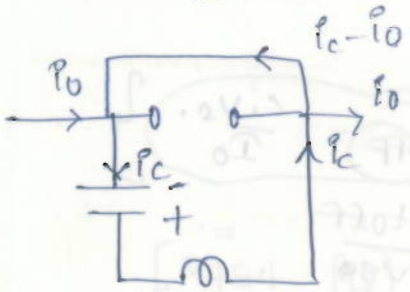
mode ②



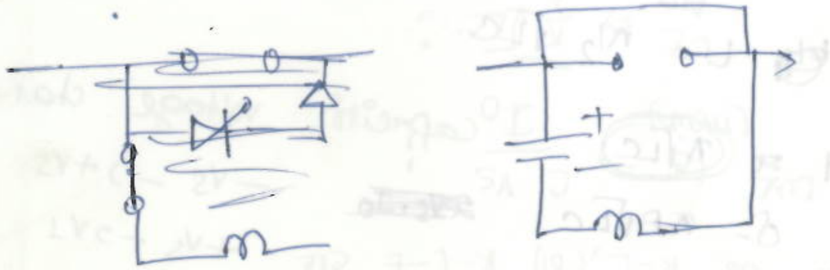
mode ③



mode ④



mode ④



Tough waveforms

$$x = \frac{I_{cp}}{I_0} \approx \frac{V_S\sqrt{C/L}}{I_0}.$$

$$T_{main} = \left[\pi - 2\sin^{-1}(1/x)\right]/\omega_0. \approx \left[\pi - 2\sin^{-1}(1/x)\right]\sqrt{LC}.$$

$$C = \left[\frac{xI_0 \cdot t_c}{V_S\left[\pi - 2\sin^{-1}(1/x)\right]}\right]$$

Peak cap voltage $\rightarrow V_S + I_0\sqrt{L/C}$

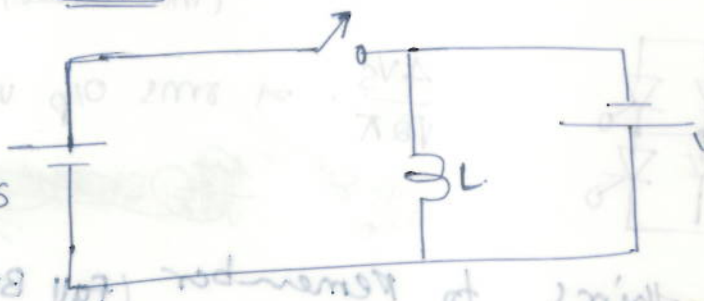
TAUX $\approx \left[\pi - \sin^{-1}(1/x)\right]\sqrt{LC}.$

$\left[\pi - \sin^{-1}(1/x)\right]$

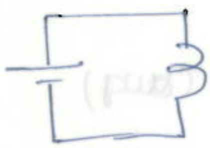
$\left[\pi - 2\sin^{-1}(1/x)\right]$

$C = \frac{xI_0 \times t_c}{V_S\left[\pi - 2\sin^{-1}(1/x)\right]}$

BUCK - BOOST CHOPPER



during Ton



$$v = L\frac{di}{dt}.$$

$$V_{in} = L\cdot\frac{\Delta I}{T_{ON}}.$$

$$L.\Delta I = V_S\, T_{ON}.$$

$$L\cdot\Delta I = V_0\, T_{off}.$$

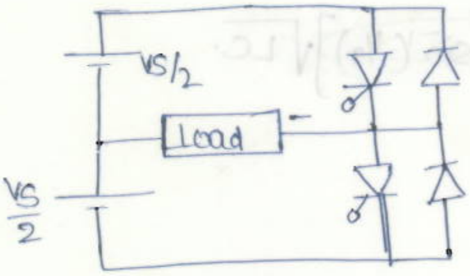
$$(V_S T_{ON} = V_0 T_{off})$$

$$\boxed{V_0 = \frac{V_S\,\alpha}{1-\alpha}.}$$

$$\frac{1+\alpha}{1-\alpha}$$

Inverters

* dc → ac converters.



Half Bridge

$\frac{2V_s}{\pi}\sin n\omega t.$

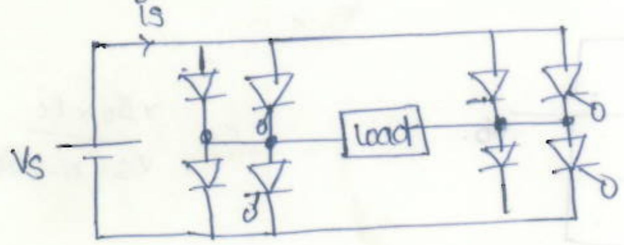
$\frac{2V_s}{\sqrt{2}\pi}$, ~~sin~~ ⇒ rms. o/p voltage.

* prefer R–L–C – underdamped loads,

$\tan^{-1}\left(\frac{X_C - X_L}{R}\right) = \theta$ ⇒ $X_C > X_L$ ⇒ under damp → Load commu– (Cap–nature)

$X_C < X_L$ ⇒ overdamp → Forced comm (ind–nature).

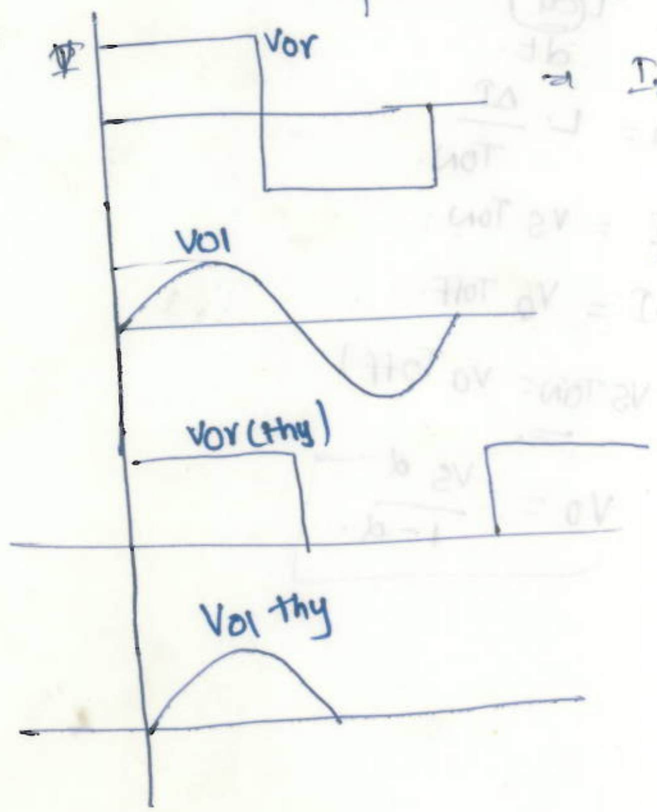
*



$\frac{4V_s}{\sqrt{2}\pi}$. → rms o/p voltage.

Important things to remember (Full Bridge).

*



→ $I_{rms} = I_0$ (avg)

$I_{avg} = \frac{1}{\pi}\int_0^{\pi} I_m \sin\omega t \Rightarrow \frac{2I_m}{\pi}.$

$I_{rms} = I_0\sqrt{\frac{1}{2}}.$

$I_{rms} \Rightarrow \left[\frac{I_m^2}{2\cancel{\pi}} \cdot \frac{\cancel{\pi}}{2}\right] = \frac{I_m}{2}.$

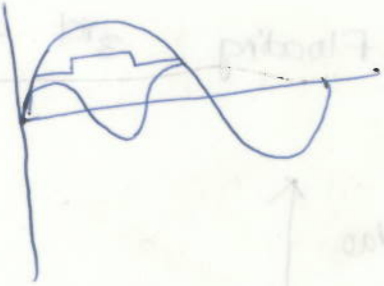
$I_{avg} = \frac{I_m \cancel{2}}{\cancel{2}\pi} = \frac{I_m}{\pi}$

* mc-morray (2.35)

$$v = \frac{L\,di}{dt}$$

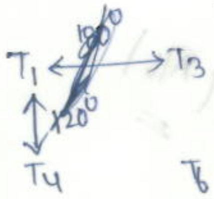
$$L = \frac{V_s\, t_q}{I_{om}} \times (2.35);$$

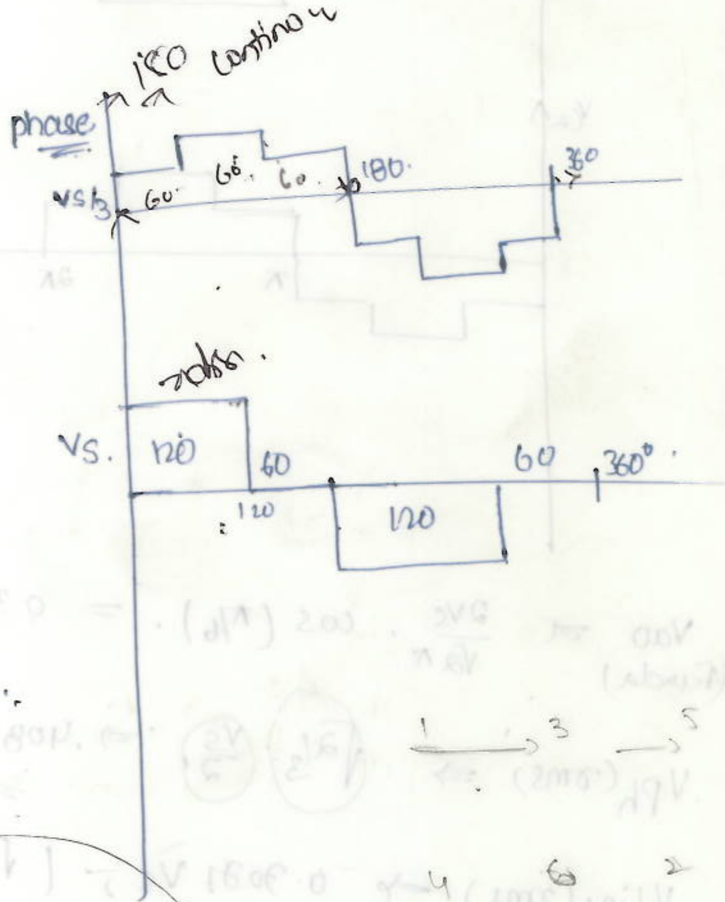
$$C = \frac{I_{om} \times t_q}{V_s} \times (2.35);$$



Three phase Inverters

180° mode





$T_1 \xrightarrow{120^0} T_3$

$T_1 \downarrow 180^0 \; T_4$ $\quad V_{ao}$ (phase) $= \dfrac{2V_s}{\sqrt{2}\pi}$.

(fund) $\quad V_{ab} \Rightarrow \dfrac{4V_s}{\sqrt{2}\pi} \cdot \cos(30)$.

V_{ab} (fnd) $\Rightarrow \dfrac{4V_s}{\sqrt{2}\pi} \cos 30 = 0.7800\, V_s$.

$V_{ab(rms)} = \cancel{0.807}\; V_s \cdot \sqrt{2/3} = 0.8164\, V_s$

V_{ao} (fund) $= 0.4503\, V_s = \left(\dfrac{V_{ab(fund)}}{\sqrt{3}}\right)$

$V_{ao(rms)} = \dfrac{V_{ab(rms)}}{\sqrt{3}} \Rightarrow 0.4714\, V_s$.

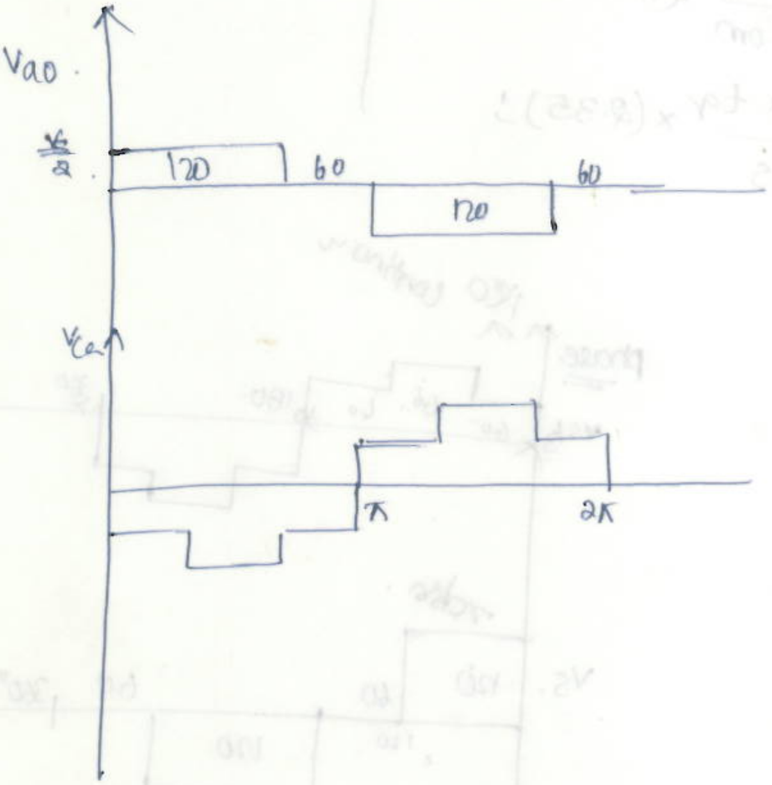
* Three ~~ton~~ thyristors conduct at any time;

* $V_s/3$

120 – mode – voltage source inverter :-

* Floating 3rd terminal (Potentially Balanced for (R) load. unbalanced for Remaining)

$\frac{V_s}{2} \times \sqrt{\frac{120}{180}} \Rightarrow$



$\frac{2V_s}{\sqrt{2}\pi} \cdot \cos(\pi/6) =$

$\frac{V_s}{2} \times \sqrt{\frac{2}{3}} =$

Vao (funda) $\Rightarrow \frac{2V_s}{\sqrt{2}\pi} \cdot \cos(\pi/6) = 0.3898 V_s$.

V_{ph}(rms) $\Rightarrow \sqrt{2/3} \left(\frac{V_s}{2}\right) \Rightarrow .4082 V_s$.

V line (rms) $\Rightarrow 0.7071 V_s$; $(\sqrt{2/3}) \times \frac{V_s}{2} \cdot \sqrt{3} \Rightarrow 0.7071 V_s$

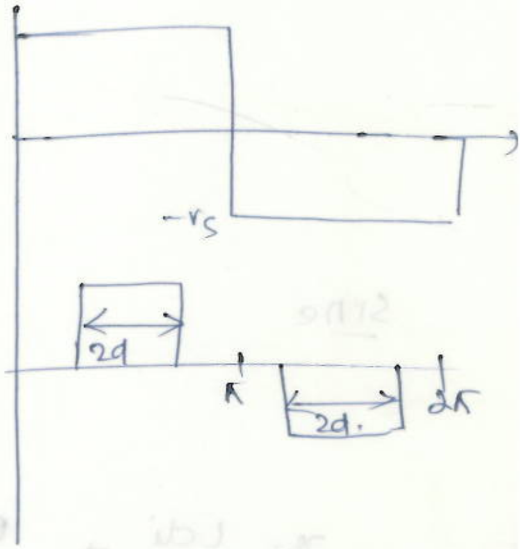
Find $\frac{V}{2} \cdot \sqrt{\frac{120}{180}}$; gives load current diff load.

then $\frac{V_s}{2} \cdot \sqrt{\frac{120}{360}}$ gives thyristor current.

PULSE WIDTH MODULATION

* ~~two~~ or less components needed,
* lower harmonics in o/p elemenated, Higher order can be filtered out. (LC filter).

Single pulse modulation



$$V_{or} = V_s \sqrt{\frac{2d}{\pi}}$$

$$V_o = \frac{4V_s}{n\pi} \cdot \sin\left(\frac{n\pi}{2}\right) \cdot \sin(nd). \quad (\max)$$

Both (sines)

$$V_{o1m} \Rightarrow \frac{4V_s}{\pi} \cdots \longrightarrow \left[\text{if } 2d = \pi\right]$$

$$\Rightarrow \left[\frac{4V_s}{\pi} \cdot \sin d\right] \text{ if } d \neq \pi/2$$

To Elemenate n^{th} Har $\Rightarrow$ make $2d = \frac{2\pi}{n}$.

$$\frac{V_{onm}}{V_{o1m}} = \frac{\sin nd}{n}. \Big\} \text{ in case } [d = \pi/2]$$

$2d = \alpha = 36$

$\frac{4V_s}{\sqrt{2}\pi} \sin(nd) \sin\left(\frac{n\pi}{2}\right)$

MULTIPLE PULSE MODULATION

$$\left[d = \frac{2\pi}{n}\right].$$

$$V_{or} = V_s \sqrt{\frac{2d}{\pi}}.$$

$2d = \alpha \Rightarrow 8\ (2d) = \frac{2\pi}{n}$. width $\Rightarrow \frac{2\pi}{n}$.

$2d = \pi$, $d = \pi/n$

$d = 180$ $\quad 2d = \alpha$

$d = 36$ $\quad n = 22°$

To eleminate n^{th} Harmonic $\Rightarrow$ $2d = \frac{2\pi}{n}$ (single pulse!)

$d = \frac{2\pi}{n}$ (multi.

Current source inverters

* no $\boxed{\text{feedback}}$ diodes,
* only SCR's, GTO's

SQ. wave current, $f_{max} = \frac{1}{10RC}$.

$C = \frac{t_q}{0.69R}$

$F_{max} = \frac{0.069}{t_q}$

sine

$C \geq \frac{0.106}{R F_{min}}$

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

$T = 1/F \Rightarrow \frac{1}{50}$.

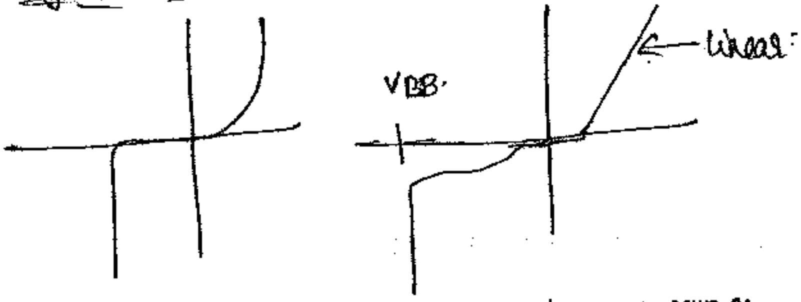
$\frac{di}{dt} = \frac{0.5}{T} \Rightarrow 25$ $\quad V_s = L \cdot \frac{di}{dt}$.

$L = V_s / \frac{di}{dt} = (\quad)$.

$t_c = RC \ln 2$.

17/03/14 IES MADE EASY POWER ELECTRONICS : Jaisairam

signal diode | power diode



* The thickness of depletion region governes reverse blocking voltage.

general purpose

- ton ≈ 25 μs
- Amps → 1 to 1000 A
- Vrating → 50V to 5KV

fast recovery

- ton = 5 μs
- I → 1A to 100A
- Vrating → 50V to 3Kv
- gold, platinum doping

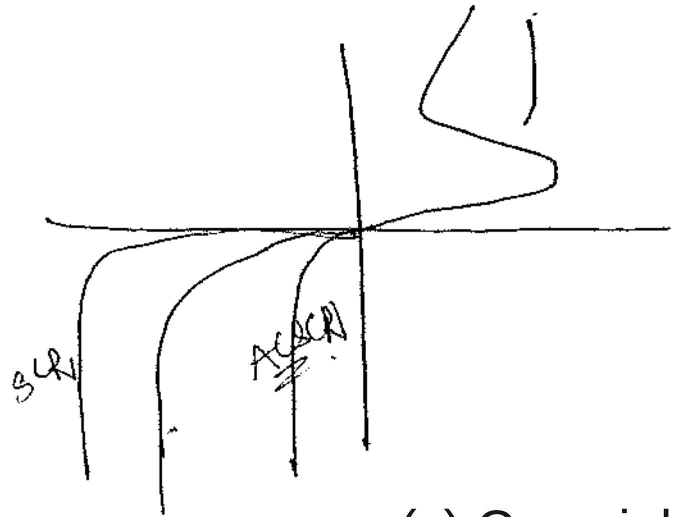
no recovery → [schottky]

- nano seconds
- limited to 300 A
- Vrating 100V
- conduction due to majority carriers
- very high switching freq

* In SCR; I(latch) = 2-4 I Hold

* Temprature & Power Avg anology :-

J.ack.son.a → Junction, casing, sink, Ambient



3 PHASE RECTIFIERS

single pulse $\Rightarrow$ $180^\circ/360^\circ$;

Two pulse $\Rightarrow$ $\frac{2\pi}{2} \Rightarrow 180^\circ$ + every 180° ;

Three pulse $\Rightarrow$ $\frac{2\pi}{3} \Rightarrow 120^\circ$, (each) ;

Six Pulse $\Rightarrow$ $\frac{2\pi}{6} \Rightarrow 60^\circ$ [Each envelop]