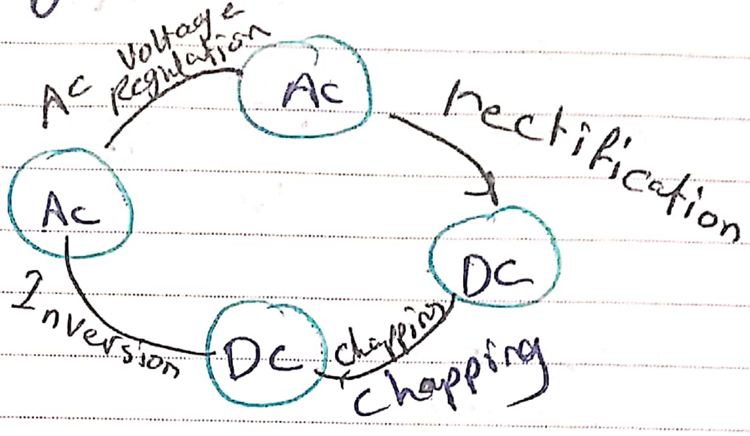
power electronics

No.

power electronics
↓
power Engineering + Electronics Eng. + Control Eng.

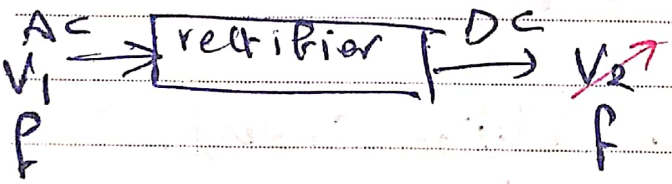
Note

why Ac? ⇒ Ac to change the frequency by reshaping the Dc into Ac



Types of converters in P.E:-

pE converter: a device that can vary the voltage current, freq, nature of a certain signal.

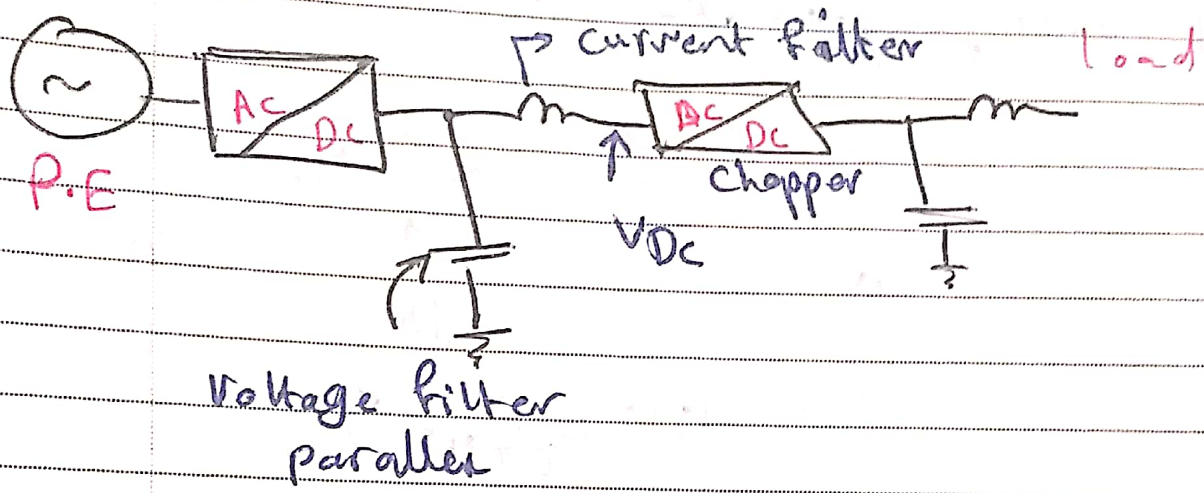


(Different Amplitude
Different nature).

① Rectification: change of nature of the signal + vary the amplitude (Avg) of the signal

Dc Signal : can be variable in Amplitude or fixed.

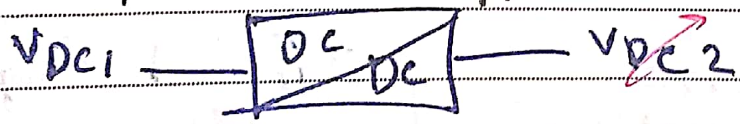
Depends ON:- the rectifier which can be fully controlled, Semi Controlled or Uncontrolled.



note: usually there is a filter at the end of rectifier (to smooth).

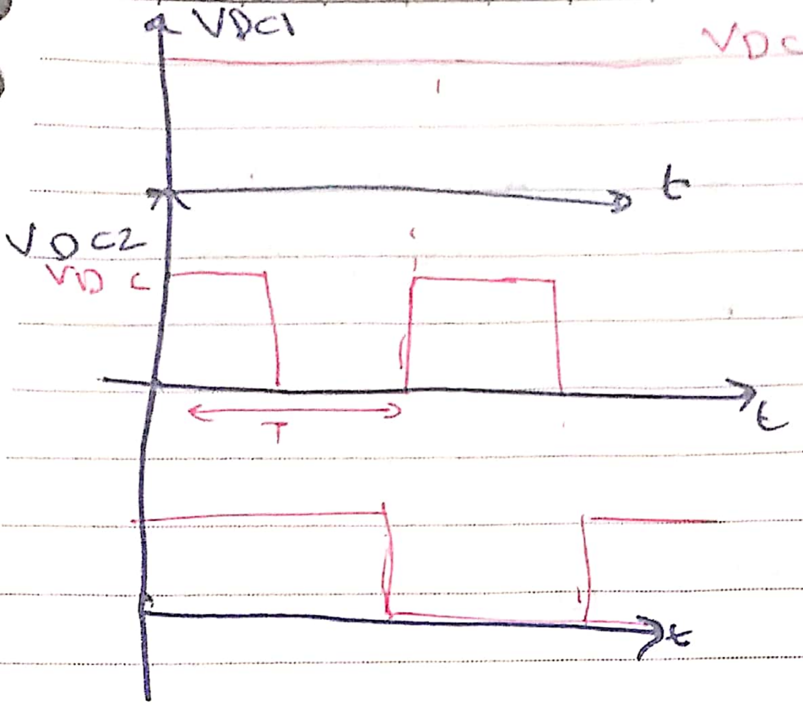
② Chopping :-

DC to DC chopper

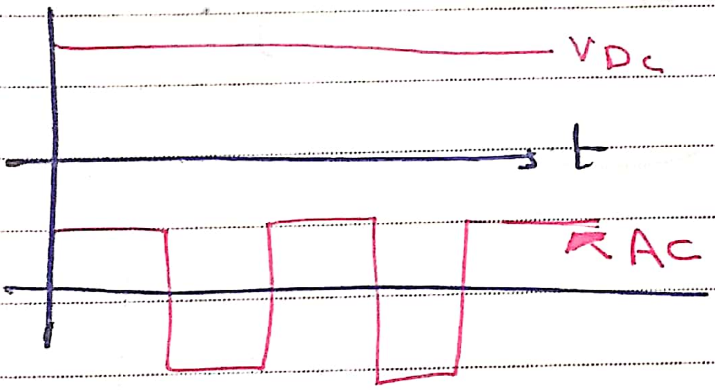


δ: control parameter (modulation Index).

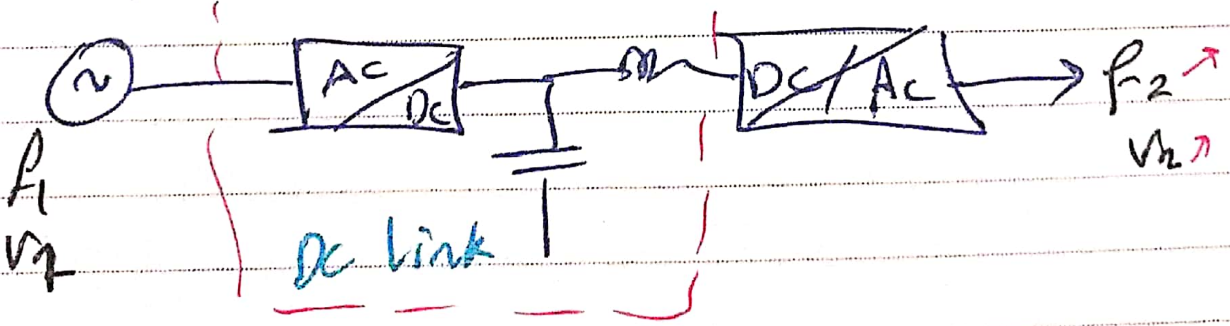
fch : filtration of harmonics



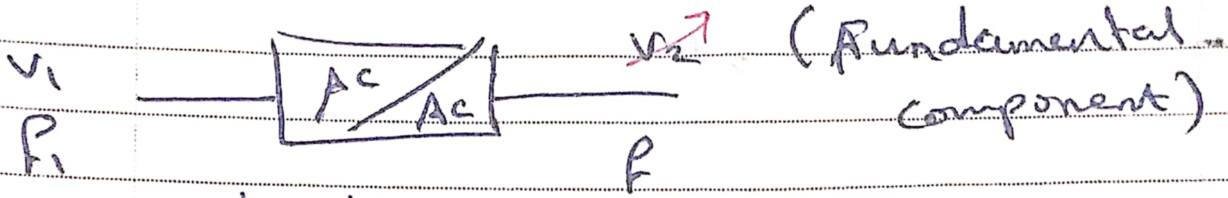
③ Inverters (Dc to Ac) converters

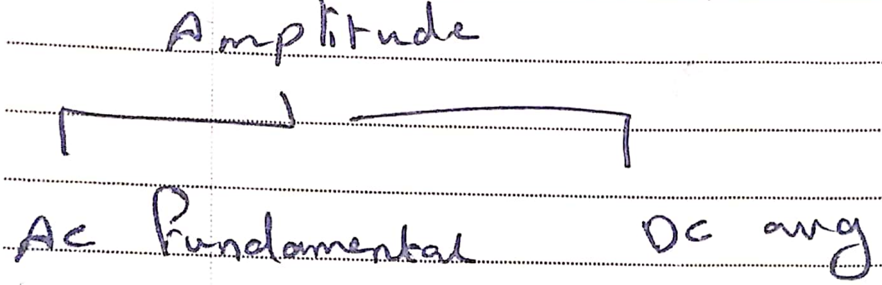


freq. converter



④ Ac voltage Regulator





The 4 converters are refered to as the family of power conditioning.

all converters in Electric power Conditioning

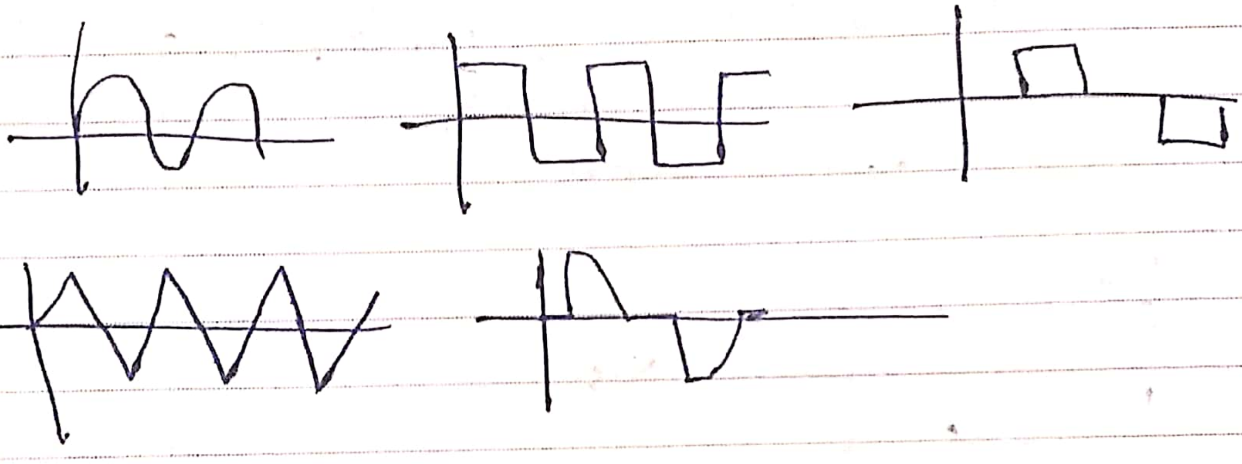
power conditioning

~~Ac~~

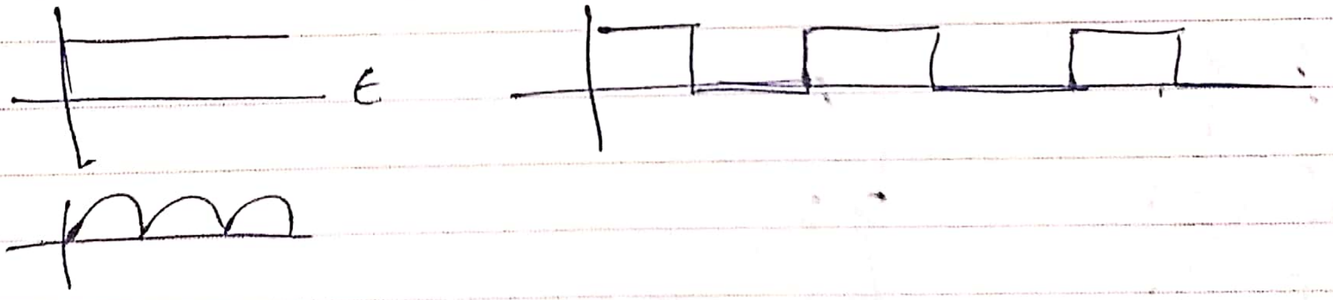
① Change of the nature of electric Signal

Ac → Dc or Dc → Ac

Ac Signal ⇒ any signal that has Zero Average amplitude



Dc Signal ⇒ any signal that has non Zero average



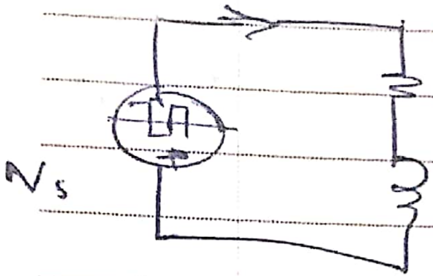
② change in frequency in Case of Ac Signals.

frequency involved in Ac Motor speed Control $N_s = \frac{60f}{p}$

③ Amplitude Control

a) average Control → Dc systems (Rectifiers + Choppers) in Dc

ⓑ Fundamental ~~amplitude~~ Control → in Ac inverters + Ac regulators

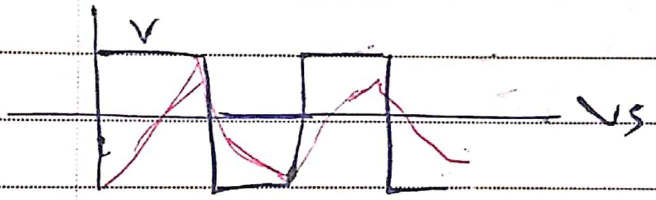


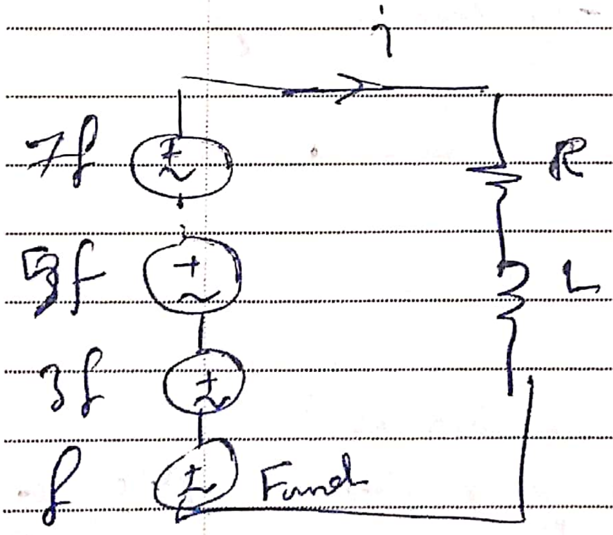
discrete

$$V_{s(t)} = \begin{cases} +V & 0 < \omega t \le \pi \\ -V & \pi < \omega t \le 2\pi \end{cases}$$

$$V\,s(t) = \sum_{n=1,2,3} V_m(n) \sin(n\omega\, t + \phi(\omega))$$

↗ fourier Series





Dc Signal Quality ⇒ Ripple Factor $= \frac{\sqrt{V_{rms}^2 - V_{av}^2}}{V_{av}}$

$0 \le Rf \le \rightarrow \infty$

$V_{rms} = V_{avg}$ ↗   ~ very bad

↑ For pure Dc   pure Ac ??

Excellent

Ac Signal Quality : Define total harmonic Destortion factor

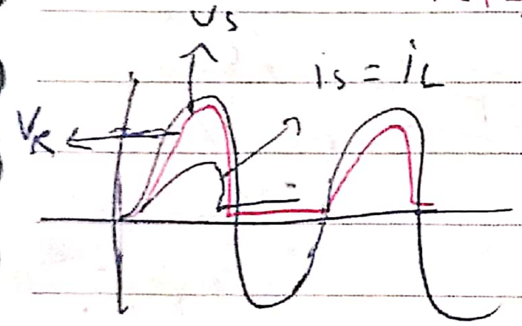
$$THDF = \frac{\sqrt{V_{rms}^2 - V_{(f)(rms)}^2}}{V_{f(rms)}}$$

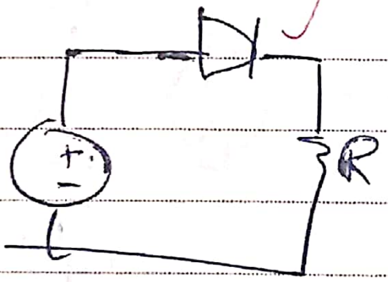
↳ $\boxed{THDF/pf}$

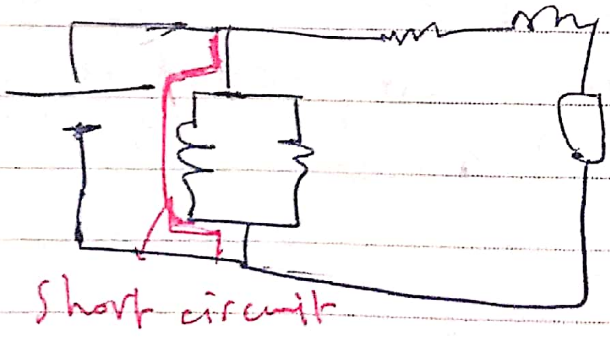
THDF

Should satisfy the Power Supplier Regulations

RF → Should satisfy the Load (Consumer).





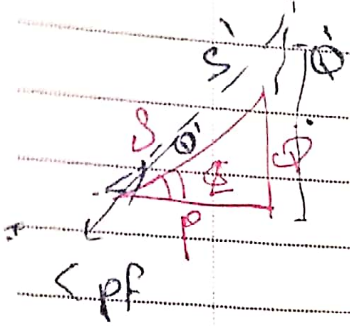


$pf = DTf * Dpf \le \cos\phi$

DTf ↓ $\frac{I_{(1)rms}}{I_{(t)rms}}$ $* \cos(\underbrace{\psi_{v(1)} - \psi_{i(1)}}_{\phi})$

φ displacement angle

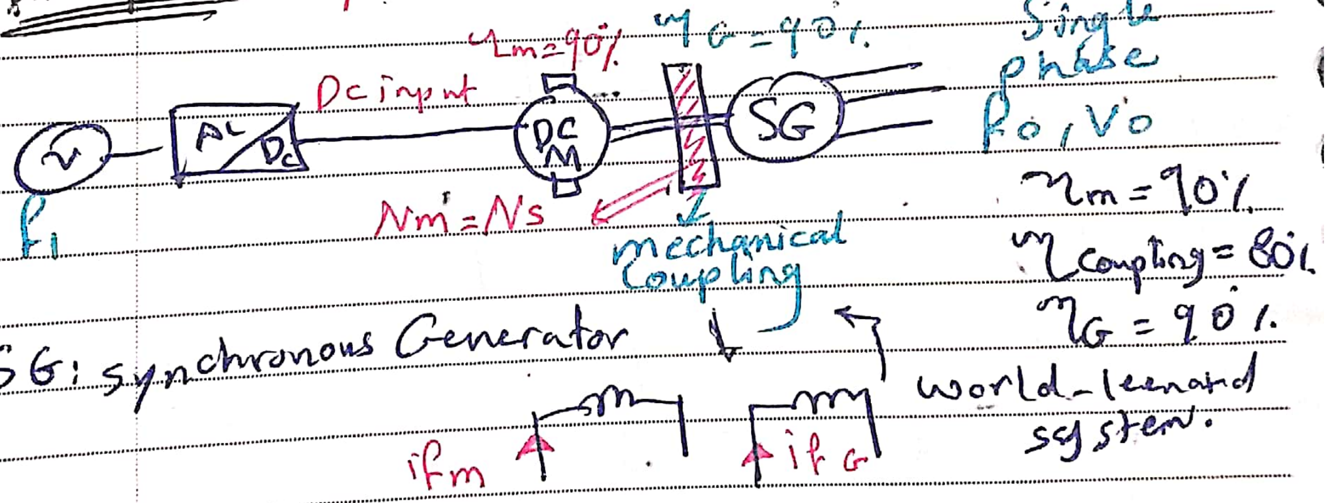
pf is usually Reduced with power electronics inverters, this is a draw back.



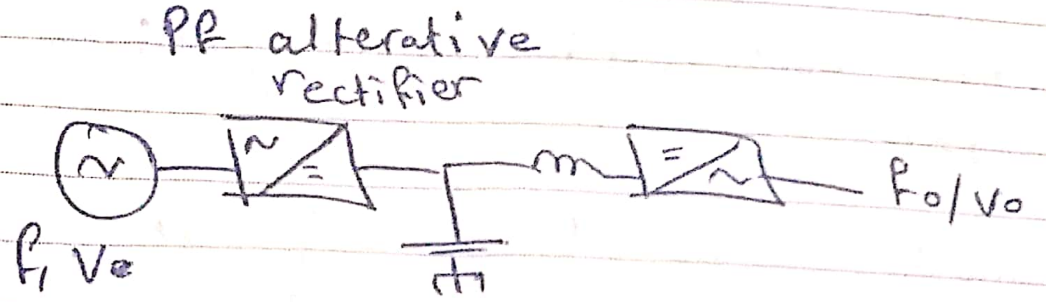
1- more losses
2- more installed Capacity

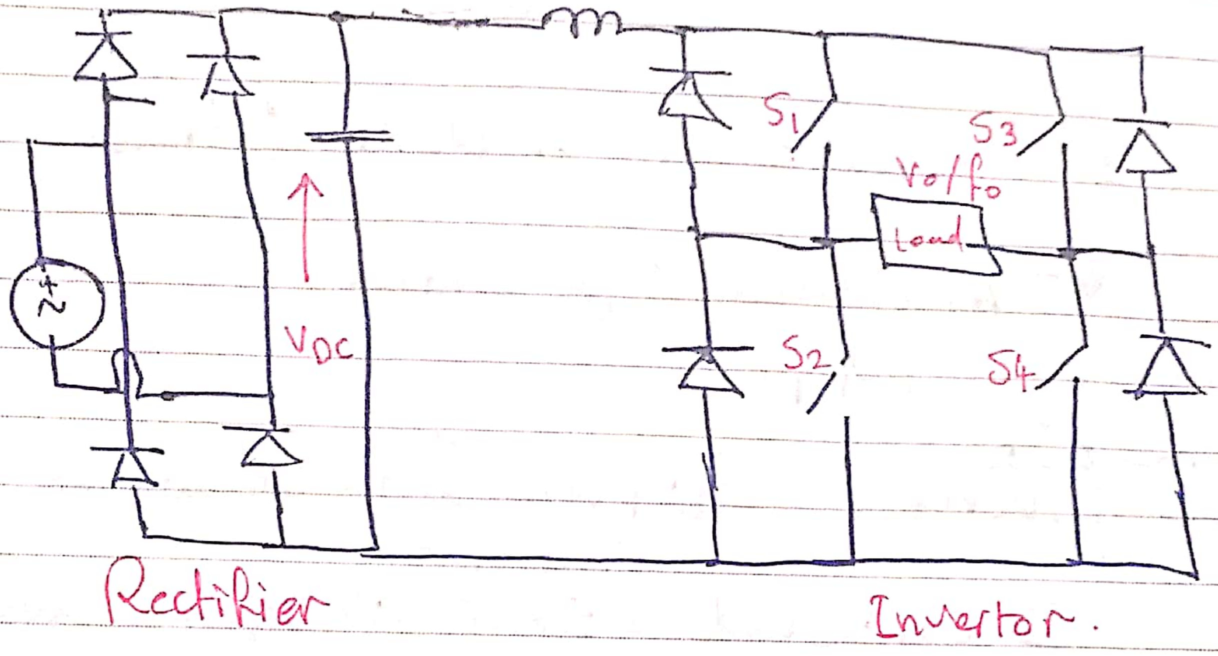
Merites ~~&~~ and drawbacks of P.E Compared to conventional systems.

Example freq control:- "Conventional"



SG: synchronous Generator





Merits of P.E

- * Much Lower Initial (capital Cost).
- * much lower maintanance requirments (maintaincefree)
- * Efficiency. 96%.
  ↓60% Conventional
- * No special foundations.
- * More Reliable
- * Less space, size & wieght
- * faster Response (efficient control).
- * No Caustic Noise.

f_o → inverter, Controlled by switching pattern of $S_1 \rightarrow S_4$.

f_o → conventional → $f_o = \frac{PN_s}{60} = \frac{P}{60} N_m$

N_m ↑ + by field weaking of DcM. $(I_{fm}\downarrow)$

↓ - Armature voltage control.

$N_m = \frac{V_t}{K I_f}$ (drop).

V_o → inverter : ① pwm with Uncontrolled rectifier

or ② Controlled rectifier with Square wave.

V_o → conventional system

$$V_{oph} = 4.44 N_{ph} * \underset{k_f * I_{fG}}{\underline{\phi_m}} * f_o$$ (controlled by I_f)

Draw backs of P.E.:-

1- No overload Capacity ; even for (very short time) this mean design to the worst case of the running.

ex : starting condition of Motor $\boxed{\text{Extra Cost}}$

No.

$\boxed{2}$ Harmonics generation, No pure Dc or pure Dc signals are generated by P. E

∴ waveforms distorted,
↓
Harmonics Impurities beside to useful Signal.

$$v(t) = V_{avg} + \sum_{n=1,2,3\ldots}^{\infty} V_m(n)(\sin(n\omega t + \psi(n))$$

$$i(t) = I_{avg} + \sum_{n=1,2,3}^{\infty} I_m(n) \sin(n\omega t + \psi(n) - \phi(n))$$

In Dc application).

V_{avg} & I_{avg} are Useful

$\sum_{1,2}$ --- are set of impurities, that Should be filtered, if not aproblem will occur

B

No.

IN AC Signals

$v(1) = V_m(1) \sin(\omega t + \psi(1))$

$i(1) = I_m(1) \sin(\omega t + \psi(1) - \phi(1))$

are the Useful Signals

Remaining are Impurities that should be avoides as much as possible

Scanned by CamScanner

Drawbacks of power electronics :-

② Harmonics Generation (Distortion of the eletric (Voltage and current Waveforms).

$$v(t) = V_{av} + \sum V_{m(n)} \sin(n\omega t + \Psi(n))$$

$$= V_{av} + V_{m(1)} \sin(\omega(t) + \Psi(1) + V_{m(2)} \sin(2\omega t + \Psi(2)$$

$$+ \dots + V_{m(n)} \sin(m\omega t + \Psi(m)) + \dots + \infty$$

Dc → Vav useful → all remaning are Impurites.

Ac → $V_{m(1)} \sin(\underline{\underline{\omega t}} + \Psi(1))$ useful → all remaning are Impurites

* To improve the quality of the signal

a) use better control topology. example multi-level wave form Rather than Square wave.

b) filtration (either voltage filtration by capacitors ~~or~~ and current filtration by inductors).

Quality paramater : THDf ↓

Harmonics Impacts

① electromagnetic distortion (badly affects communication systems)

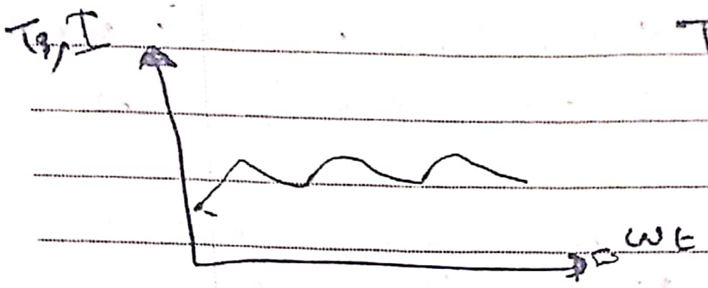
② badly affect nearby consumers (supply voltage distortion)

③ Overheating of electrical machines (motors in specific).

In Dc motors → Torque developed due to Average current

other components Cause ⓐ- Torque pulsation badly realized at low speed.

ⓑ- motor Overheating.



$T_q = k i$

$P_{cu} = I^2 R_a$

Copperloss

$I = I_{av} + I_m(1) \sin(\omega t + \varphi(1) - \Phi(1)) + ----$

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

Pcu without harmonics → (pure Dc).

$= I_{av}^2 R_a$

Pcu with harmonics $= I_{rms}^2 R_a$

Since → $I_{rms} > I_{av}$ then Pcu with harmonics > Pcu without

$$\frac{P_{cu} \text{ without}}{P_c \text{ with harmonics}} = \left(\frac{I_{av}}{I_{rms}}\right)^2$$

this leads to overheating by the Same Ratio, The motor may not tolerate such an increase of heat and may be damaged

Solutions:- ① motor oversizing
Leads to More motor cost + lower efficiency due to Running Underloaded

② Motor deRating, implying that the motor is loaded by less load power by ~~average~~ $\left(\frac{I_{av}}{I_{rms}}\right)$

Harmonics

in Ac $\left(\frac{I_F(rms)}{I_t(rms)}\right)^2$ $\frac{P_{cu} \text{ without harmonics)}}{P_{cu} \text{ (with harmonics)}}$

derating factor = $\frac{I_F(rms)}{I_{total}(rms)}$

Harmonis effects on Pf in

$Pf \neq \cos\phi$.

power factor Reduction is One of the drawbacks of powerelectronics

pf can Only be defined as $\frac{\text{Real power}}{\text{Apparent power}}$.

Rectifier → $pf_{in} = DPF * DTF < \cos\phi$

Merit: More efficient than the drawbacks
Research activities are directed towards improving the performance evaluation of power electronics systems.

Classifications of power electronics switches.

1- diode family → ① Conventional diodes (up to 400 Hz) → (Rectifier) diodes
② Fast Recovery diodes (high freq) → (Inverter/Chopper) diodes

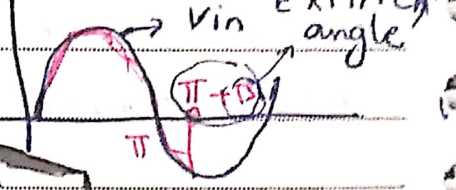
2- Thyristors family (1st one SCR) father of P.E

3. power transistors (main switch IGBT)

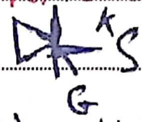
Ⓐ Classification According to the Controllability of switches

Supply ↰ load ↰

1) Uncontrolled ON, Uncontrolled off → diodes



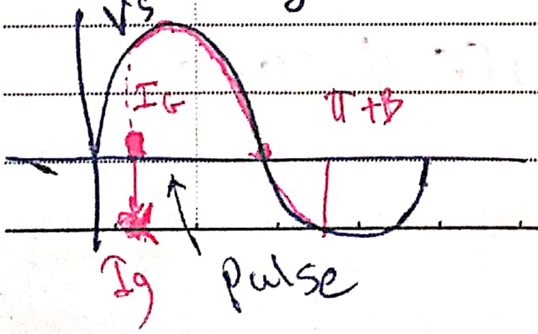
2) controlled ON, Uncontrolled off
(Thyristors) SCR Thy.

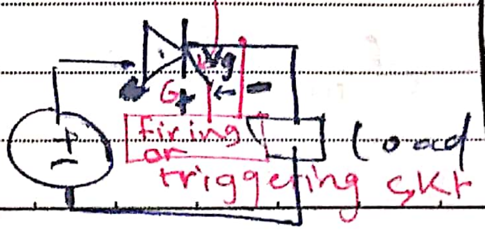


3) Silicon Controlled Rectifier

β: extinction angle
load dependent
$0 \leq \beta \leq ..$

controlled on by the current into the gate





$V_G = 1.5 \rightarrow 5V$

I_G switch power dependent scale: few to severals tens of mA

* *

SCR can be switched on when:

a- F.B   b. Apply gate current at an angle α

α known as the firing angle / the triggering angle oR the phase delay angle

$0 \leq \alpha \leq \pi$

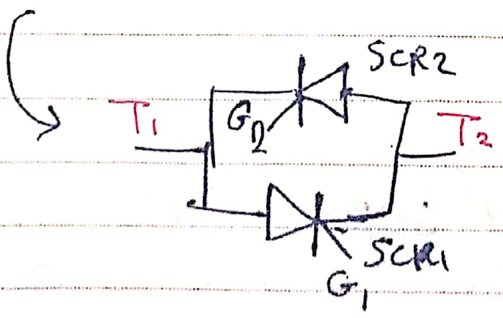
* switch off is uncontrolled (depends on the load nature & α

Once the SCR is ON, it behaves like a diode (the gate looses control)

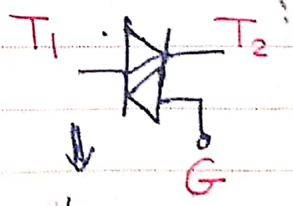
Frequency α is Same as the Supply freq.
This is simplies α is synchronized with Vs.

TRIAC: TRIOD for AC

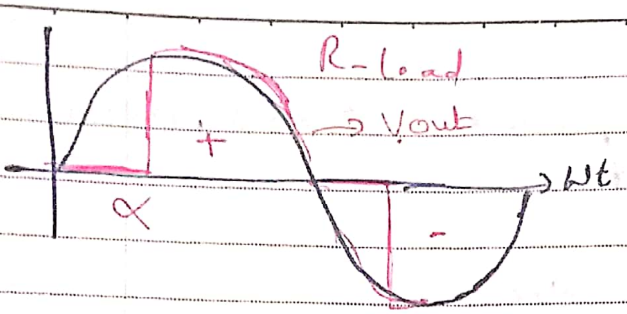
equivalent to two Untiparallel connected SCRs

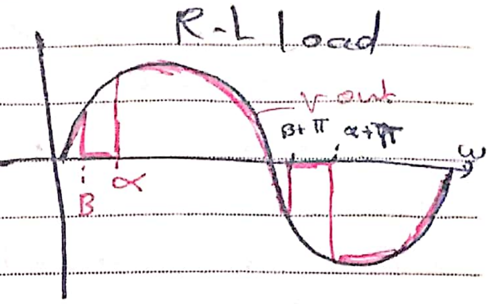


AC switch



low power AC switch



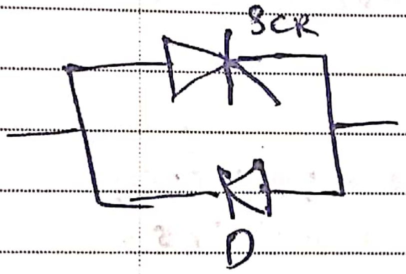


18/6

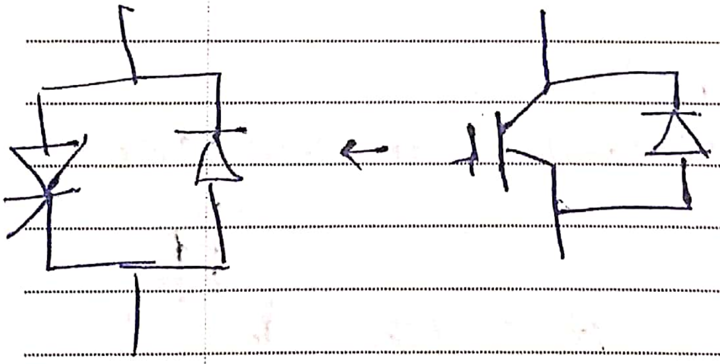
classifications of P.E switches

* Controlled ON, Uncontrolled off
  SCR, TRIAC, RCT

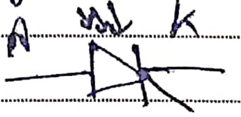
RCT : Reverse Conducting Thyristor
(Thyrode)



was used in SCR-Controlled inverters
SCR : main switch
D : free wheeling / Feedback Switch



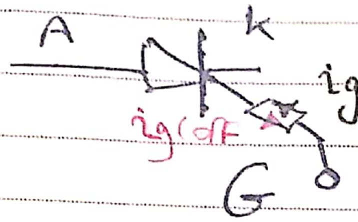
LASCR : Light activated SCR



very large power Applications.
(HVDC T)
High voltage Direct Current transmission

No.

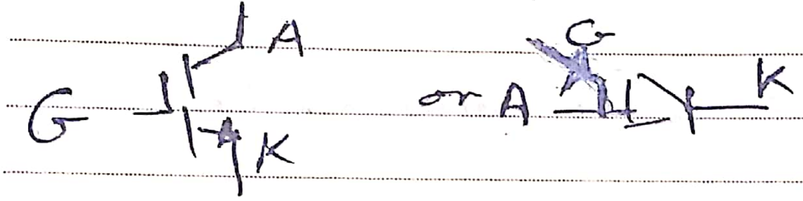
3) Controlled ON, Controlled off



ig (ON) ① GTO : gate Turn off Thyristor

to switch ON: Same as SCR
to switch off :- ne gate current pulse, but it's amplitude must be very large, Igate (off) ≃ 80% Iload.

② MCT: MOS controlled Thyriston

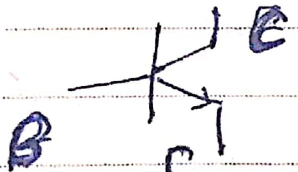


switch ON: Short positive pulse to the Anode with respect to the gate ⇒ G-
A+

switch off: short negative = = =
G+
A-

almost same amplitude (small pulse).

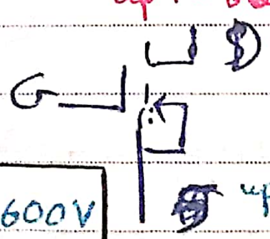
③ All Transistors are Controlled ON, Controlled off



up to 10kHz, 200A, 600V

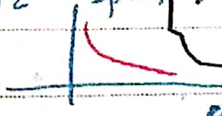
BJT
Bipolar
Junction Transistor
(current Controlled)

up to 800V

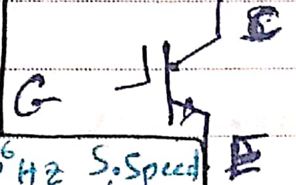


600A

up to 10^6 Hz



MOSFET
(Voltage controlled switch).
-20 V < VGS < +20 V



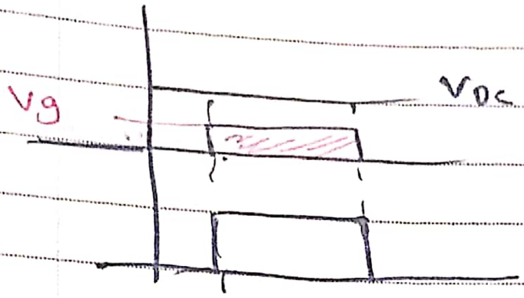
→ insulated Gate
IGBT Bipolar
Transistor

99% invertors and choppers use IGBT
- voltage Controlled
up to 100kHz

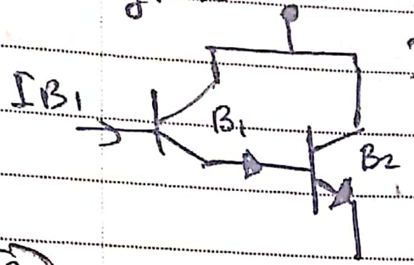
FIVE APPLE
2000V
2000A

Scanned by CamScanner

No.



Darlington



$I_{B2} = I_{E1}$

$\beta = \beta_1 * \beta_2$

Ⓑ classification in Terms of nature of the Control signal.

a) Latching switches
b) continuous switches. (Trigger)

@ latch switching : single short pulse is required to switch on and off if controlled off
all Thyristors are latching switches.

(b) continuous switching :-
all Transistors (Drive)

Ⓒ Voltage with standing Capability

① Unipolar
tolerate one polarity either positive or negative
all transistors,
Certain Types of GTO, MCT

② bipolar
Certain Types of GTO
SCR, TRIAC, LASCR
~~[illegible]~~
Charge control

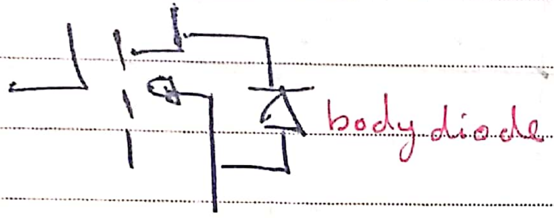
D) Current with Standing Capability.

a) Unidirectional

all remaining switches are Unidirectional.

b) bidirectional

TRIAC, RCT (AC), MOSFET Module

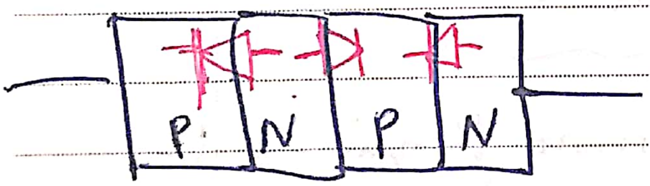


SCR: Silicon Controlled Rectifier.

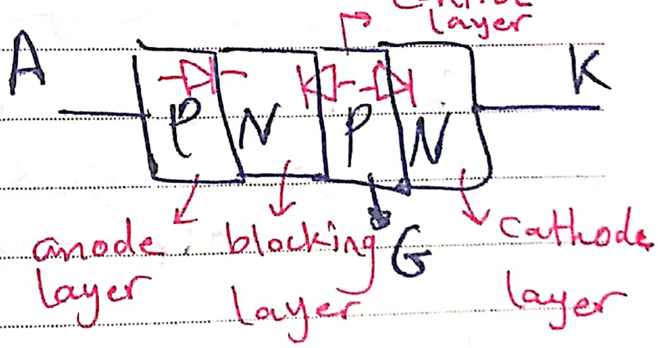
Defined:-

it is a 4-Layer, 3-Terminals, Bi-Stable "tri-stable", Semi conductor switch

-ve case



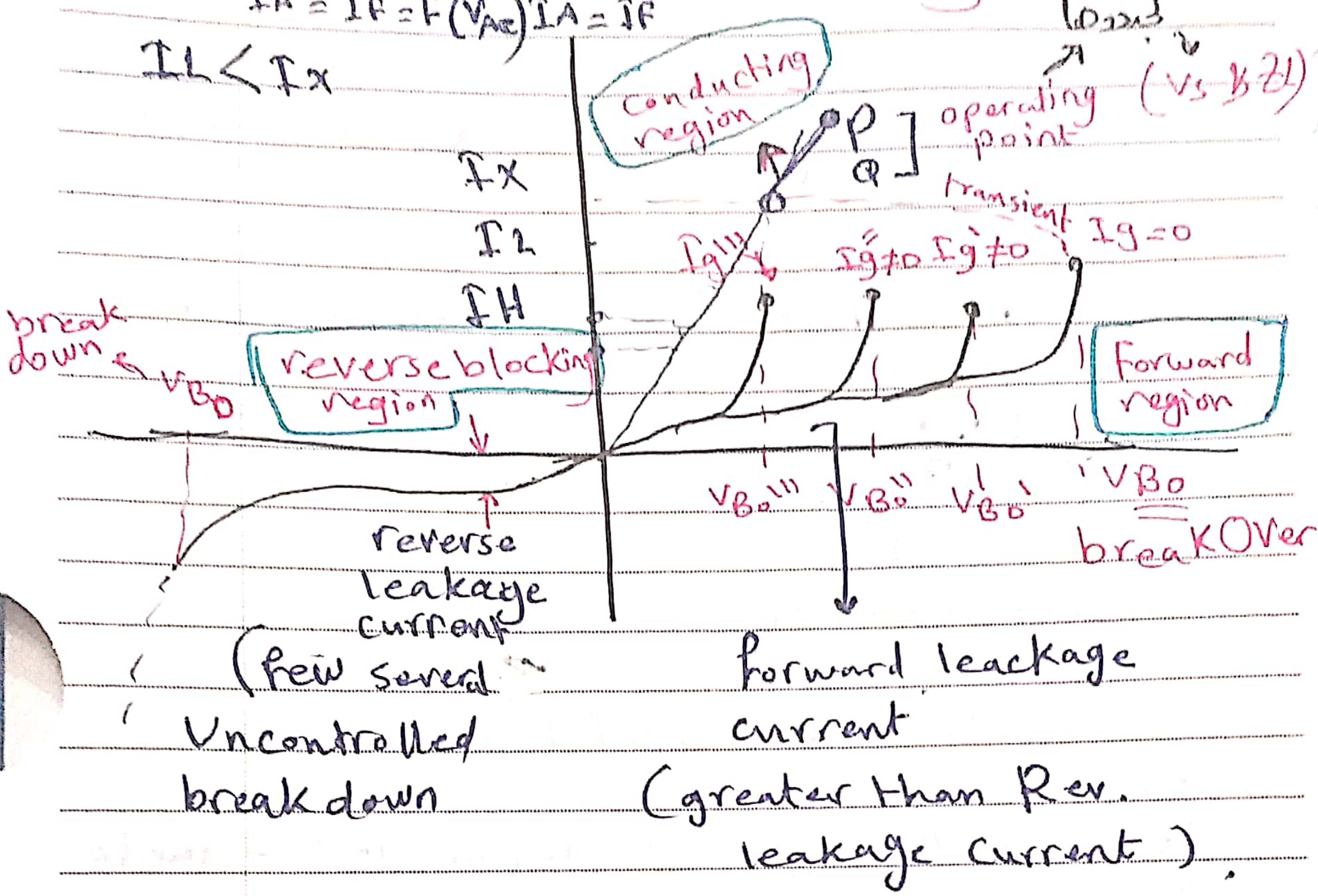
+ve case



* to be forward bias: (+ve) voltage to be connected to anode with respect to the Cathod.

* V/A characteristics (steady state).

$I_A = I_F = f(V_{AK})$ $I_A = I_F$



* I_L : Latching current :-

The Min. Forward Current Required to Start SCR conduction
off → ON state

I_H → Holding current

The Min Forward Current required to keep the SCR ON

No.

above I_H → ON
below I_H → off

Switching off process = Commutation process

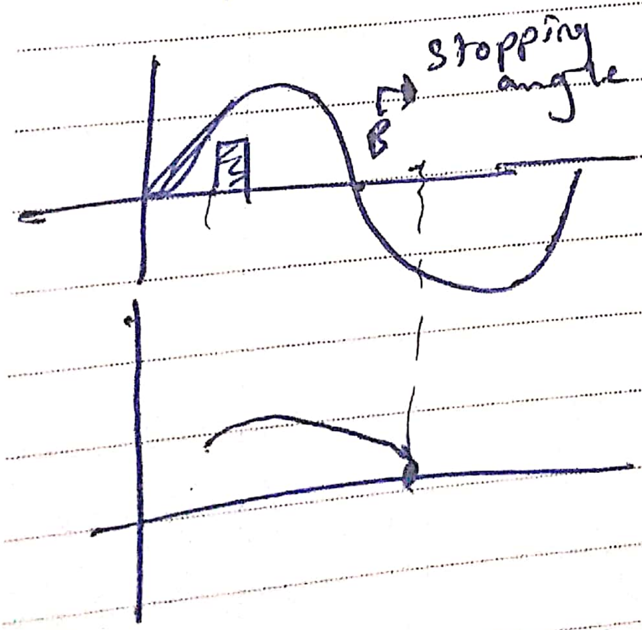
Note:- Load Highly Inductive → wider pulse

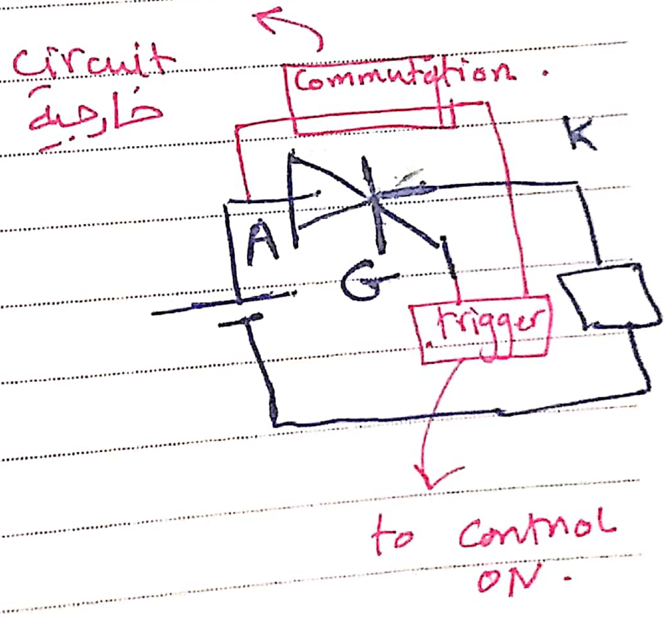
Commutation

Natural

Supply Ac

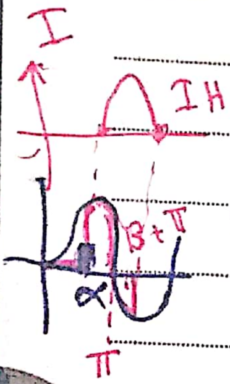
Forced

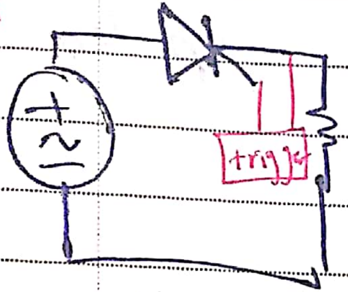




Sunday :- 23/6

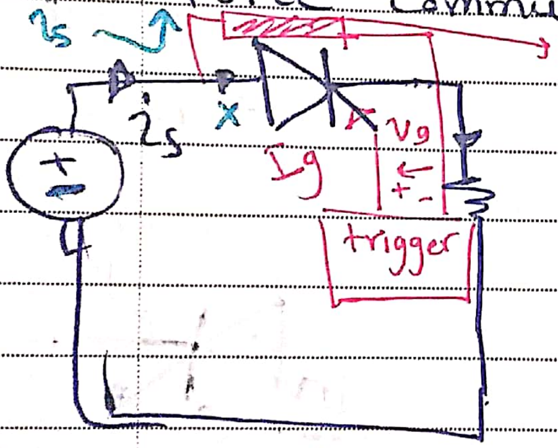
to switch off (commutation) SCR
a - If < IH
and
b - SCR to be reverse biased.





Commutation Can be natural in Ac Excited circuits.

Force Commutation in Dc Excited Circuits -

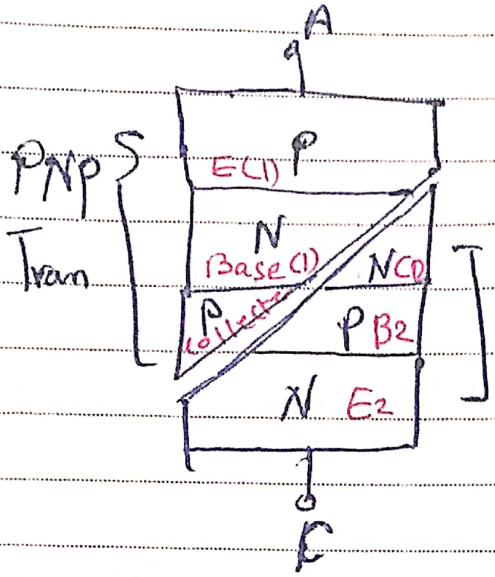


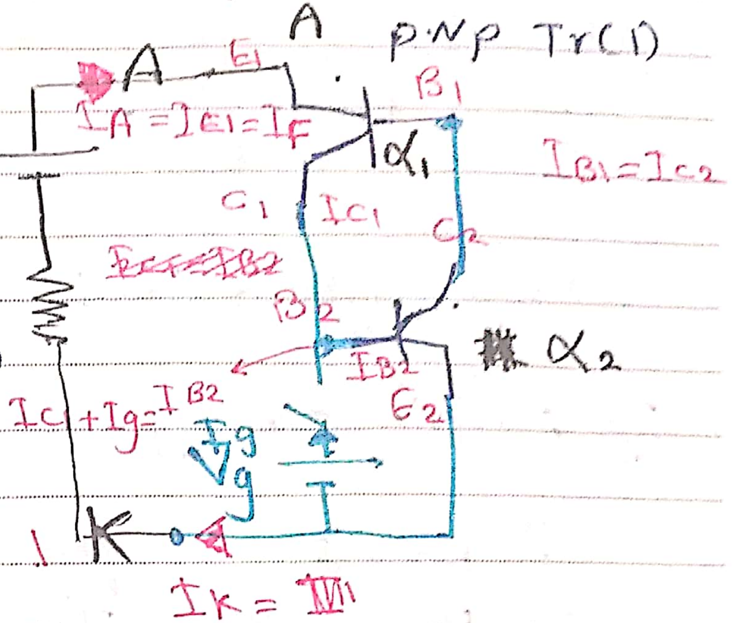
force commutation circuit
(- provides alternative path for SCR Current

b - to apply Reverse biasing to the SCR
(by Using Commutation Circuitry Capacitors + Auxiliary Thy. + ...).

R.B to be applied for aperiod ~~of~~ T that is slightly greater than Toff
(Turn off Time, Usually given by the manufacturer).

The two transistor model of SCR





$$\boxed{I_C \;:\; I_B \quad I_E}$$

$$I_{E1} = \alpha_1 I_{E1} + I_{CBO(1)}$$

$$I_{C2} = \alpha_2 I_{E2} + I_{CBO(2)}$$

$$I_f = \frac{\alpha_2 I_g + \overset{I_{CBO}}{\left(I_{CBO}(1) + I_{CBO}(2)\right)}}{1-(\alpha_1+\alpha_2)} \qquad (\alpha_1+\alpha_2) < 1$$

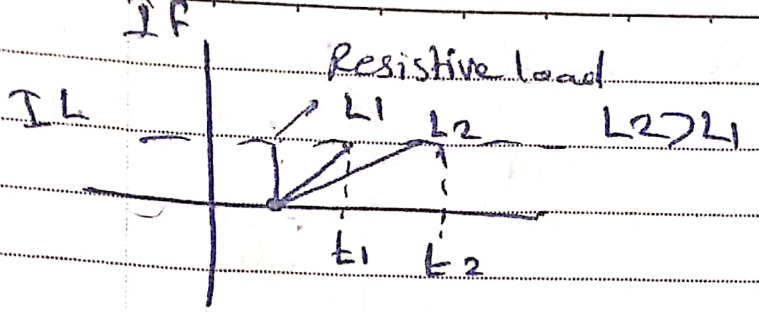
$$0.95$$

* if If is made greater than I_L then the SCR is turned ON Successfully

How Can If increased to switch ON SCR ??

↳ by applying asufficient gate Signal.

natural method to switch ON SCR



2) by light Activation (for LASCR)

3) switch ON by increased leakage Current

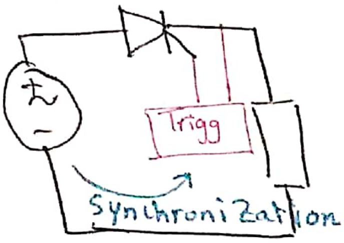
I_{CBO}, I

a) by applying High V_{AK} Voltage externally Such that $V_{AK} > V_{BO}$ (not a proper method)

b) by Tempreture rise over the Recommended Value

Firing Cuircuits

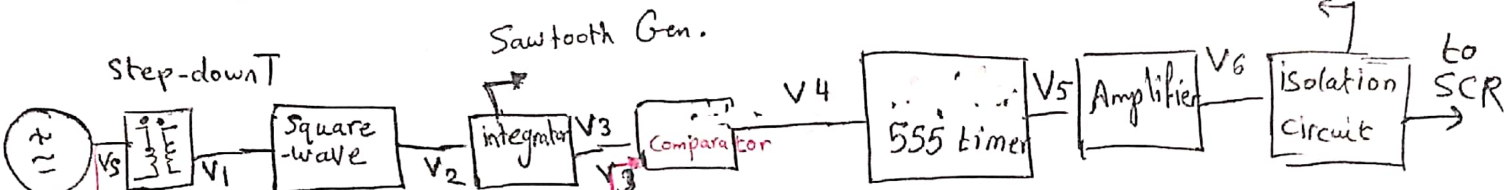
Firing → triggering

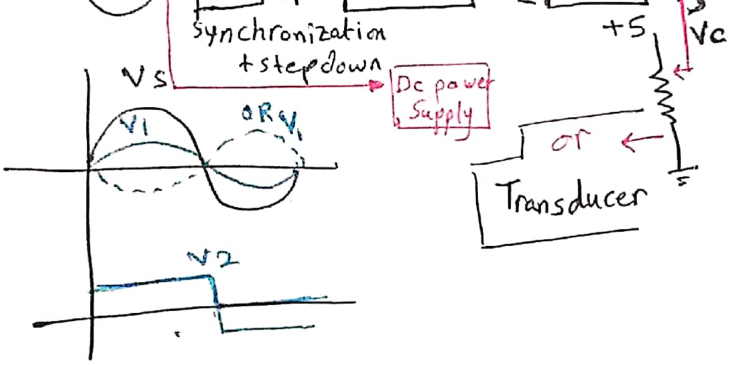


Vs, f

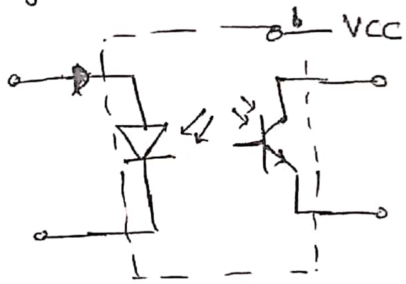
Core material never Saturate.

↑ pulse transformer or opto Coupler





opto Coupler

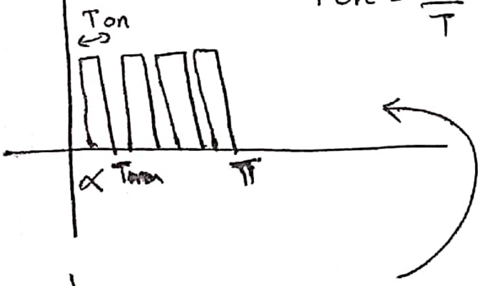


→ Carrier frequency (10–20)KHz

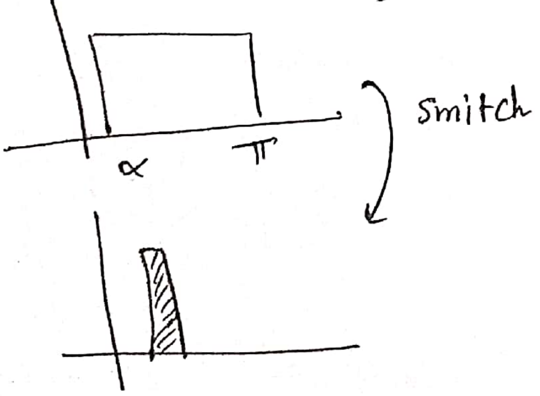
$f_{ch} = \frac{1}{T}$

$\gamma = \frac{T_{on}}{T}$

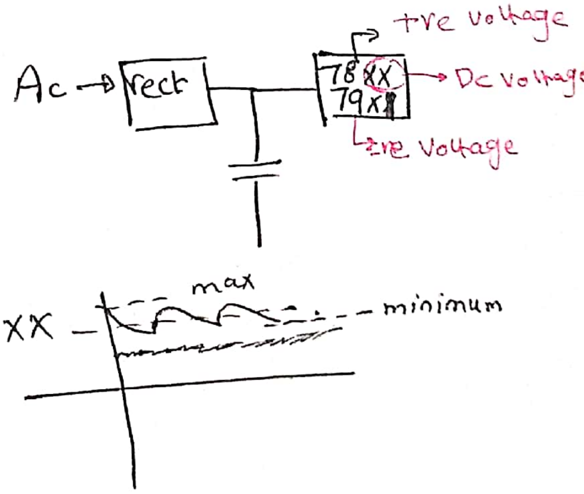
$\simeq 0.6$



555 Timer



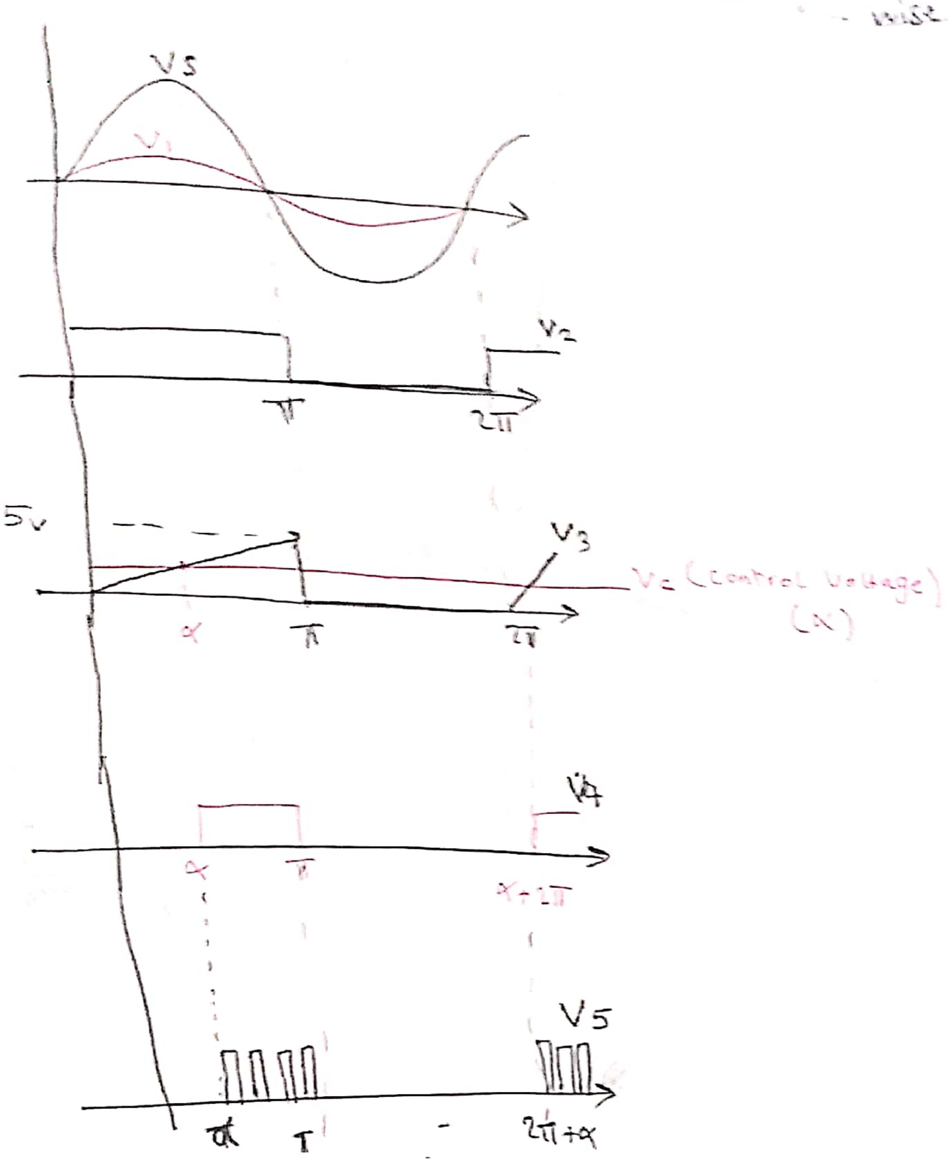
Dc power Supply.



XX must be > minimum

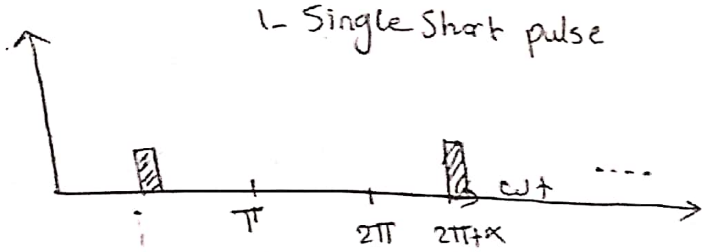
- wise over the Recommend

②



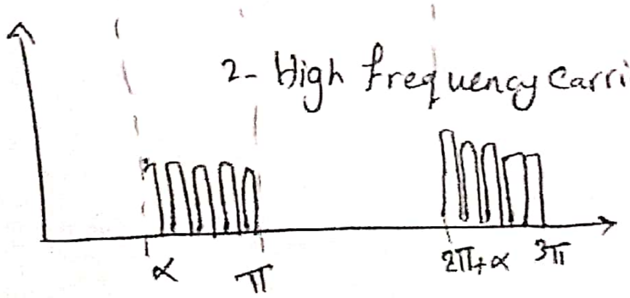
Types of Triggering Signals :-

1- Single Short pulse



- less Losses
- Uncertain Trig especially for higher Inductive Loads.

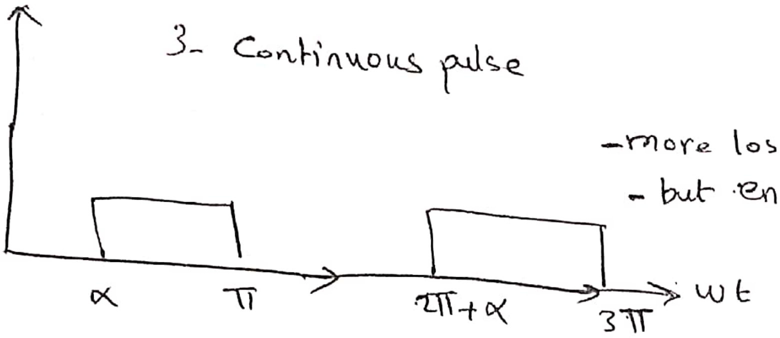
2- High frequency Carrier Signal.



- medium losses
- ensure trig

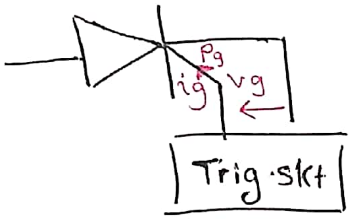
⟸ MOST Common.

3- Continuous pulse



- more losses (high losses).
- but ensures Trig.

Gate characterstics :-

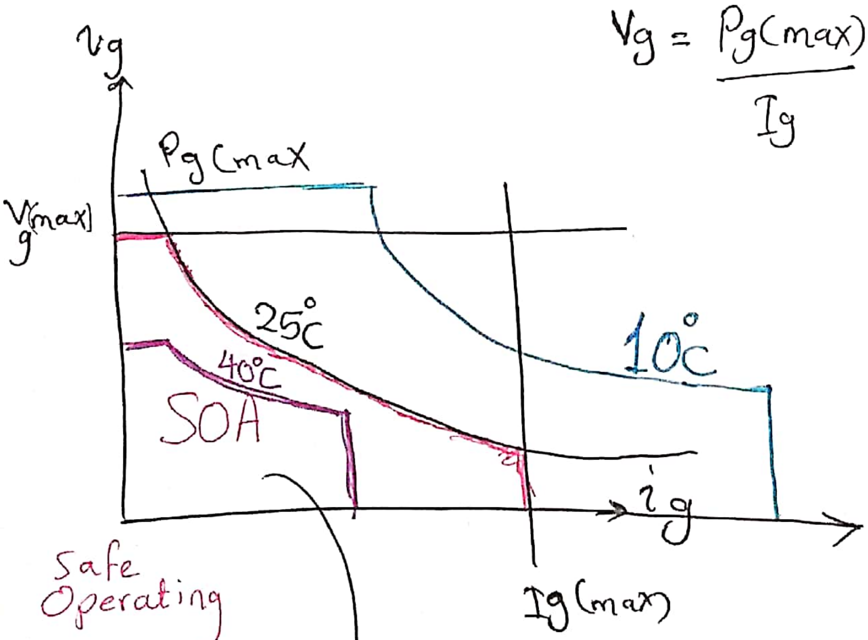


$V_g = f(i_g)$.

To start with the limitations.
(given by the Manufacturer).

- $V_g(max)$
- $I_g(max)$
- $P_g(max) = V_g * I_g$

$$V_g = \frac{P_g(max)}{I_g} = \frac{\text{constant}}{I_g}$$



Safe Operating Area

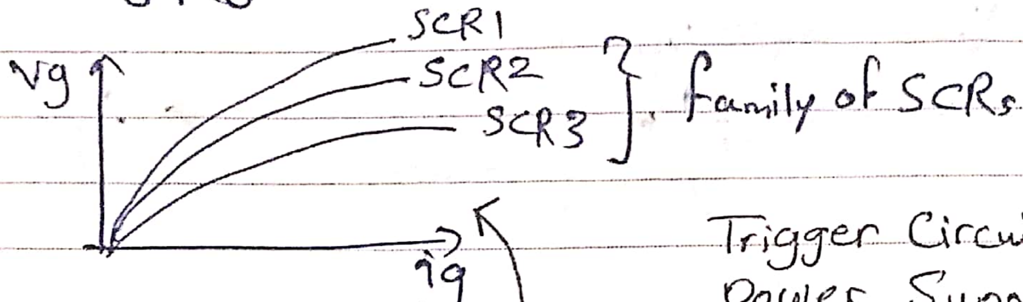
Usually given as a function of Tempreture → Ampient

25-6-2019

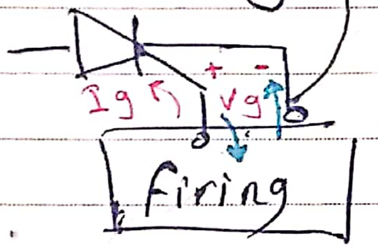
Gate characteristics:-

Ⓐ Safe Operating Area SOA
(Tempreturoe dependent, Given by the Manufacturer).

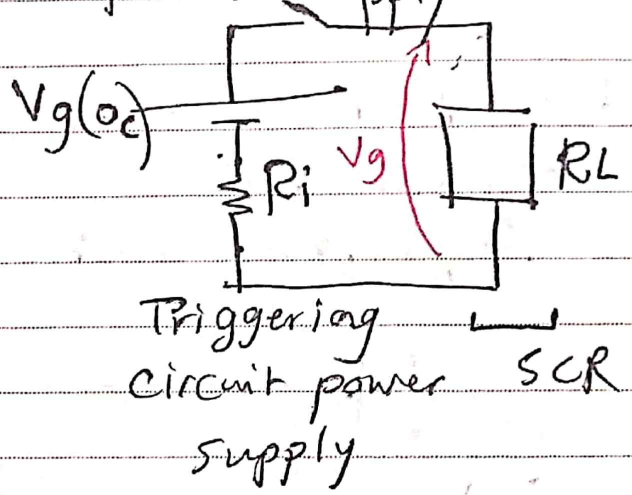
Ⓑ $V_g = F(i_g)$ of the SCR itself (Manufacturer data).



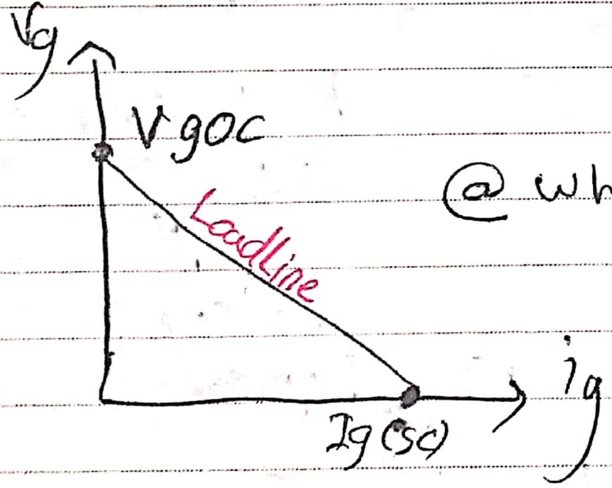
Ⓒ



Trigger Circuit is Dc power Supply



$V_g(oc) = V_g + i_g R_i$

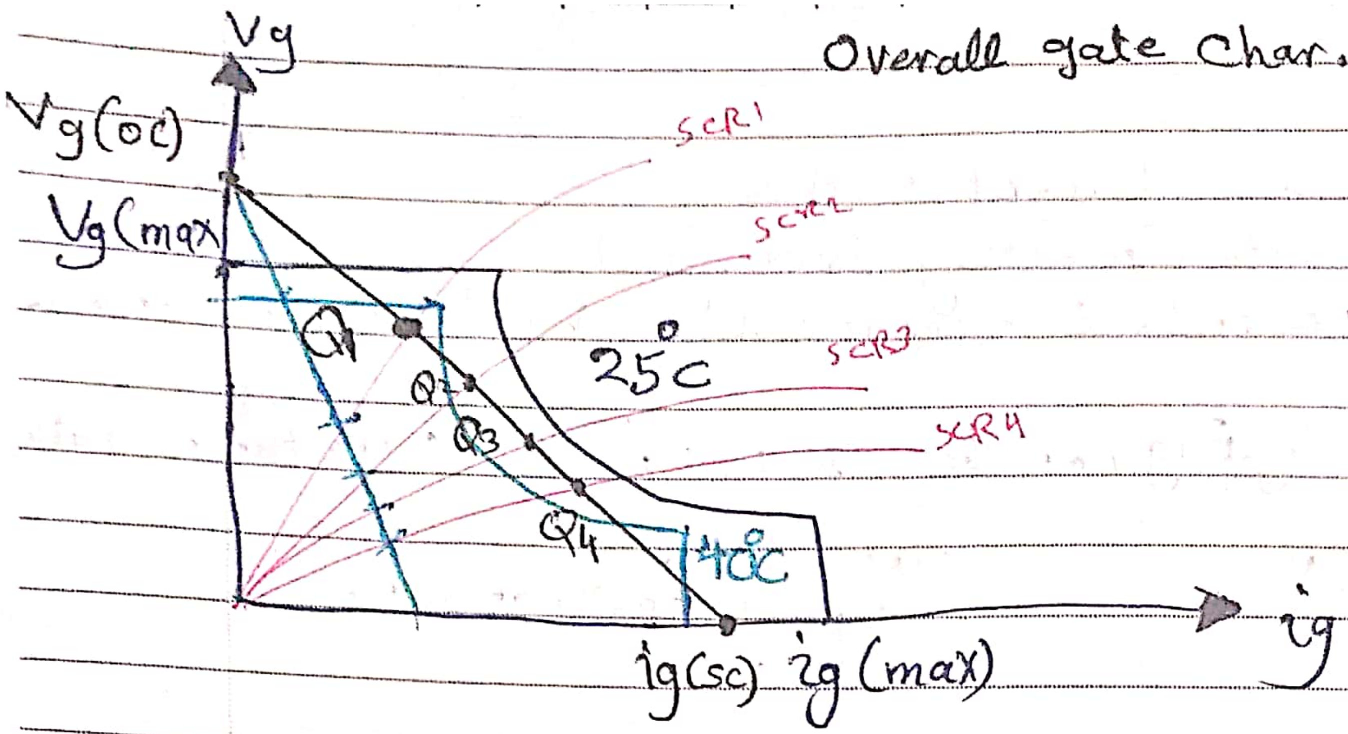


ⓐ when Open circuitind, $I_g = 0$
$V_g = V_o(oc)$

ⓑ when Short circuited
$V_g = 0$. $V_g(oc) = I_{g_{sc}} R_i$

$$I_g(sc) = \frac{V_g(oc)}{R_i}$$

Overall gate Char.

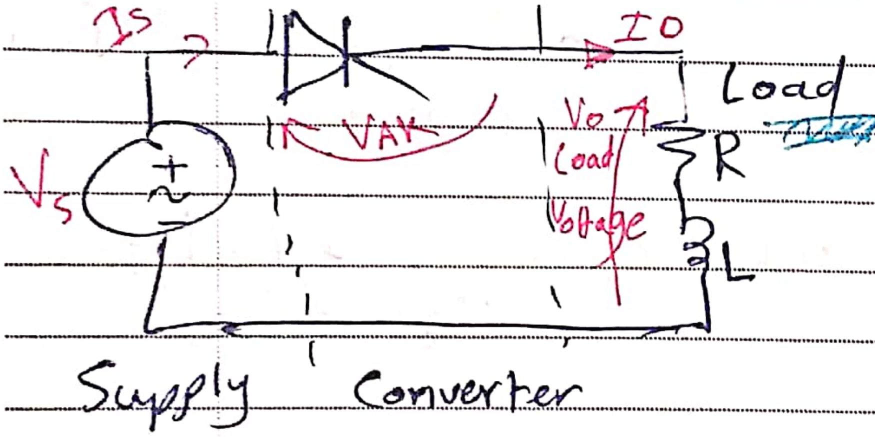


Circuits analysis :-

Rectifiers :- Controlled

to start with

Single phase - half wave Controlled Rectifier



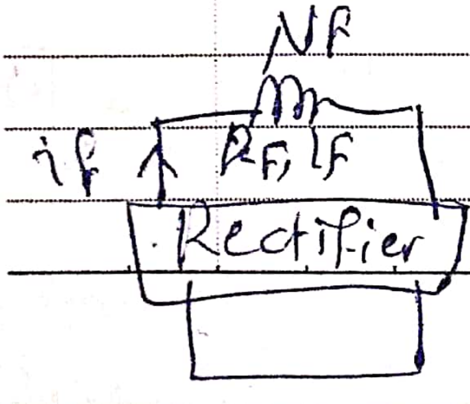
R →

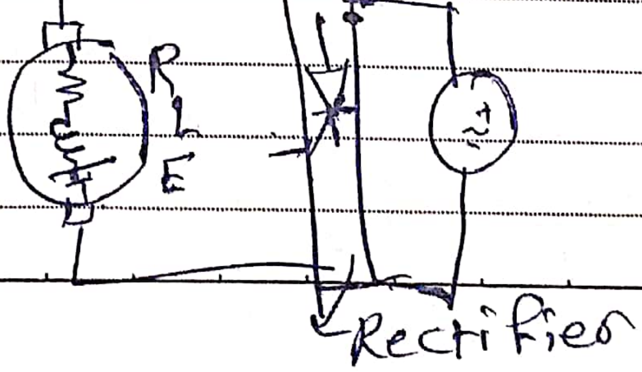
R-L field skt

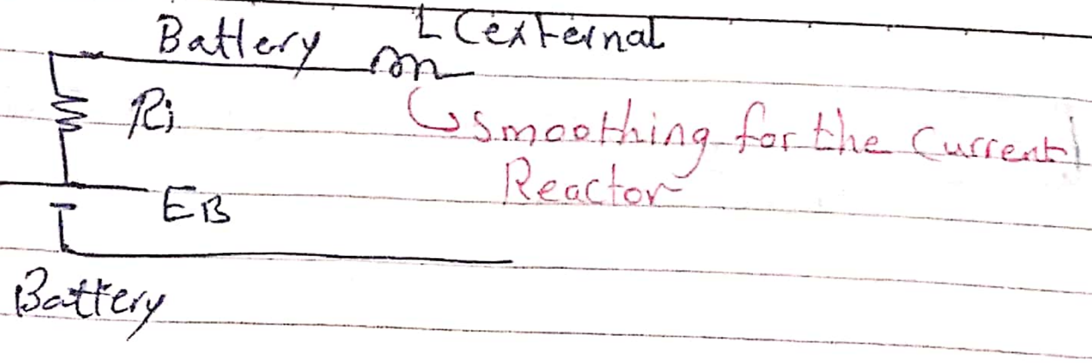
R-L-E

Battery

Demotor







Supply Side (Line Side)

$V_s = \underline{V_m}\,\sin(\omega t) \longrightarrow 2\pi f$.   [f: Supply or fundamental frequency.

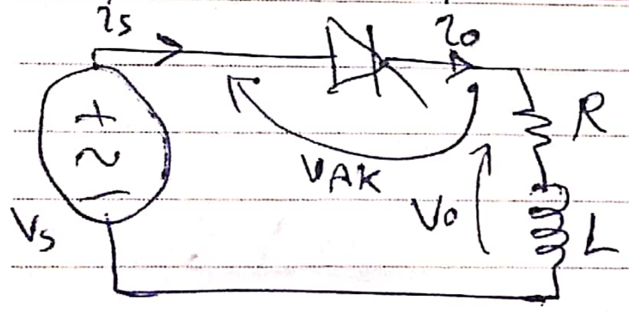
↳ peak per phase (max).

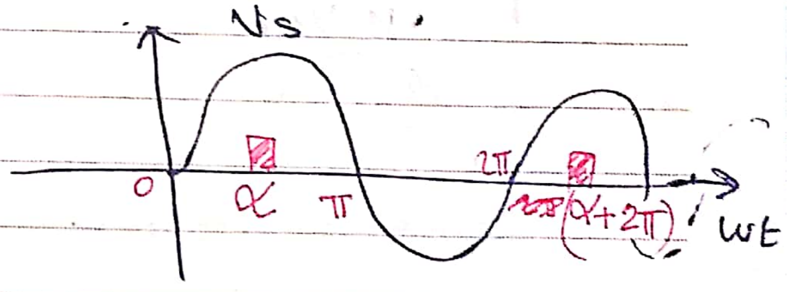
$\tau = \frac{L}{R}$ → Load Time Constant.

$\tau \to 0$ for pure Resistive load.

$\tau \to \infty$ for pure inductive load.

Single phase, half-wave, controlled Rectifier





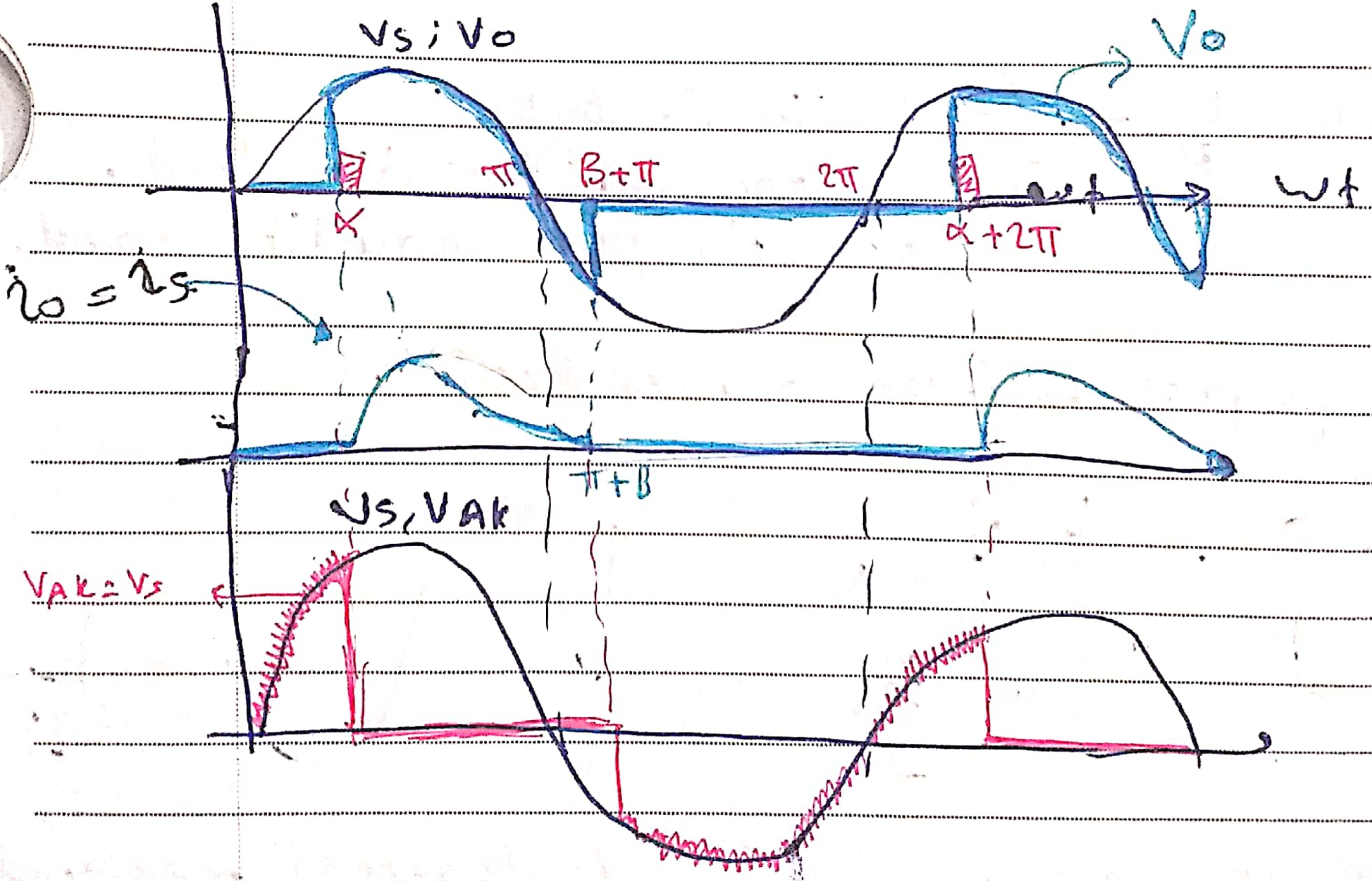
α: The angle at which the SCR Triggered, measured with respect to the Zero-crossing point, after which the SCR becomes forward Biased

No.

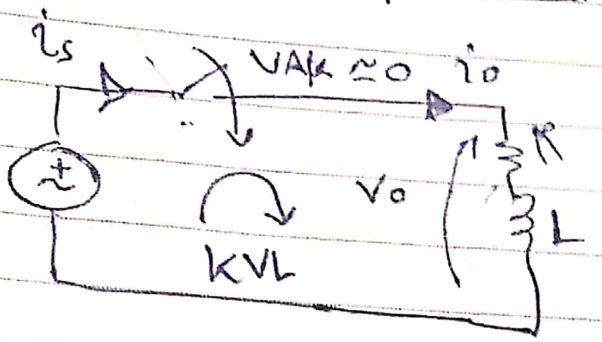
$\boxed{0 \leq \omega t \leq \alpha}$ SCR is Forward biased But Untriggered. ⇒ (Forward blocking Region) only small negligible Forward leakage current is expected.

$$\therefore \underset{\text{zero}}{\cancel{V_{out}}} + V_{AK} + (-V_s) = 0 \qquad \boxed{V_o = 0}$$

$$\boxed{\therefore V_{AK} = V_s}$$



$\alpha \le \omega t \le \boxed{}$



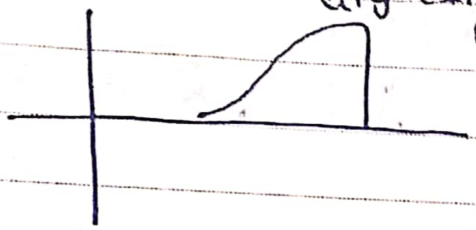
1st order non-Homo. D.E

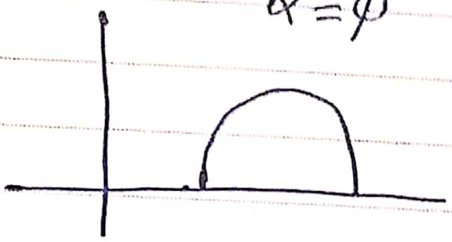
$V_o = V_m \sin \omega t = IR + L\frac{dI}{dt}$.

$i = i_s = i_o$

Current shapes


Low inductive load


High Inductive load


$\alpha = \phi$

$PIV = V_m$ (peak inverse Voltage).

SCR Voltage Rating $= (\underbrace{2 \to 3}_{\text{safety factor.}})$ PIV

$V_s = 240V$ Rms

SCR Rating $(2 \to 3) * \sqrt{2} * 240$

$= (2-3).\,339$

$680 \to 1020$ V.

Solution for i

$$V_s = V_m \sin \omega t = iR + L\frac{di}{dt}$$

$$i = \frac{V_{max}}{Z}(\sin\omega t - \phi) \oplus \text{steady state solution.}$$

$$A e^{-t/\tau}$$

$$\Downarrow$$

$$i = \underbrace{\frac{V_{max}}{Z}\sin(\omega t-\phi)}_{\text{steady state solution}} + \underbrace{\overset{\text{integration Constant}}{A} e^{-t/\tau}}_{\text{natural response solution.}}$$

Load Impedence at supply freq.

$$Z = R + j\omega L = \sqrt{R^2 + (\omega L)^2}\angle\theta$$

$$\frac{V_m}{Z} = I_m$$

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right) \text{ (load phase angle at supply freq.)}$$

$$i = I_m \sin(\omega t - \phi) + A e^{\rho\omega t}$$

$$\tau = L/R$$

$$e^{-t/\tau} = e^{-\frac{Rt}{L}} = e^{-\frac{R\omega t}{\omega L}} = e^{-\frac{R}{\omega L}\omega t} = e^{\rho\omega t}$$

$$\boxed{\rho = \frac{-R}{\omega L}} = \frac{-1}{\tan\phi} = -\cot\phi$$

Apply I.C.C , where at $\omega t = \alpha \longrightarrow i = 0$

$$0 = I_m (\sin\alpha - \phi) + A e^{\rho\alpha}$$

$$\therefore A = - I_m (\sin\alpha - \phi) * e^{-\rho\alpha}$$

$$\therefore I \quad \boxed{i = I_m \sin(\omega t - \phi) - I_m (\sin\alpha - \phi) e^{-\rho\alpha} \cdot e^{\rho\omega t}}$$

to Evaluate β :-

β = Extinction angle . زاوية الإطفاء

The angle that takes the forward Current to drop to $I_H \approx 0$ after the point at which SCR becomes R. Biased.

Applying final current condition

at $\omega t = \pi + \beta$, $i = 0$

$$0 = \cancel{I_m} \sin(\pi + \beta - \phi) - \cancel{I_m} \sin(\alpha - \phi) e^{-\rho\alpha} e^{\rho(\pi + \beta)}$$

$$0 = -\sin(\beta - \phi) - \underbrace{\sin(\alpha - \phi) e^{\rho(\pi - \alpha)}}_{\text{Constant}} e^{\rho\beta}$$

assuming

$$k = -\sin(\alpha-\phi)\, e^{\rho(\pi-\alpha)}$$

$$\therefore 0 = -\sin(\beta-\phi) + k e^{\rho\beta}$$

(How to evaluate β in Such a Transcendental Equation.

Solution.

a) Trial and Error.
b) Graphical Solution.
c) Numerical Solution. (ex. Newton Raphson method..

assuming

$$k = -\sin(\alpha - \phi)\, e^{\rho(\pi - \alpha)}$$

$$k \Rightarrow \begin{cases} \textcircled{0} & \beta = \phi \quad \alpha = \phi \\ \oplus & \alpha < \phi \\ \ominus & \alpha > \phi \end{cases}$$

$$\therefore 0 = -\sin(\beta - \phi) + k e^{\rho\beta}$$

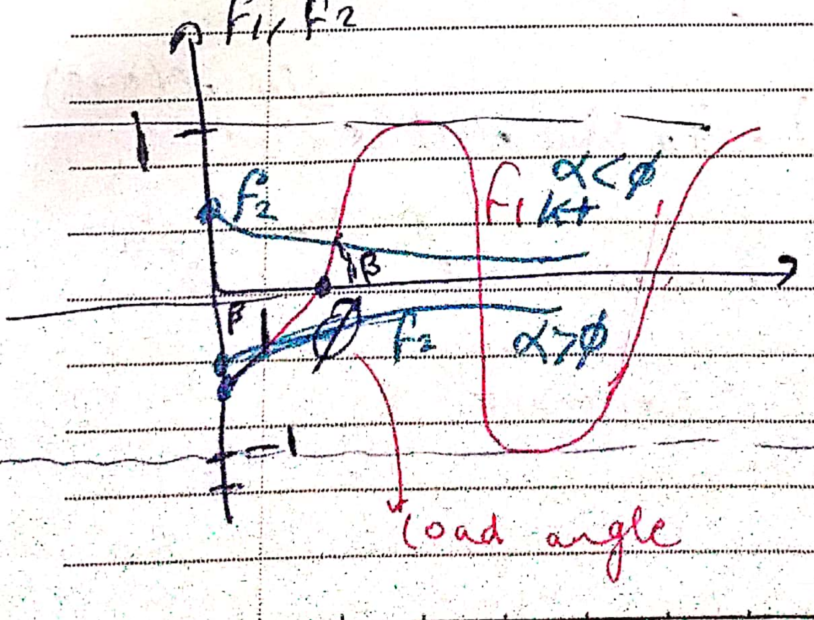
How to evaluate β in Such a Transcendental Equation

Solution.

a) Trial and Error.
b) Graphical Solution.
(c) Numerical Solution. (ex. Newton Raphson method.

$$\sin(\beta - \phi) = k \cdot e^{\rho\beta}$$

$$f_1(\beta) = f_2(\beta)$$



$\beta < \phi$
k is negative

$\beta > \phi$
k is positive

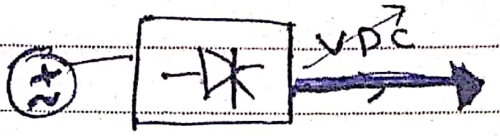
$\alpha = 30°$ $\phi = 45°$

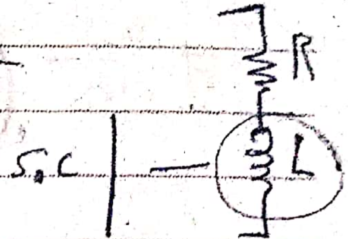
ⓐ $\beta = 30°$

ⓑ $\beta = 45°$ $V_{DC} = V_{AV} = ?$

ⓒ $\beta = 46°$ $I_{DC} = I_{av} = \frac{V_{av}}{R}$

ⓓ $\beta = 32°$





Ripple F_V RF_i

Usually $(R.F_i \leq RF_V)$

RF_i for inductive   0.65

$RF_i =$ ⓐ 0.65

ⓑ 0.4

ⓒ 0.8

ⓓ 0

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

$$= \frac{V_m}{2\pi}\left(-\cos\omega t\right)^{\alpha} = \boxed{\frac{V_m}{2\pi}\left(\cos\alpha + \cos\beta\right)}$$

$V_o(rms) =$

↳ to calculat R.f

$$V_{orms} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi+\beta} (V_o)^2\, d\omega t}$$

$$= \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi+\beta} Vm^2 \sin^2 wt \, dwt} = \sqrt{\frac{Vm^2}{2\pi}\int\left[\frac{1-\cos 2wt}{2}\right]d}$$

$$= \sqrt{\frac{Vm^2}{4\pi}\left(wt - \frac{1}{2}\sin(2wt)\right)}$$

$$\boxed{= \sqrt{\frac{Vm^2}{4\pi}\left[\underbrace{\pi+\beta-\alpha}_{rad} - \frac{1}{2}\sin(2\beta) + \frac{1}{2}\sin(2\alpha)\right]}}$$

Pure Resistive $\alpha = 0$
Diode H.w Rectifier $\beta = 0$

$$RF_v = \frac{\sqrt{V_{rms}^2 - V_{avg}^2}}{V_{o\,avg}}$$

$$RF(i,o) = \cancel{\frac{V_{rms}}{i_o \text{ or } R}}$$

(it's not pure Sinusoidal).

$$V_o = \underbrace{120}_{V_{av}} + 120\left[\sum_{1,2,3} \frac{1}{n}\sin(nwt \pm \varphi(n))\right]$$

$V(1) = \frac{120}{1}\sin(wt) = 120/\sqrt{2}$

$i_1 = 120/\sqrt{2}Z_1$

$V(2) = \frac{120}{2\sqrt{2}}$ --→

$V(3) = \frac{120}{3\sqrt{2}}$ ---

$\hat{i}_2 = \frac{120}{2\sqrt{2}\, Z(2)}$ $\qquad Z_2 = \sqrt{R^2 + (2\omega L)^2}$

$\hat{i}_3 = \frac{120}{3\sqrt{2}\, Z(3)}$ $\qquad Z3 = \sqrt{R^2 + (3\omega L)^2}$

$$I_{rms} = \sqrt{I_{av}^2 + I_{(1)rms}^2 + I_{(2)rms}^2 + I_{(3)rms}^2 + \cdots}$$

* * *

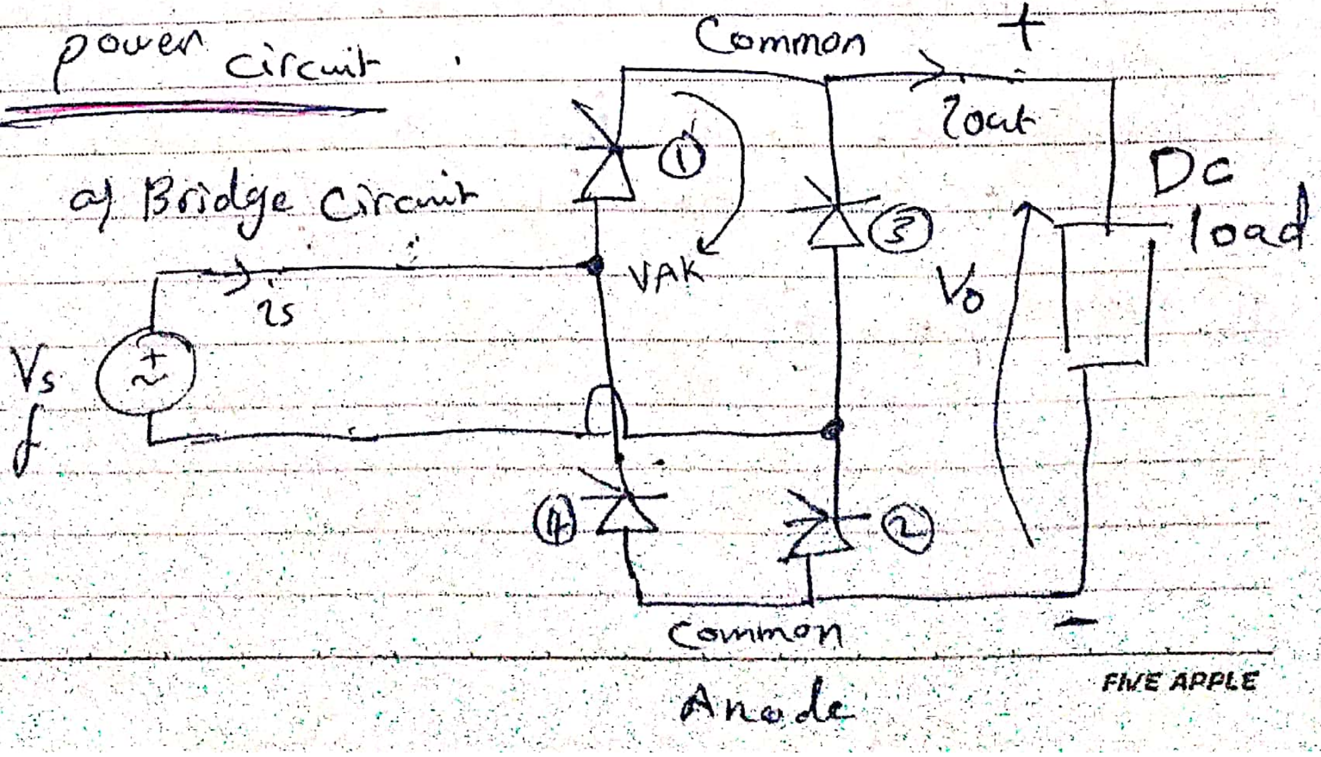
$\beta = 0$ for pure R

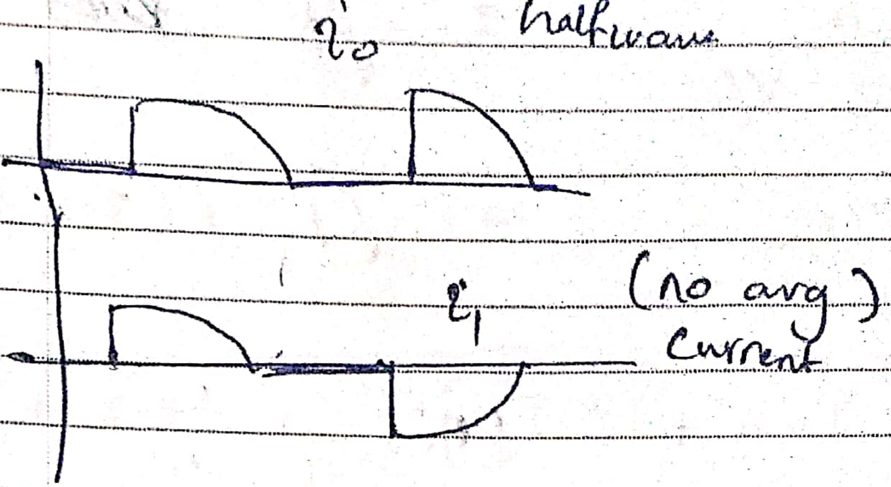
$$\boxed{V_{o(av)} = \frac{V_m}{2\pi}(1+\cos\alpha)}$$

* single phase - full wave, fully-controlled Rectifier

power circuit :

a) Bridge circuit





• 1/7/2019.

Full-wave Rectifier : Merits over half wave Rectifier (Zero Average)

① The Line (Supply or Input) current is AC
This will avoid any problems connected to the average Dc components.

② More power Can be generated with Only Small Extra Cost Compared To half wave Rectifier

③ Less Distortion to the Input line Current).
(less total harmonic distortion) ~~Current~~
THDF

④ Better input pf

SCR 1 and SCR 2 Should by Simultanuosly triggered at α
Same as for SCR3 and SCR4
1) at ($\omega t = \alpha + \pi$)

$0 \le \omega t \le \pi$ SCR 1 and 2 are forward B
SCR 3 and 4 are Reverse B

$\alpha \le \omega t \le \pi + \beta$

KVL

$$V_s - \underset{\text{Neg}}{V_{AK_1}} - V_{out} - \underset{\text{Neg.}}{V_{AK2}} = 0$$

$$\boxed{\therefore V_0 = V_s}$$

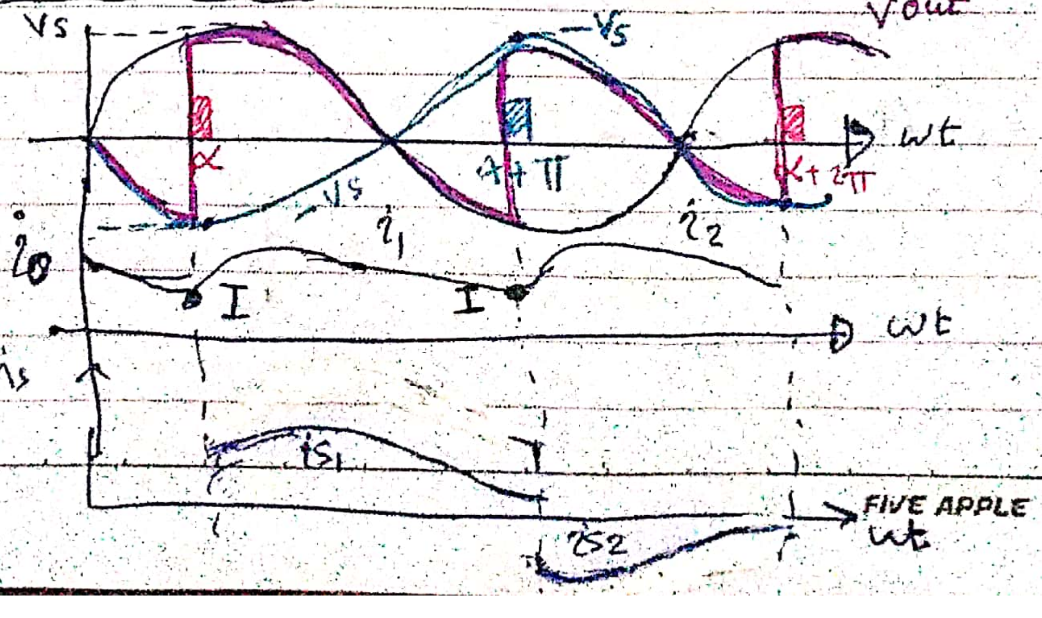
$\pi \le \omega t \le 2\pi$ SCR① and SCR 2 RB
SCR3 and SCR4 FB

$\pi + \alpha \le \omega t \le 2\pi + \beta$ KVL

$$V_s + V_o = 0$$

$$\boxed{V_o = -V_s.}$$

Analysis



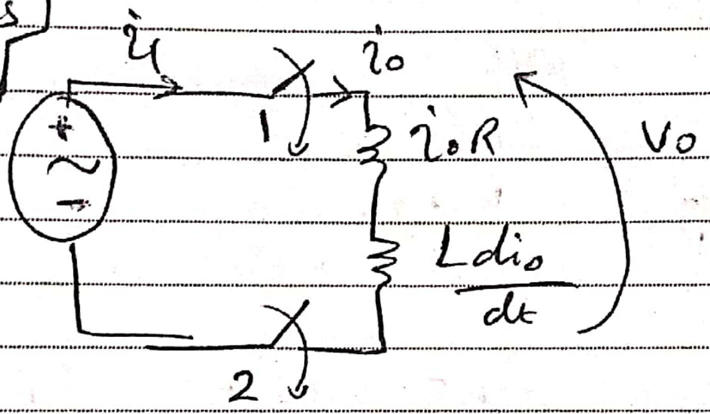
Full wave Rectifier

The expected current Wave form for Load can be

a- Continuous (Continuous Current mode CCM).

b- Discontinuous (Discontinuous DCM)

assume Continuous C.C.M



$$V_s = i_o R + L\frac{di}{dt}$$

$$i_o = I_m \sin(\omega t - \phi) + A e^{\rho \omega t}$$

$\boxed{I ec\ i}$ at $\omega t = \alpha$, $i_o = I$

$$I = I_m \sin(\alpha - \phi) + A e^{\rho \alpha}$$

$$A = \left[I - I_m \sin(\alpha - \phi)\right] e^{-\rho \alpha}$$

$$i_o = I_m \sin(\omega t - \phi) + \left[I - I_m \sin(\alpha - \phi)\right] e^{-\rho\alpha} \cdot e^{\rho \omega t}$$

No.

apply final current condition F.C.C

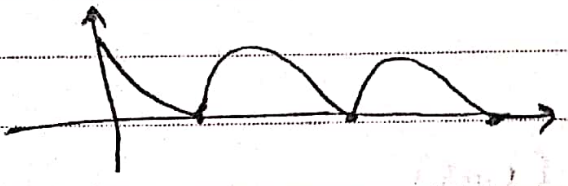
wherat at $\omega t = \pi + \alpha$ $\quad i_0 = I$

$$I = I_m \sin(\pi + \alpha - \phi) + (I - I_m \sin(\alpha - \phi)\, e^{-\rho\alpha}\, e^{\rho(\pi+\alpha)}$$

$$I = -I_m \sin(\alpha - \phi) + \left[I - I_m \sin(\alpha - \phi)\right] e^{\pi\rho}$$

$$I\left[1 - e^{\rho\pi}\right] = -I_m \sin(\alpha - \phi)\left[1 + e^{\rho\pi}\right]$$

$$I = \textcircled{-}\underline{\underline{I_m \sin(\alpha - \phi)}} \cdot \left[\frac{1 + e^{\rho\pi}}{1 \overset{\text{سالبة}}{-} e^{\textcircled{-\rho}\pi}}\right] \begin{matrix} \to \textcircled{+} \\ \to \textcircled{+} \end{matrix}$$



when $I = 0$
critical case

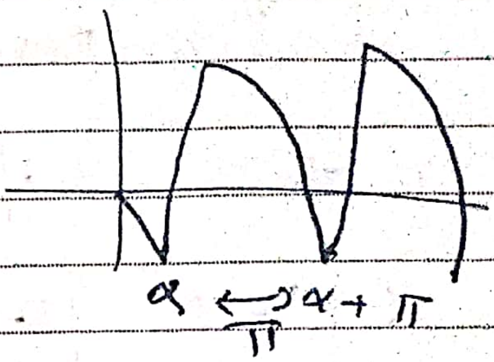
$$I \begin{cases} 0 & \alpha = \phi \to \text{critical Case.} \\ + & \alpha < \phi \to \text{C.C.M} \\ - & \alpha > \phi \to \text{D.C.M} \end{cases}$$

I will never be negative practically.

CCM

$$V_o(av) = \frac{1}{\pi}\int_{\alpha}^{\alpha+\pi} V_m \sin(\omega t)\, d\omega t.$$

$$= V_m/\pi \left(-\cos\omega t\right]_{\alpha}^{\alpha+\pi}$$



$$= \frac{V_m}{\pi}\left[-\cos(\pi+\alpha) + \cos\alpha\right].$$

$$\underset{CCM}{V_o(av)} = \frac{2V_m}{\pi}\cos\alpha.$$

$$I_o(av) = V_o(avg)/R$$

$$V_o(rms) = \frac{V_m}{\sqrt{2}} = V_s(rms)$$

$$\underset{CCM}{V_o(rms)} = \sqrt{\frac{V_m^2}{2\pi}\left(\pi + \beta - \alpha - \frac{1}{2}\sin(2\beta) + \frac{1}{2}\sin 2\alpha\right.}$$

~~Vo(rms)~~ Special case

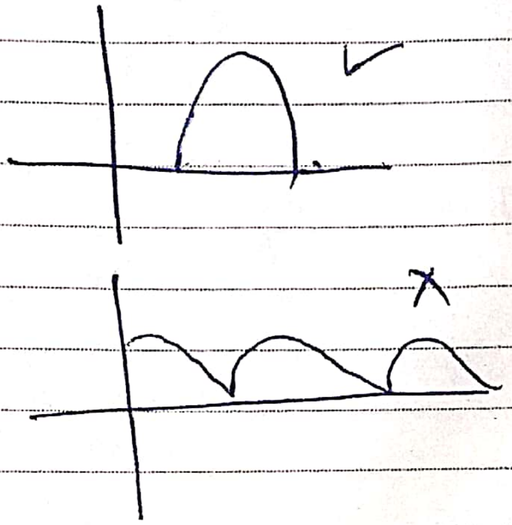
$\alpha = \phi$ → critical Case

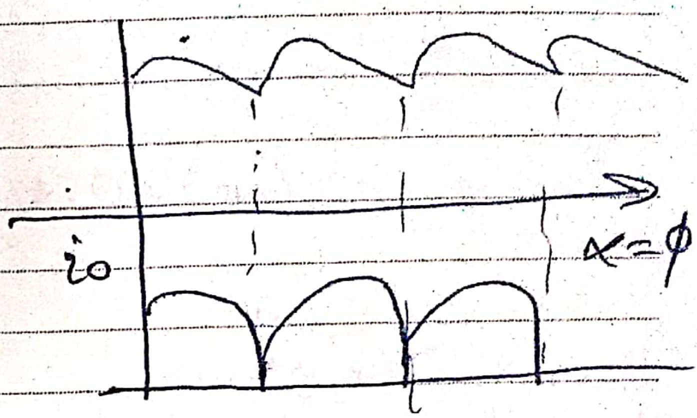
$$i_o = I_m \sin(\omega t - \phi) + [I - \hat{I}_m \sin(a - \phi)$$

$$\cdot e^{-\rho\alpha} \cdot e^{\rho\omega t}$$

$i_o = I_m \sin(\omega t - \phi)$ $I = 0$

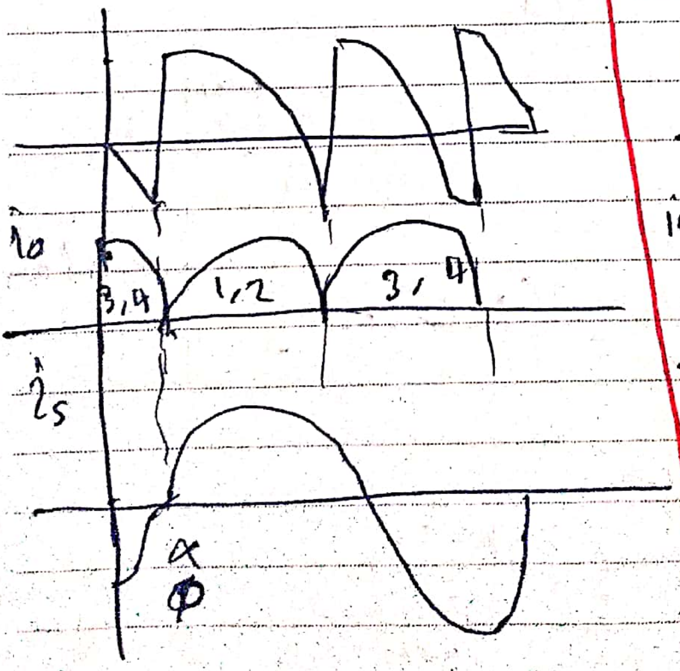
CCM





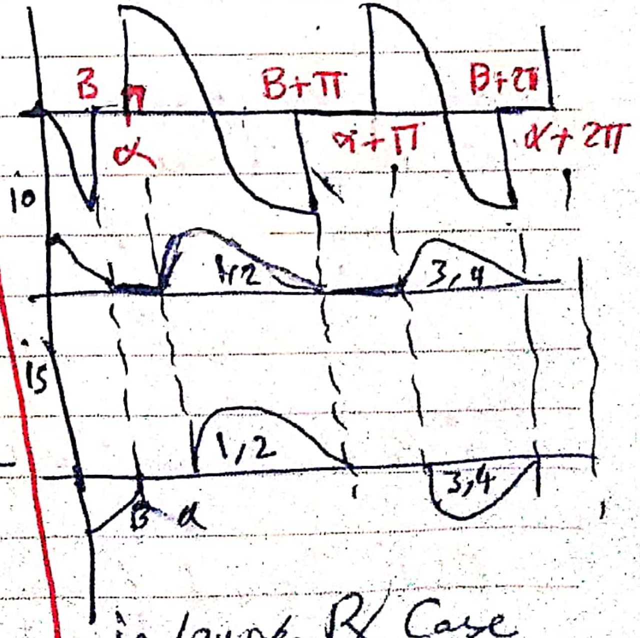
in Critical Case (CT)

$V_{o(av)} = \frac{2V_m}{\pi}\cos\alpha$
CT



$PF_m = \cos\alpha$] pure sin
$T(H)F_{i_s} = 0$

DCM



~~in pure R Case~~
~~$R \ne 0$~~   ~~$X \to x = 0$~~
~~$\phi = \tan^{-1} \omega L/R$~~

No.

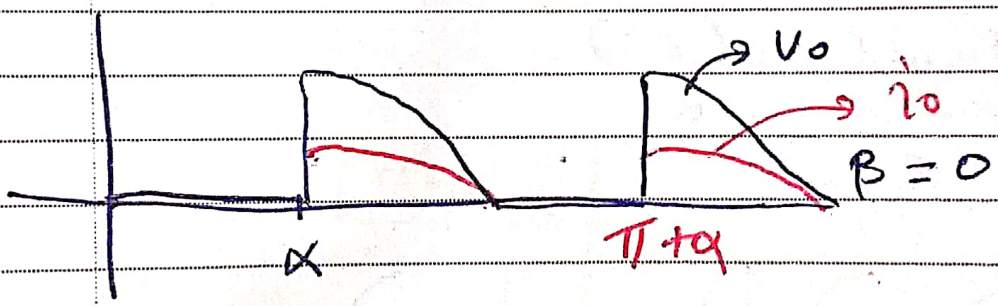
in Pure Resistive case

$R \neq 0 \quad L \to X = 2wfL = 0 \qquad \phi = \tan^{-1}\frac{wL}{R} \to 0^\circ$

$\rho = \frac{-R}{wL} \to -\infty$

$i_0 = I_m \sin(wt) + 0 \therefore I_m = \frac{V_m}{R}$

$$\boxed{\begin{aligned} i_0 &= I_m \sin wt \\ V_0 &= V_m \sin wt \end{aligned}}$$



Mode of operation

CCM :- Never

CT case : $\alpha = \phi = 0^\circ$

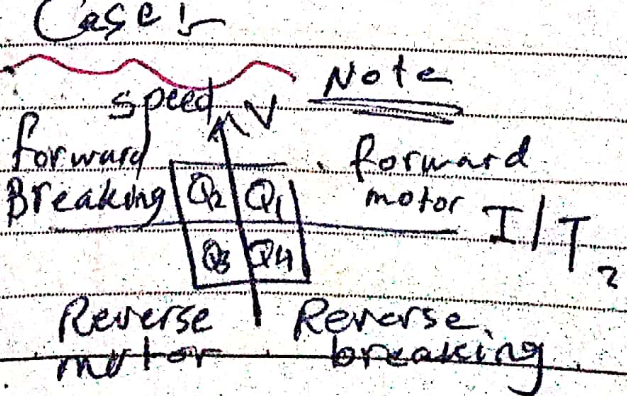
DCM : $V_0(avg.) = \frac{V_m}{\pi}(1+\cos\alpha)$

} pure Resistive loading condition

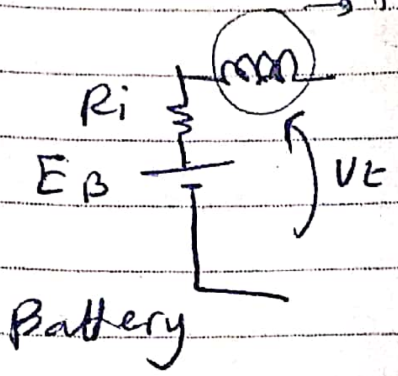
Other Special Case :-

Note

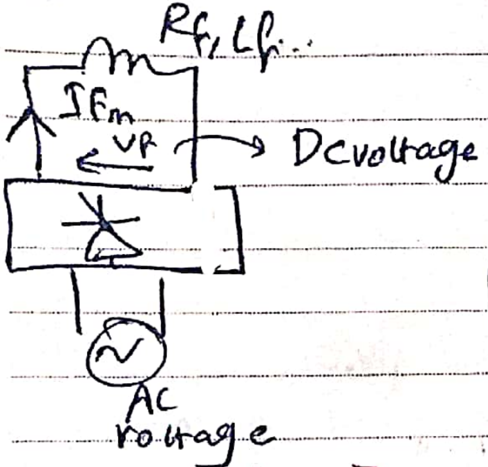
RLE Load



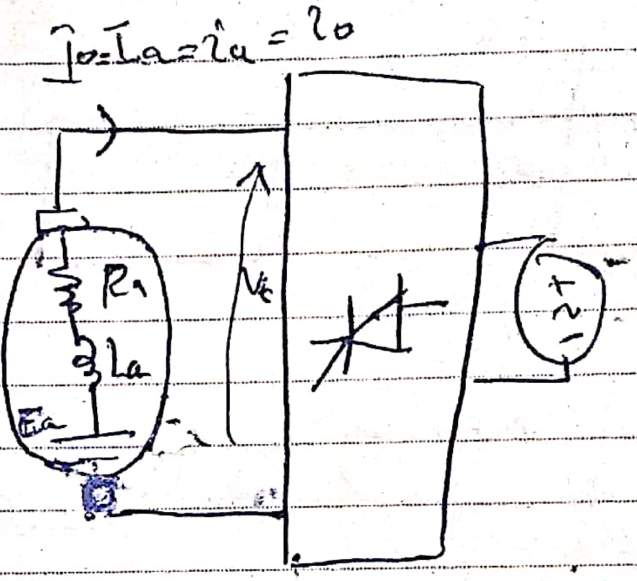
ⓐ Battery with inductive filter
→ to Reduce harmonics



ⓑ Dc Motor



Field circuit



Armature circuit.

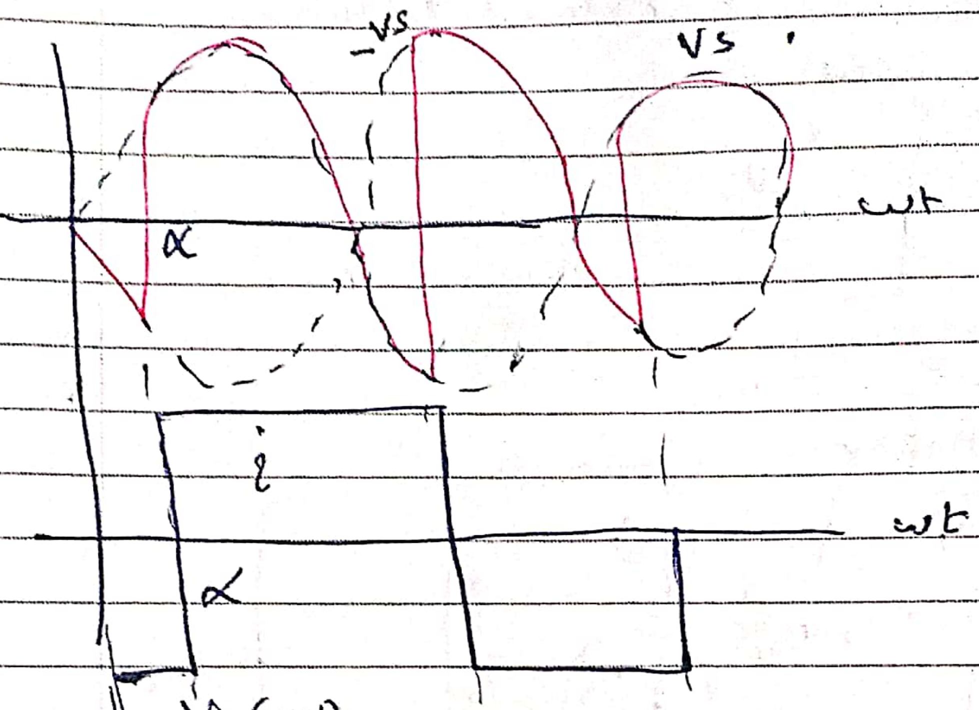
assume that the armature Inductance is So large Such that the load current is almost Ripple free or (Virtually Constant).

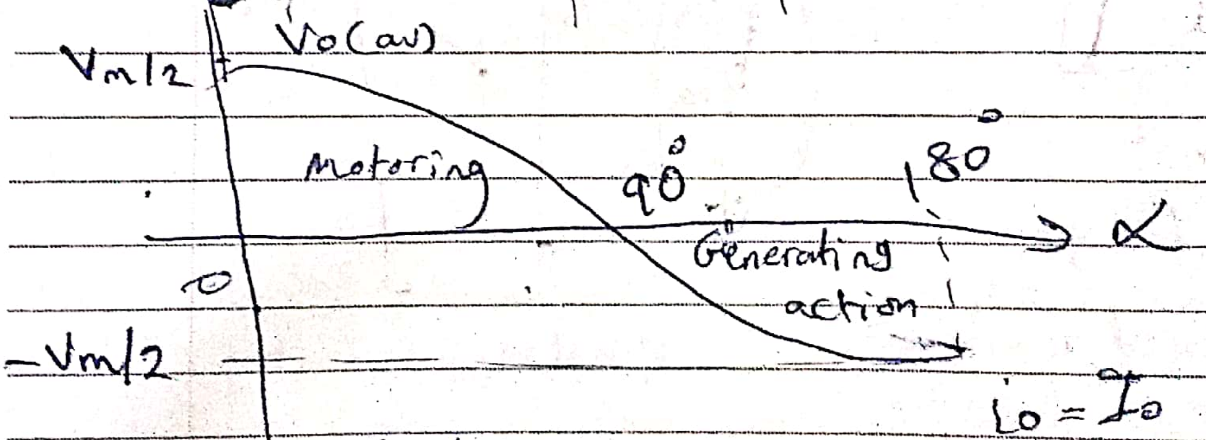
$$\frac{L\,di_a}{dt} \to 0$$

Mode of Operation : CCM pure DC

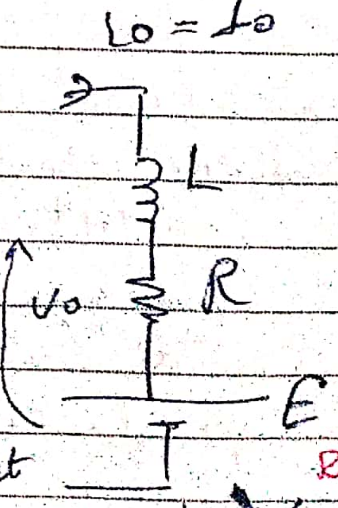
$$V_o(av) = \frac{2V_m \cos\alpha}{\pi} \qquad 0 \le \alpha \le 180^\circ$$

3-7-2018





$$V_{o(av)} = \frac{2V_m}{\pi}\cos\alpha$$
CCM



$$V_{o(av)} = RI_o + 0 + E$$

torque development → $T_q = K_a \phi I_a$
$= K_a I_a$

speed dependent → $E = K\phi\omega_m = K_a'\phi N_m$

Rev/m

RPM

$$\omega_m = \frac{2\pi \cdot N_m}{60}$$

$P_{shaft} = \omega_m . T_{sh}$.

$V_o(av) \rightarrow \frac{2V_m}{\pi} \cos\alpha = RI_o + E$

↑ the control parameter

$P_{out} = \underbrace{I_o^2 R}_{\text{copper loss}} + E I_o$ $P_o = I_a . V_o(av)$

↳ developed Armature power to be converted into mechanical power.

$= I_o(I_o R + E) = I_{o(av)} . V_o(av)$.

☆ **Load** voltage Ripple :-

▲ $V_o(av) = \frac{2V_m}{\pi} \cos\alpha$.

▲ $V_o(rms) = V_s(rms)$.

▲ $RF_{vo} = ---$.

☆ Load current Ripple . $R.F_{io} = 0$

☆ Supply voltage (pure sinusoidal) . THDF = 0

☆ Supply current

↓

(Square wave)

THDF = 48.43% fixed irrespected of α

No.

i_s harmonics Only Odd due to it's Symmetry

$\underbrace{1^{st}}_{\text{useful fundamintal}}, \underbrace{3^{rd}, 5^{th}, \dots}_{\text{Impurities.}}$ harmonics

HW

show that $I_{supply} = \sum_{1,3,5,\dots}^{\infty} 4 I_o / n\pi \, \sin(n\omega t \overset{\psi(n)}{- n\alpha})$

and prove 48.43%

the number

$C(n) = \sqrt{A^2(n) + B(n)^2}$

$$THDf = \sqrt{\frac{I_s^2(rms) - I_s(F)^2_{rms}}{I_{sF}(rms^2)}}$$

$$I_s(rms) = I_o = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} I_o \, d\omega t}$$

$$I_s(rms) \approx \sqrt{\left(\sum_{n=1,3,5,9,7\dots} \frac{4 I_o}{n\pi\sqrt{2}}\right)^2}$$

$$I_s(F)_{rms} = \frac{4 I_o}{\pi\sqrt{2}}$$

Input pF

$$pf_{in} = \frac{P_{\cancel{in}}\ real\ (\omega)}{S_{in}(VA)} = \frac{P_o(\omega)}{S_{in}(VA)}$$

$$= \frac{\cancel{I_o} \cdot V_o(av)}{V_s(rms) \cdot \underbrace{\cancel{I_o}}_{I_s(rms)}} = \frac{V_o(av)}{V_s(rms)}.$$

alteratively

$$V_s = V_m \sin(\omega t) + 0 + 0$$

$$i_s = \frac{4 I_o}{\pi} \sin(\omega t \underbrace{- \alpha}_{\psi(1) = -\alpha}) + \frac{4 I_o}{3\pi} \sin(3\omega t \underbrace{- 3\alpha}_{\psi(3)})$$

$$+ \frac{4 I_o}{5\pi} \sin(5\omega t \underbrace{- 5\alpha}_{\psi(5)}) + ---$$

$$P_s = \left(\frac{V_m}{\sqrt{2}} \cdot \frac{4 I_o}{\pi\sqrt{2}} + 0 + 0 ---\right) \cos(\theta_{v_1} - \theta_{i_1})$$

$$P_s = v_s(rms) \cdot I_{sf}(rms) \cdot \cos(\alpha)\ \psi(1)$$

$$pf = \frac{\cancel{V_s(rms)} \cdot I_{sf}(rms) \cdot \cos\psi(1)}{\cancel{V_s(rms)}\ I_s(rms)}.$$

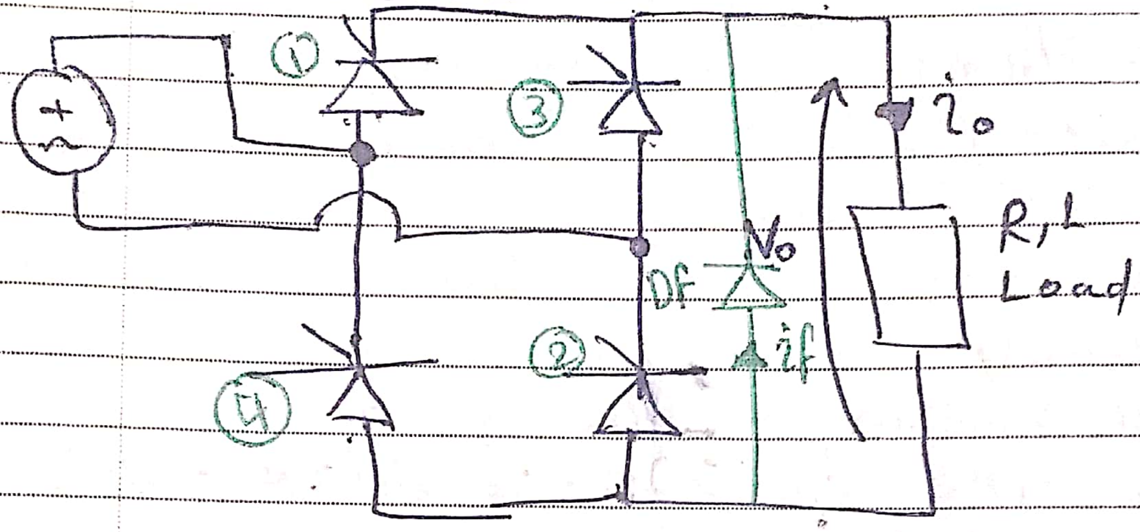
$$\underbrace{\frac{I_{sF}(rms)}{I_s(rms)}}_{<1} \cdot \underbrace{\cos\psi(1)}_{<1} \quad \text{displacement Factor.}$$

distortion factor $DTF \times DPF < 1$

$Pf_{in} = DTF \cdot Dpf$

7/7 الأحد

Semi controlled Rectifier



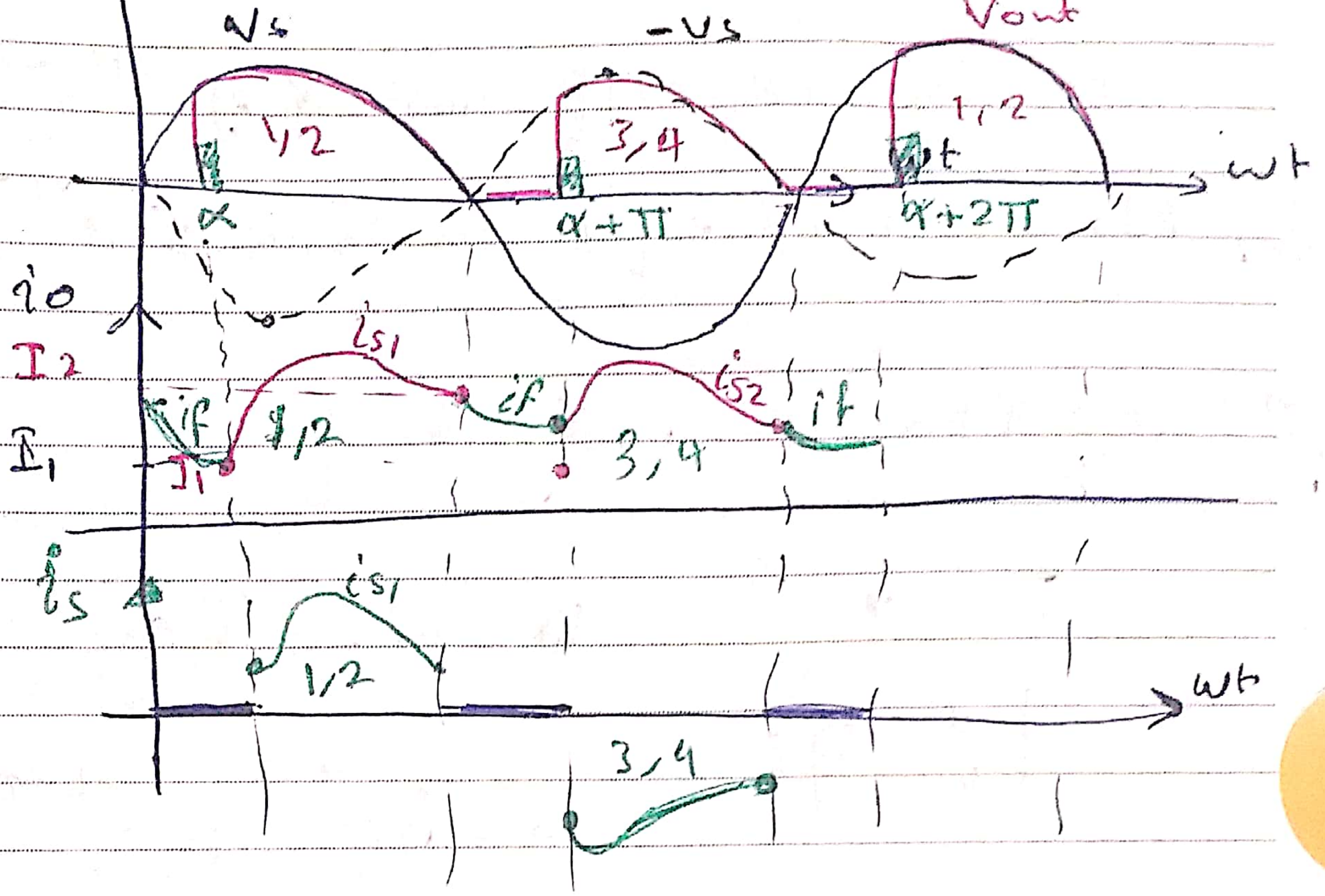
advantage:-
to clip any negative part of the V_o

This Results in higher average Voltage for the Same Value of α.

* **disadvantage:** there is NO possibility for Negative Output Voltage
in this Case No possible Motor Control in the 4 quadrants of Tq/speed Characteristics.

Df : free wheeling Diode
if existed ⇒ semi-controlled
if not ⇒ fully controlled.

assume CCM



$\alpha \le \omega t \le \pi$

SCRs ; 1, 2, F.B and Triggered

$v_o = V_m \sin \omega t = i_{s_1} R + L \frac{di_{s_1}}{dt}$.

$i_{s_1} = I_m \sin(\omega t - \phi) + A e^{\rho \omega t}$

ICC: at $\omega t = \alpha$, $i_{s_1} = I_1$

$\therefore I_1 = I_m \sin(\alpha - \phi) + A e^{\rho\alpha}$

$A = [I_1 - I_m \sin(\alpha - \phi)] e^{-\rho\alpha}$

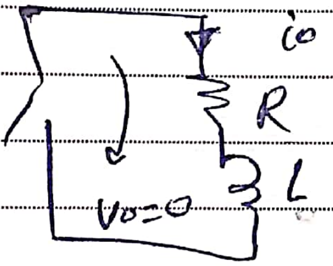
$i_{s_1} = I_m \sin(\omega t - \phi) + (-I_m \sin(\alpha - \phi) + I_1) e^{-\rho\alpha} e^{\rho \omega t}$

FCC :- at $\omega t = \pi$ $i_{s_1} = I_2$

∴ $I_2 = I_m \sin(\pi - \phi) + [I_1 - I_m \sin(\alpha - \phi) e^{-\rho\alpha} e^{-\rho\pi}$

① $\boxed{I_2 = I_m \sin\phi + [I_1 - I_m \sin(\alpha - \phi) e^{\rho(\pi - \alpha)}}$

$\boxed{\pi \le \omega t \le \pi + \alpha}$ **Freewheeling Area**



$$0 = i_0 R + L \frac{di_0}{dt}$$

$$i_0 = Be^{\rho\omega t} = Be^{-t/\tau}$$

2CC :-

at $\omega t = \pi$, $i_0 = I_2$

$$I_2 = Be^{\rho\pi} \rightarrow \boxed{B = I_2 e^{-\rho\pi}}$$

$$i_0 = B I_2 e^{-\rho\pi} . e^{\rho\omega t}$$

FCC! at $\omega t = \pi + \alpha$
$i_0 = I_1$

$$I_1 = I_2 e^{-\rho\pi} e^{\rho(\pi+\alpha)} = \underline{\underline{I_2 \; e^{\rho\alpha}}} \quad \text{②}$$

$$I_2 = I_m \sin\phi \left[I_1 - I_m \sin(\alpha-\phi) \right] e^{+\rho(\pi-\alpha)}$$

$I_1 =$

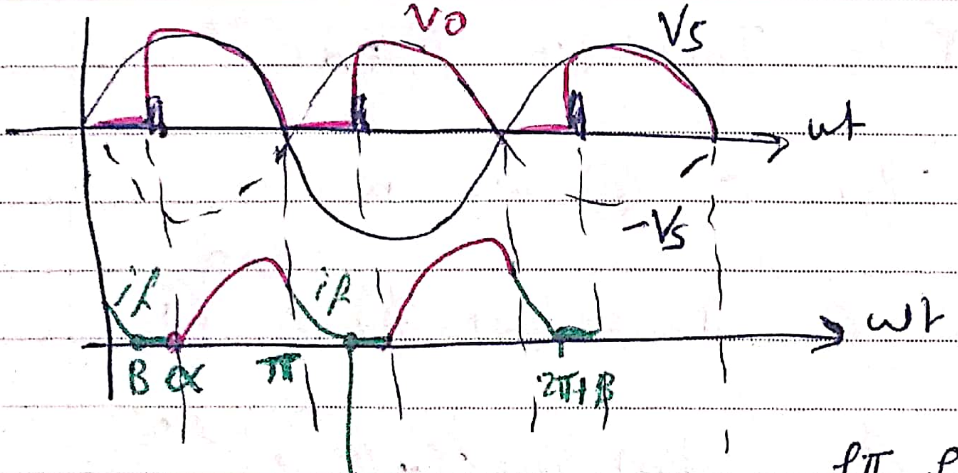
$I_2 =$

if $I_1 > I_H \longrightarrow$ CCM

if $I_1 = I_H \longrightarrow$ Critical Case

if $I_1 < I_H \longrightarrow$ DCM

$\boxed{\text{DCM}}$



$i_o = i_F$ (Free wheeling Area) $= I_2 e^{-\rho\pi} e^{\rho\omega t}$

at $\omega t = \pi + B$ $\qquad i_R = I_H \smile$ Holding Current

$$I_H = \underset{(DCM)}{I_2} e^{-\rho\pi} e^{\rho(\pi+B)} \qquad I_H = I_{2(DCM)} \, e^{\rho\beta}$$

$$e^{\rho\beta} = \frac{I_H}{I_2(DCM)}$$

$$\rho\beta = \ln\left(\frac{I_H}{I_2(DCM)}\right)$$

$$\boxed{\underset{(rad)}{\beta} = \frac{1}{\rho} \ln\left(\frac{I_H}{I_2(DCM)}\right)} \rightarrow ③$$

$\alpha = \beta \rightarrow$ (critical case)

$B > \alpha \rightarrow$ CCM

$B < \alpha \rightarrow$ DCM.

For DCM

~~I~~ $i_s = I_m \sin(wt - \phi) + Ae^{\rho wt}$

$i_{s1} = 0$ @ $wt = \alpha$

$0 = I_m \sin(wt - \phi)\ e^{\rho\alpha} A$

$A = -I_m \sin(\alpha - \phi)\ e^{-\rho\alpha}$

$i_{s1} = I_m \sin(wt - \phi) - I_m \sin(\alpha - \phi)\ e^{\rho\alpha} e^{\rho wt}$

at $wt = \pi$, $I_2(DCM)$

No.

$$I_2(Dcm) = I_m \sin(\pi - \phi) - I_m \sin(\alpha - \phi) e^{-\rho\alpha} e^{\rho\pi}$$

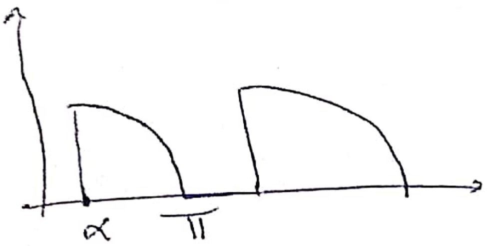
$$= I_m \sin\phi - I_m \sin(\alpha - \phi) e^{-\rho\alpha} e^{\rho\pi}$$

$$I_2(Dcm) = I_m \left[\sin\phi - \sin(\alpha - \phi) \right] e^{\rho(\pi - \alpha)}]$$

power electronics

8-7-2018

* $V_{o(av)}$ S.C.R $= \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d\omega t$



$= \frac{V_m}{\pi}\left[-\cos \omega t\right]_{\alpha}^{\pi}$

$\boxed{V_{o(av)} \text{ S.C.R} = \frac{V_m}{\pi}(1+\cos\alpha)}$ → semi controlled

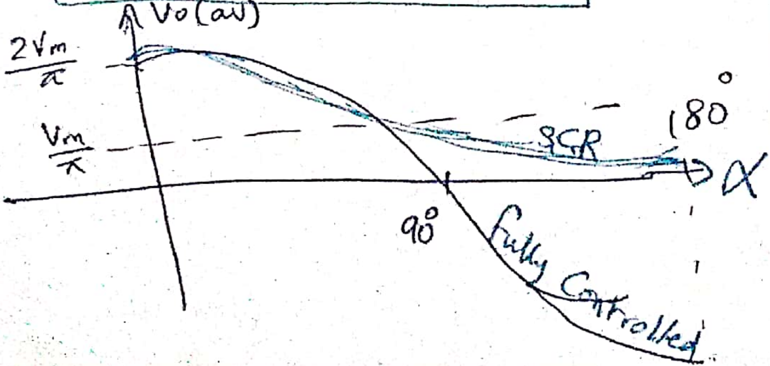
For both
CCM
DCM

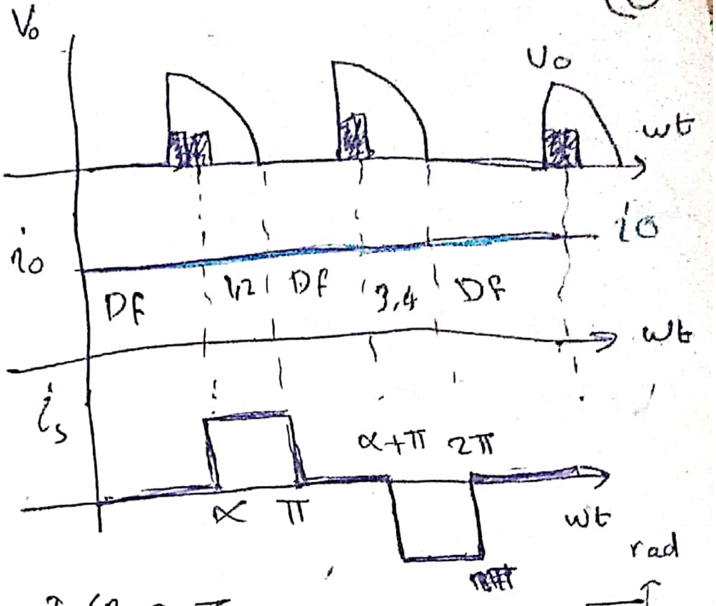
$V_{o(av)}$ Fully Controlled $= \begin{cases} \frac{2V_m}{\pi}\cos\alpha & \text{CCM} \\ \frac{V_m}{\pi}\cos\alpha + \cos\beta & \text{D.CM} \end{cases}$

$I_{av} = \frac{V_{o(av)}}{R}$

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

Case; Ripple free $i_o = I_o$





$I_{o(Rms)} = I_o$

$I_{o(av)} = I_o$

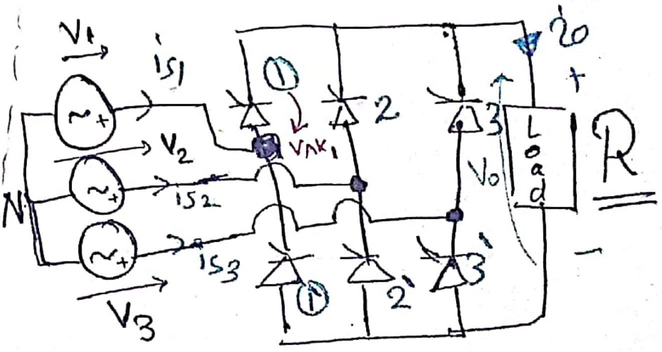
$I_{s(av)} = 0$

$I_{s(rms)} = \sqrt{\frac{\pi-\alpha}{\pi}}\, I_o$

$I_o = \frac{\frac{V_m}{\pi}(1+\cos\alpha) - E}{R}$

3-phase Rectifier Circuits

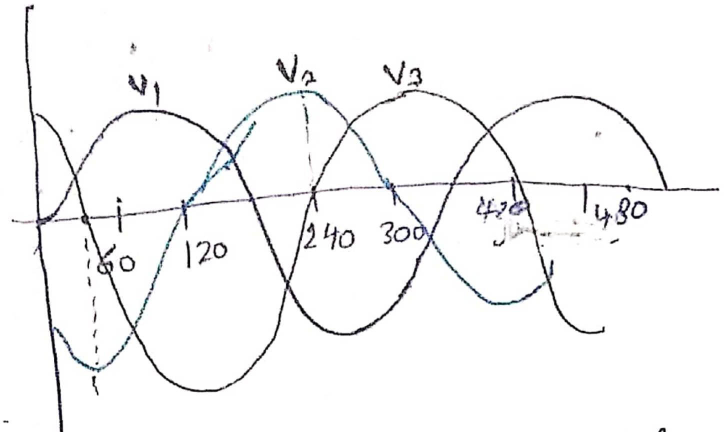
* Full wave [Bridge] [6-pulse]



Supply:- 3-phase, + Sequence,

Balanced Supply

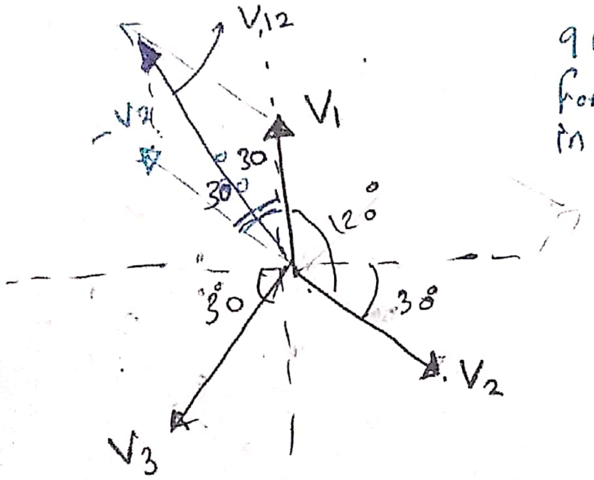
- equal Amplitude (Rms value or peak)
- equal Frequency
- phase shift 120°



$V_1 = V_m \sin(\omega t)$

$V_2 = V_m \sin(\omega t - 120^\circ)$

$V_3 = V_m \sin(\omega t + 120^\circ)$



9 voltages wave forms are involved in wave form constructions.

$V_{12} = V_1 - V_2 = \sqrt{3}\, V_m \sin(\omega t + 30^\circ)$

$V_{23} = \sqrt{3}\, V_m \sin(\omega t - 90^\circ)$.

$V_{31} = \sqrt{3}\, V_m \sin(\omega t + 150^\circ)$.

$V_{21} = \sqrt{3}\, V_m \sin(\omega t - 150^\circ)$

$V_{32} = \sqrt{3}\, V_m \sin(\omega t + 90^\circ)$

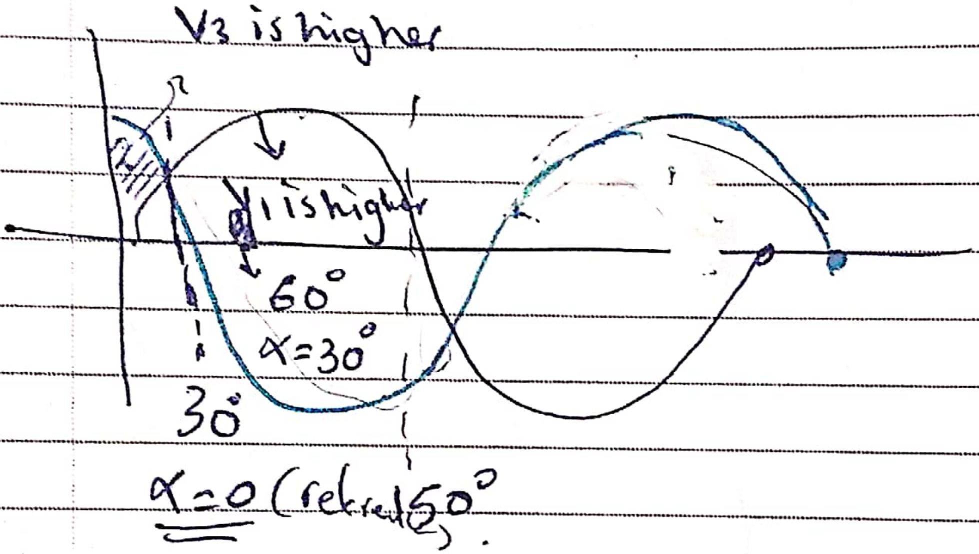
$V_{13} = \sqrt{3}\, V_m \sin(\omega t - 30^\circ)$

No.

9-7-2019. الثلاثاء

① Refrence of measuring α

wt=0 isn't the good Reference.



Refrence of measuring α is the angle at which V_1 becomes highest in polarity compared to V_2, V_3.

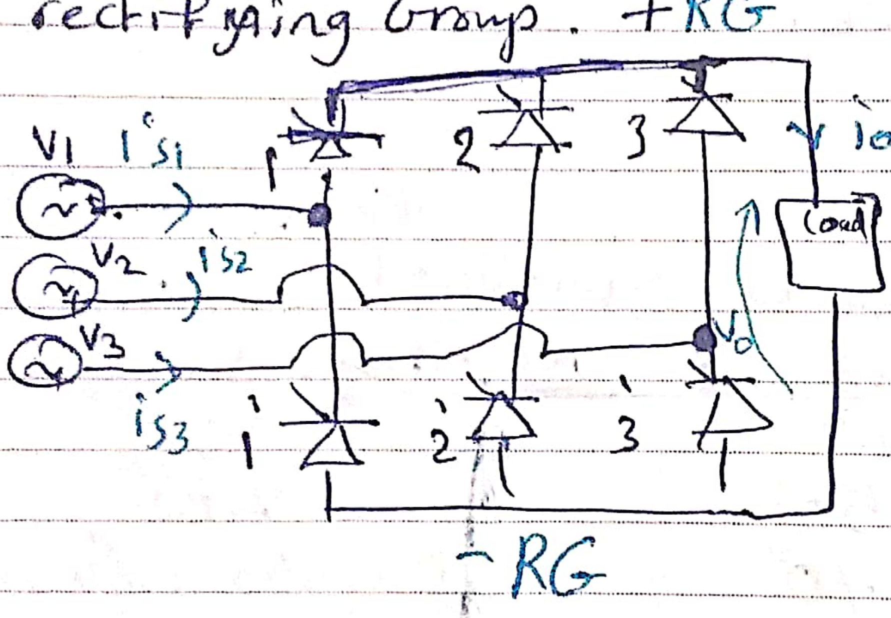
$wt = 30° = \pi/6$

if $\alpha = 30°$ SCR_1 is triggered at $wt = \underline{\underline{60°}}$

if SCR1 is triggered at $\omega t = 120°$

$\alpha = 90°$.

② two SCRs should simultaneously conduct one from the positive Rectifying Group, the second from the negative rectifying Group.



$SCR_1 \longrightarrow SCR_2'$ or SCR_3' , $\boxed{SCR_1' \; X} \to$ Short circuit

~~SCR~~

③ ~~The~~ ② + providing that the two ~~thyr~~ SCRs that belong to the Same phase will never conduct simultaneously.

$SCR_2' \longrightarrow SCR_3$ or SCR_1

No.

Since in the positive group or negative group 3 SCRs to share conduction in One period of symmetry

each SCR is expected to Conduct for 120°

Sharing two other ~~they~~ SCRs from the Opposite group 60° each.

Ex

$\alpha = 0°$ $\quad \alpha_{min} = 0$ equivilient to Uncontrolled Rectifier }

	triggered at ωt =	~~Rectifier~~ end conduction at
SCR_1	30°	150°
SCR_2	150°	270°
SCR_3	270°	(270-360°)·(0-30°)
SCR_1'	30+180° = 210°	330°
SCR_2'	330°	(330-360°)(0→90°)
SCR_3'	90°	210°

Sequence of triggering

① SCR_1 at 30°) 60°

② SCR_3' at 90°

③ SCR_2 at 150°) 60°

④ SCR_1' at 210°

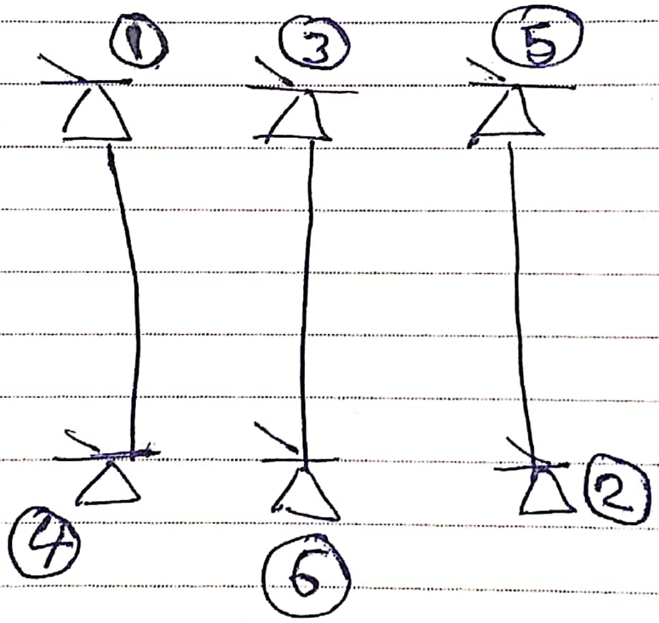
) 60°

⑤ SCR_3 at 270

) 60°

⑥ SCR_2' at 330

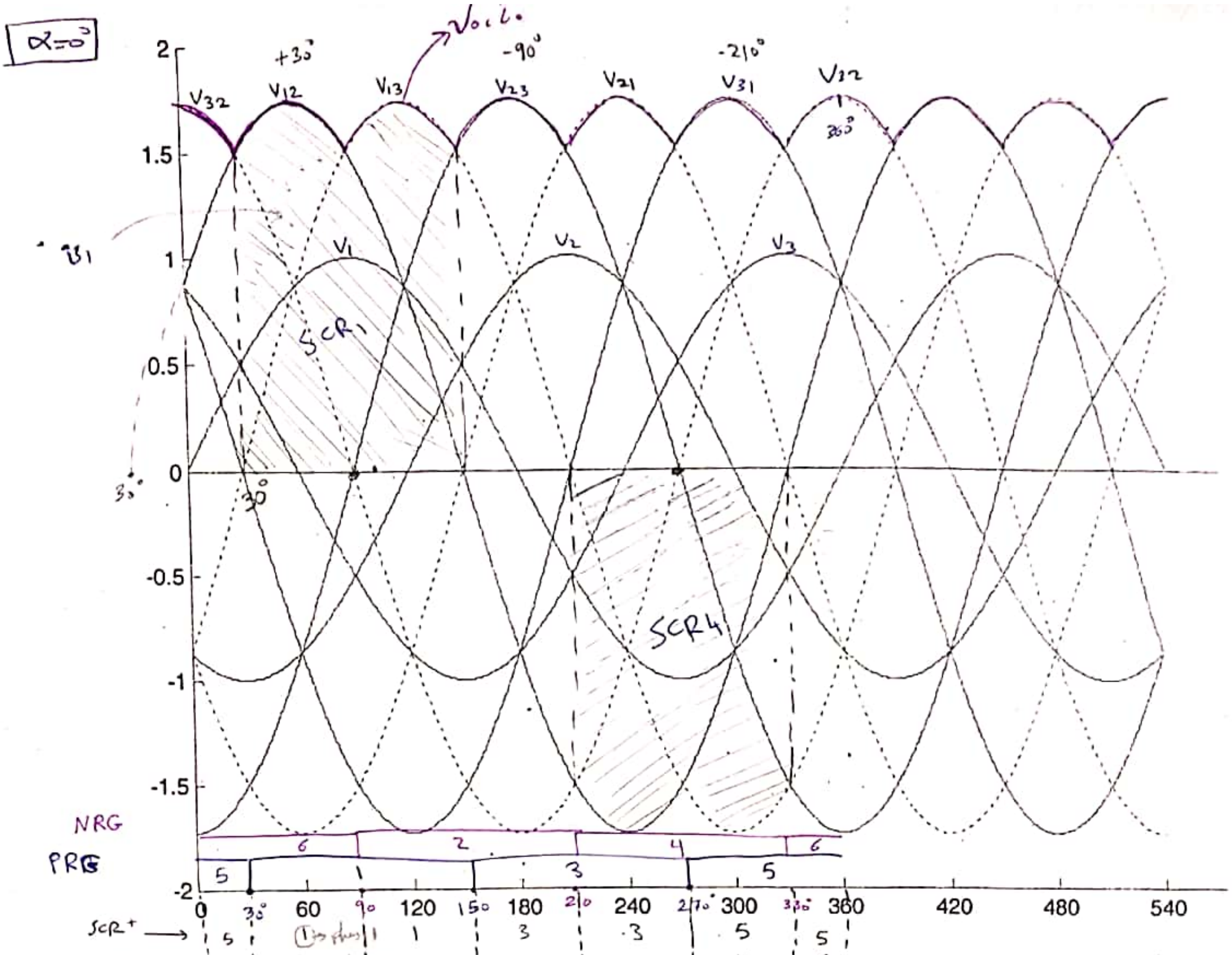
according to which SCRs are numbered in it's standard form.



ex if α = 60°, SCR 5 is triggered

at 1→ 90
2→ 150
3→ 210
4→ 270
5→ 330
6→

$$\boxed{\underbrace{(SCR * 60) + (\alpha - 30^\circ)}.}$$

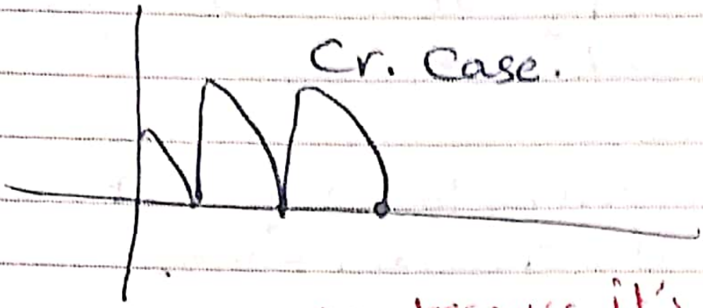


SCR⁺ →	5	① → phase 1	1	3	3	5	5
SCR⁻ →	6	6 → phase 2	2	2	4	4	6
V_o	V_{32}	V_{12}	V_{13}	V_{23}	V_{21}	V_{31}	V_{32}

No. 14 - 7

$\alpha = 60°$ $\boxed{HW}$ $\rightarrow \alpha = 60°$ Critical Case

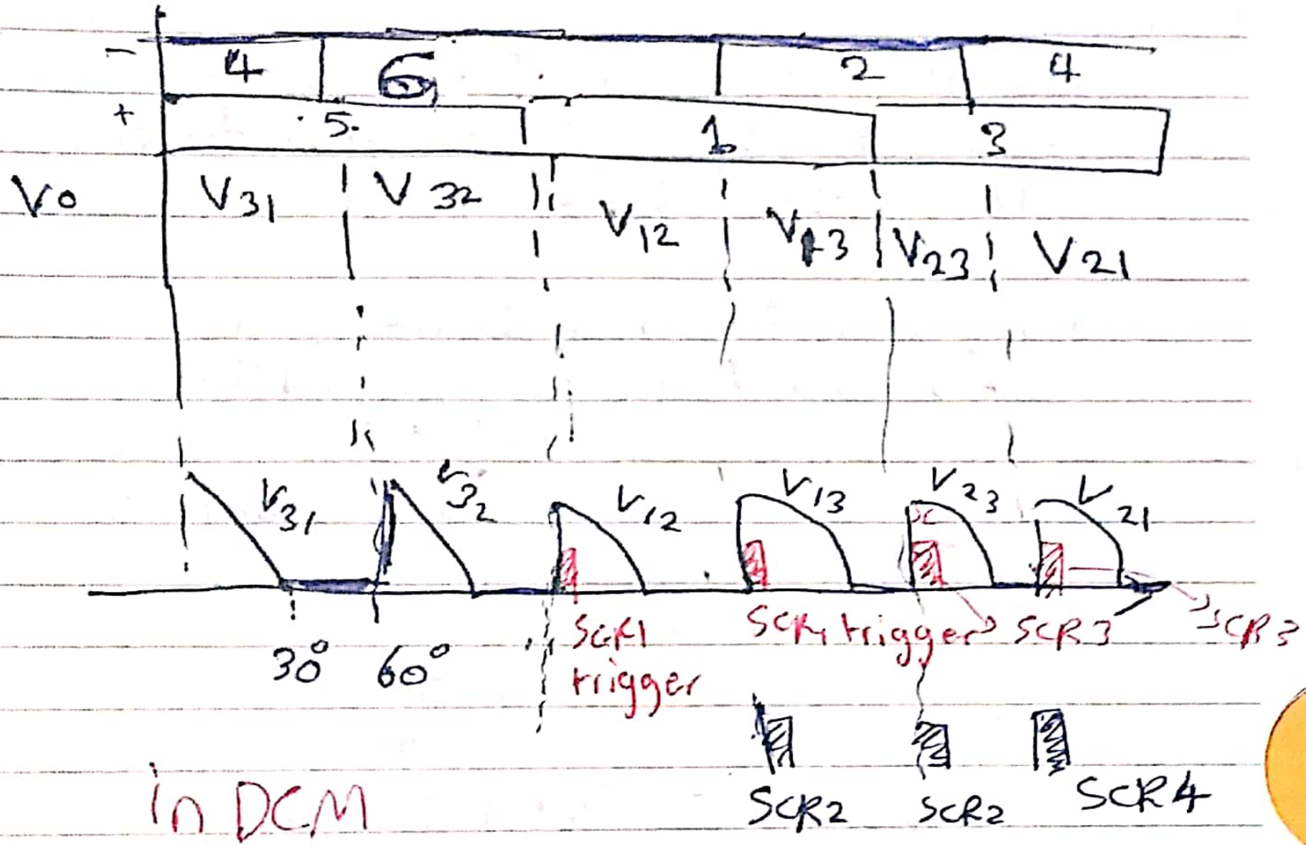
$\alpha = 90°$



$\alpha = 90°$

second trigger because it's DCM

SCR	Trig*	1. END
1	120°→180	240° ?
2	180°	360
3	240°→300°	~~420~~ 360°
4	300 0 ——→	260° 60°
5	3~~68~~0 ——→	120°
	~~420°~~ 60° ——→	120°.



in DCM
2 Trigger

α+30°
and α+60°

SCR	
1	105
2	165
3	225
④	285,345
	✓

Q if α=75°

SCR1 triggered at

a) 105
b) 165
c) 165,105 ✓
d) ---

due to load current Discontinuity.
each SCR should be triggered twice
with a phase shift of 60°

if not, the Rectifier behaves as
if bieng half wave Rectifier

* * * * * * *

$$V_{o(av)\,CCM} = \frac{1}{\left(\frac{2\pi}{6}\right)} \int_{\alpha+\frac{\pi}{6}}^{(\alpha+\frac{\pi}{6})+\frac{\pi}{3}} V_{12}\, d\omega t$$

$$= \frac{3}{\pi} \int_{\alpha+\frac{\pi}{6}}^{\alpha+\frac{\pi}{2}} \sqrt{3}\, V_m \sin\left(\omega t + \frac{\pi}{6}\right) d\omega t$$

$$= \frac{-3\sqrt{3}\, V_m}{\pi} \cos\left(\omega t + \frac{\pi}{6}\right) \Bigg]_{\alpha+\pi/6}^{\alpha+\pi/2}$$

$$\frac{3\sqrt{3}\,V_m}{\pi}\left(-\cos\left(\alpha+\frac{\pi}{2}+\frac{\pi}{6}\right)+\cos\left(\alpha+\pi/6+\frac{\pi}{6}\right)\right)$$

$$\boxed{V_{o\,(av)\,ccm}=\frac{3\sqrt{3}\,V_m}{\pi}\cos\alpha}$$

Constant . في كل DCM .

$$V_{o(av)\,DCM}=\frac{1}{(2\pi/6)}\int_{\alpha+\pi/6}^{5\pi/6}\sqrt{3}\,V_m\sin\left(\omega t+\frac{\pi}{6}\right)d\omega t$$

$\alpha+\pi/6$ $5\pi/6$

$$\frac{3\sqrt{3}\,V_m}{\pi}\left[-\cos\left(\omega t+\frac{\pi}{6}\right)\right]_{\alpha+\pi/6}$$

$$=\frac{3\sqrt{3}\,V_m}{\pi}\left[-\cos\left(\frac{5\pi}{6}+\frac{\pi}{6}\right)+\cos\left(\alpha+\frac{\pi}{6}+\frac{\pi}{6}\right)\right]$$

$$V_{o\,av\,DCM}=\frac{3\sqrt{3}\,V_m}{\pi}\left[1+\cos\left(\alpha+\frac{\pi}{3}\right)\right]$$

$$V_{o(av)\,ccm}=V_{o(av)\,Dcm}\longrightarrow \text{critical Case.}\ \Rightarrow \alpha=\alpha_c=60^\circ$$

$$\frac{3\sqrt{3}\,V_m}{2\pi}\overset{?}{=}\frac{3\sqrt{3}\,V_m}{2\pi}.$$

✓

what is the Max possible firing angle if Resistive Load.

$\alpha_{max} \rightarrow ?? = \underset{DCM}{V_{oa(v)}} = 0°$

$V_{o(av)} = 0 = \frac{\sqrt{2} V_m}{\pi}\left(1+\cos\left(\frac{\pi}{3}+\alpha\right)\right)$

$1+\cos\left(\alpha+\frac{\pi}{3}\right) = 0$

$\cos\left(\alpha+\frac{\pi}{3}\right) = -1$

$\alpha + 60° = 180°$

$\boxed{\alpha = 120°}$

$$\alpha = \begin{cases} 0 \le \alpha < 60, & \text{for CCM} \\ 60°, & \text{for critical} \\ 60 < \alpha \le 120, & \text{for DCM.} \end{cases}$$

HW $V_{o(Rms)} = ?$ in CCM
DCM

No

$$\sqrt{\frac{1}{\frac{2\pi}{6}} \int_{\alpha' + \frac{\pi}{6}}^{\alpha' + \frac{\pi}{2}} v_{12}^2 \, d\omega t}$$

$$V_o(rms)\Big|_{CCM} = \sqrt{\frac{1}{2\pi/6} \int_{\alpha + \frac{\pi}{6}}^{\alpha + \frac{\pi}{2}} \left[\sqrt{3}\, V_m \sin\left(\omega t + \pi/6\right)\right]^2 d\omega t}$$

$$V_o(rms)\Big|_{DCM} = \sqrt{\text{Same} \int_{\alpha + \frac{\pi}{6}}^{5\pi/6} - - -}$$

~~DCM~~

$$CCM = \frac{3V_m}{\sqrt{\pi}} \sqrt{\frac{\pi}{3} - \frac{1}{4}\left[\sin\left(2\alpha + \frac{4\pi}{3}\right) - \sin\left(2\alpha + \frac{2\pi}{3}\right)\right]}$$

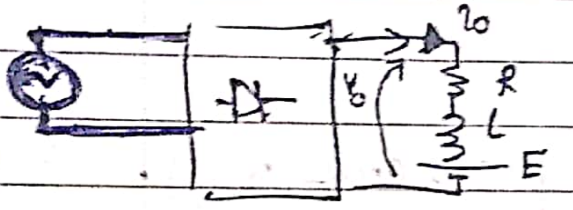
$$DCM = \frac{3V_m}{\sqrt{\pi}} \sqrt{\frac{1}{2}\left(\frac{2\pi}{3} - \alpha\right) + \frac{1}{4} \sin\left(2\alpha + \frac{2\pi}{3}\right)}.$$

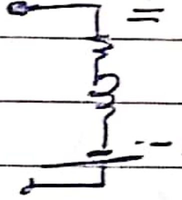
* Controller Single phase, Full wave fully controlled Bridge Rectifier

Supply 100 V (Vrms), 60 HZ, Sinusoidal

Load Series RLE Load $R = 0.5\,\Omega$
L is sufficiently large such that the load current is Ripple free and Equal to 10 A

$$E = \begin{cases} 65\,V & \text{motoring action} \\ -75\,V & \text{Breaking action} \end{cases}$$





by changing the field polarity.

a) Find α

b) PF input

c) which Source is delivering power to the other

ⓓ THDF of ~~Ev~~ i_s

e) RF of Vo and io

F) sketch ~~addwave~~ allwave Forms of interest.

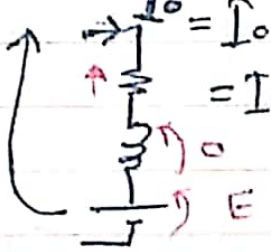
$\alpha \Rightarrow$ $V_o(av) = \frac{2V_m}{\pi} \cos\alpha$

ccm → because It is Ripple free pure Dc

$V_o(av) = 2 * \frac{(110)\sqrt{2}}{\pi} \cdot \cos\alpha$

$V_o(av) = I_o(av) R + E$ v_o

$= I_o(rms) = I_o = 10A$



$= I_o(rms)$
$= I_o(av)$

$10 * 0.5 + 65 = 70V$

$\alpha = \cos^{-1}\left(\frac{70 * \pi}{2\sqrt{2}(110)}\right) = \underline{\underline{45°}}$

$\boxed{\alpha = 45°}$

$PF_{in} = \frac{P_{input}(w)}{S_{input}(VA)} =$

$P_{in}(w) = p_{out}(w)$ → lossless Rectifier.

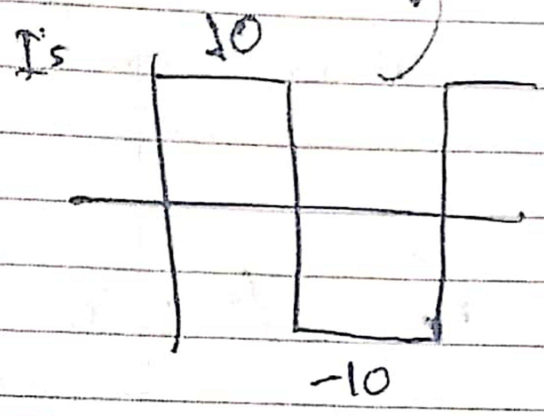
$p_o = I^2_o(rms)^{R} + I_o(av)E$

$p_o = I_o^2(R) + I_oE = 700W$

$S_{in} = V_{supply}(rms)\ I_s(rms)$.

$S_{in} = 110V. \times 10 = 1100$

$I_s(rms) = 10A$



$p_{in} = \frac{700}{1100}$ 0.636 lagging.

(inductive load).

OR $PF_{in} = DPF \times DTF$

$DPF \Rightarrow \cos\varphi_{(1)} = -n\alpha$

$\varphi_1 = -45° = 0.707$

$DTF \Rightarrow \frac{I_{s(1)}rms}{I_{s(t)}rms} = \frac{9}{10} = 0.9$

$pf_{in} = 0.707 \times 0.9 = 0.636$
lagging pf

$c(n) = \frac{4I_o}{n\pi}$

$c(1) = \frac{4I_o}{\pi}$

$I_{s(1)rms} = \frac{C(1)}{\sqrt{2}}$

$= \frac{4I_o}{\sqrt{2}\pi} = 9A$

the Ac source supplies power to load ~~delivery~~ (Motoring / Charging)

$$THDF :- \frac{\sqrt{I_{(S)rms}^2 - I_{(1)(rms)}^2}}{I_{(1)}(rms)} = 48.9\%$$

$$= \frac{10^2 - 9^2}{9} =$$

$$Rf_{Vo} = \frac{\sqrt{Vo(rms)^2 - Vo(av^2)}}{Vo(av} \quad \frac{\sqrt{110 - 70}}{70}$$

$Rf_{io} = 0\%$

$Rf_{Vo} = 121\%$

$Vo(rms) = Vo(supply\ rms) = 110\ V$

CCM

$Vo(av) = 70V$

(b)

$Vo(av) = I_oR + Emf$

$10.0.5 - 75 = -70\ V$

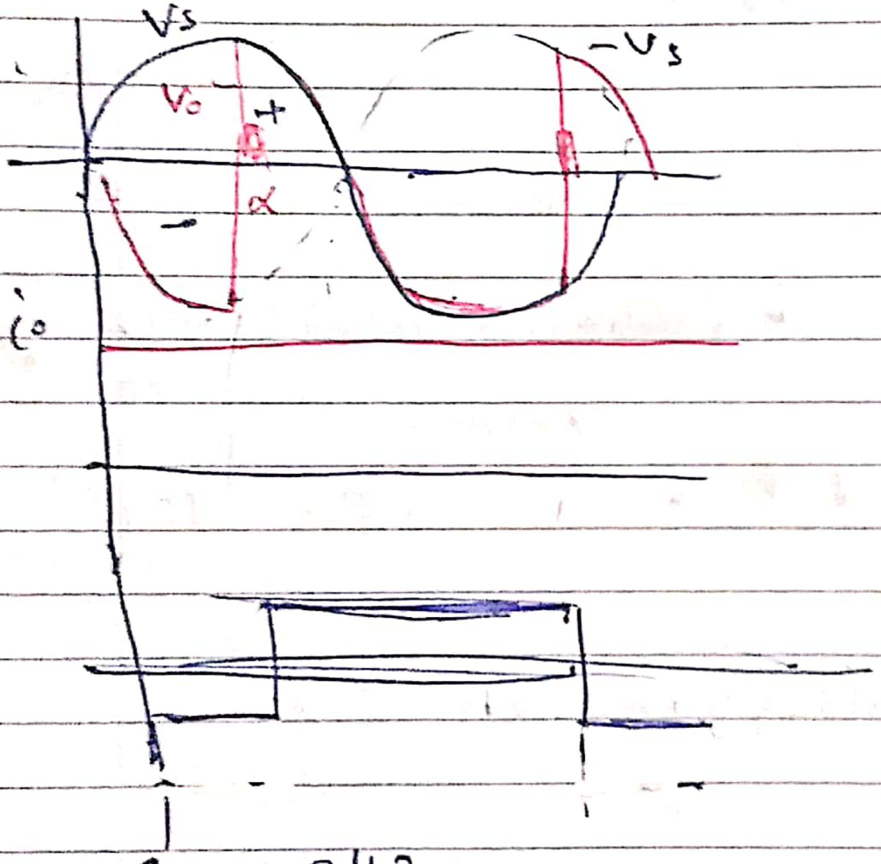
$$\alpha = \cos^{-1}\left(\frac{-70\pi}{2\sqrt{2}(110)}\right) = 135^{\circ}.\ 790^{\circ}$$ ✓

$$PF_{in} = \frac{P_{in}(W)}{S_{in}(VA)} = \frac{-V_o I_o}{S_{in}}$$

$$= \frac{-70 \times 10}{110 \times 10} = \boxed{-0.636}$$

the Supply is consuming P ←

lagging.



TADF = 48.43%

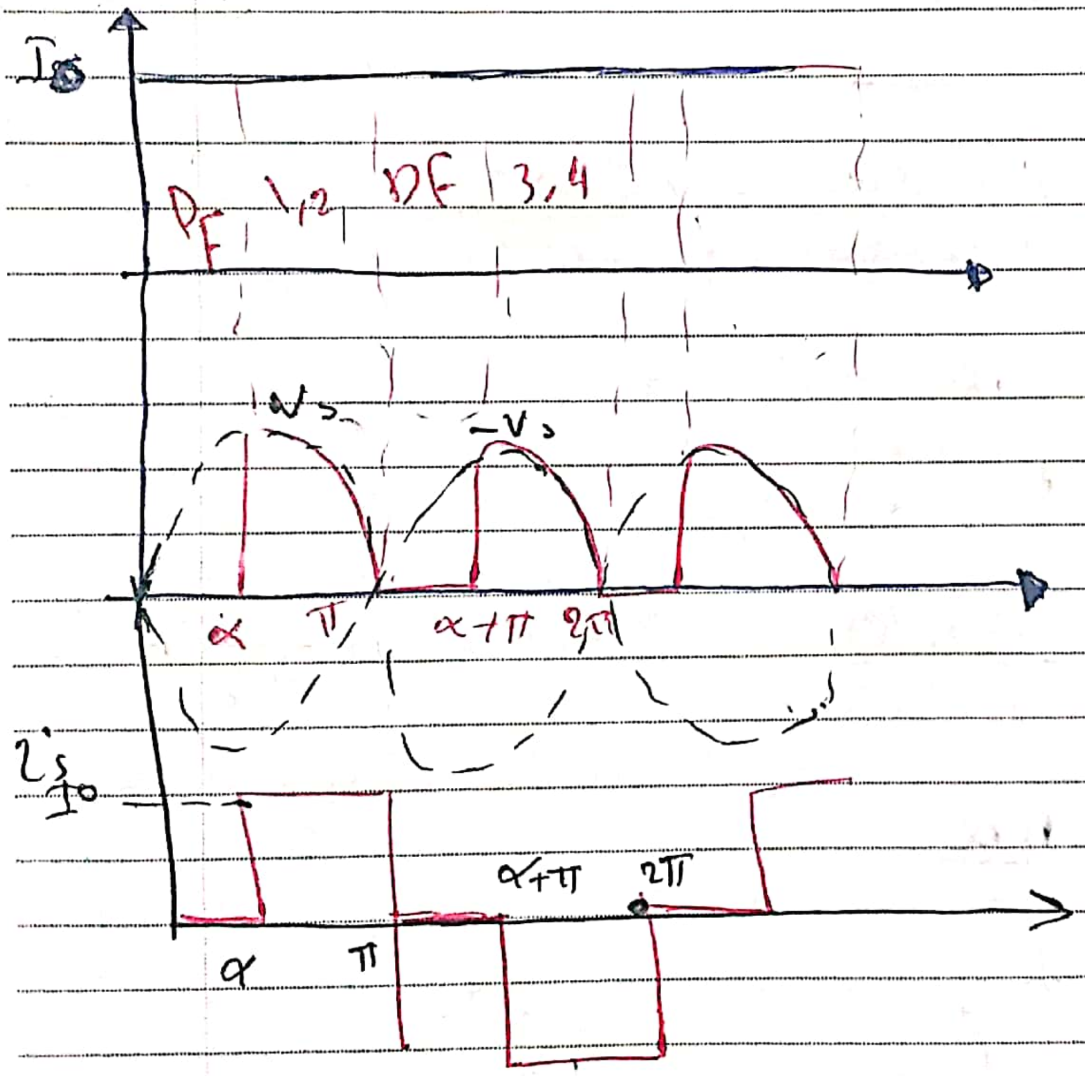
RF_{vo} = 121% $R_{f\,io} = 0$

٧/١٦ الأربعاء .

Q) if a free-wheeling diode is Connected to the circuit while E=65V and all parameters still the Same (DF parallel to the load).

Find ~~Complete per~~ all performce parameters.

Io = 10A



$$V_o(av) = \frac{V_m}{\pi}(1+\cos\alpha)$$

$$I_oR + Emf = 5+65 = 70$$

$$70 = \frac{V_m}{\pi}(1+\cos\alpha).$$

$$\boxed{\alpha = 65.5^\circ}$$

$$PF_{in} = \frac{P_{out}(w)}{S_{in}(VA)} = \frac{V_o(av)\, I_o}{V_s(rms) \cdot I_s(rms)}.$$

$$I_s(rms) = \sqrt{\frac{180-65.5}{180}}\, I_o$$

$$= 7.97A$$

$$PF = \frac{70.10}{110.7.97} = 0.798 \simeq 0.8 \text{ Lagging PF}$$

Better than fully Controlled.

$$\psi(n) = -\frac{n\alpha}{2}$$

$$C(n) = ?$$

$$THDF = \sqrt{\frac{I_s(rms)^2 - I_{s(1)}(rms)^2}{I_{(1)}(rms)}}$$

$$Rp\,vo = \frac{\sqrt{vo^2(rms) - Vo^2(av)}}{Vo(av)}$$

Vo(rms) if fully Controlled = Vs(rms)

⊛ is Semi Controlled $V_o rms < V_s(rms)$.

$$Vo(rms) = \sqrt{\frac{Vm^2}{2\pi}\left(\pi + \cancel{\beta} - \alpha + \frac{1}{2}\sin(2\alpha) - \cancel{\frac{1}{2}\sin(2\beta)}\right)}$$

Vo(rms) = [illegible]

Rpvo (in Semi controlled is Better) = [illegible]

Given controller single phase fully Controlled Rectifier Bridge Supply 220V 50Hz Sinusoidal Load R-L Load (R=10Ω, L = 55.133mH) for α=60° evaluate performence paramters.

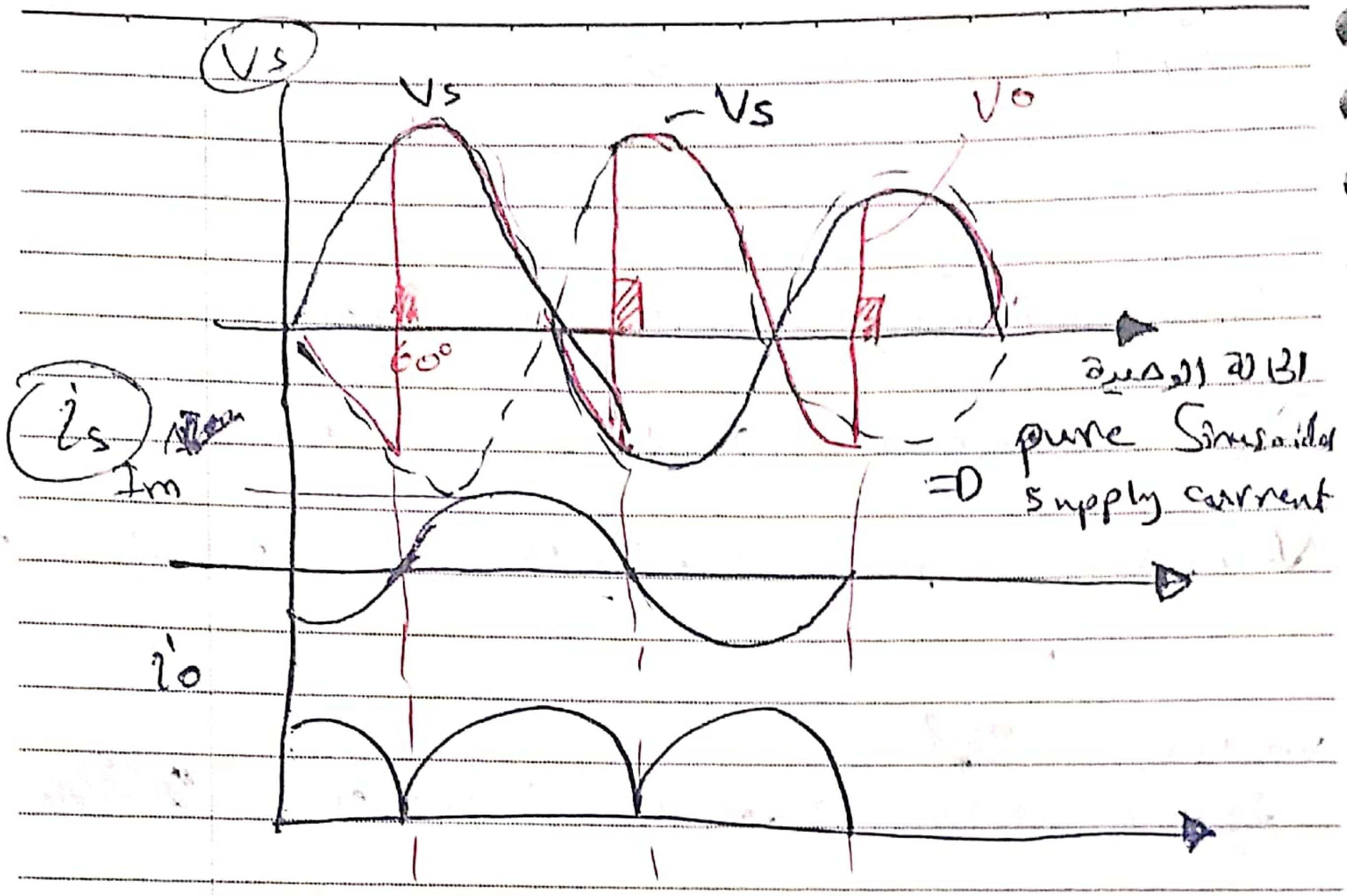
⊛ α & φ

$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right) = \phi$ $\omega L = 17.3\Omega$

$\tan^{-1}\left(\frac{17.3}{10}\right)$ ⇒ $\phi \approx 60°$ $\boxed{\text{Critical mode}}$

$\pi + \beta = \pi + \alpha$

No.



$i = I_m \sin(\omega t - \phi)$ - - - -

$V(rms) = 220\ V$

$V_o(av) = \frac{2V_m}{\pi}\cos(60°) = \frac{2(220\sqrt{2})\left(\frac{1}{2}\right)}{\pi}$

$K_p I_o =$

$I_o(av) =$

$I_m = \frac{V_m}{Z}$ $\quad Z = \sqrt{10^2 + (17.3)^2} = \frac{V_o(av)}{R}$

No.

$I_o(rms) = \frac{I_m}{\sqrt{2}}$

$Pf = \cos\alpha = 0.5$ lagging

THDF = 0.

No.

17-7 الاربعاء.

Q1) controlled :- Single-Phase, full wave Centertapped Rectifier

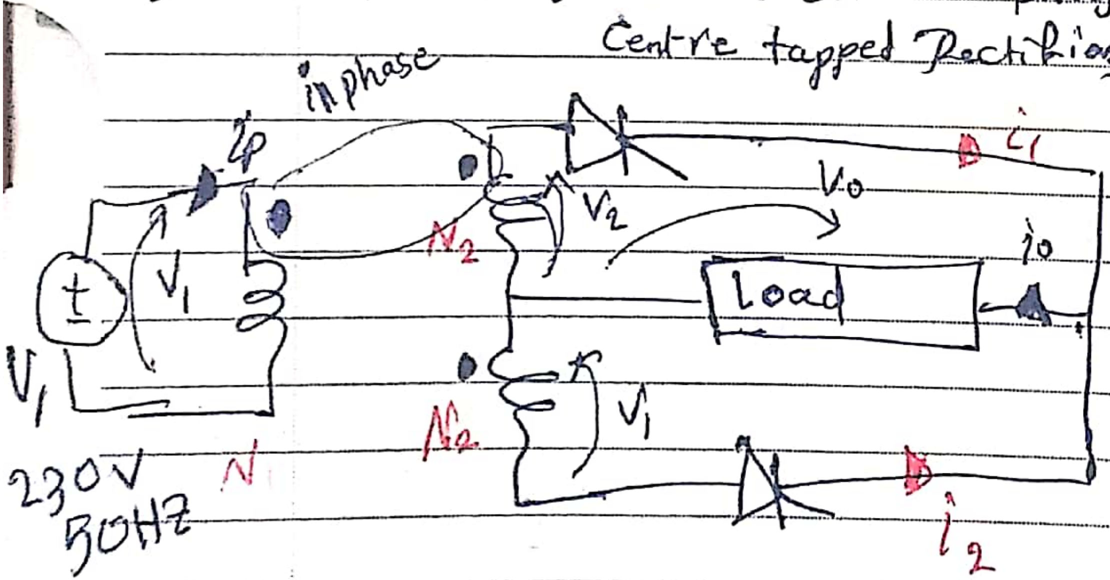
Supply | 230 V, 50 HZ, Sinusoidal

Transformer | (230V / 115-115V), 2KVA, 50HZ

Load | pure Resistive 15 Ω

1) Max possible load average current
2) α? for $I_o(av)$ = ~~10A~~ 5A

3) α = 45° pf in = ??
5) select suitable voltage & current Rating of the ~~SCR~~ SCR
4) State the major difference between Bridge and Centre tapped Rectifiers.



a(turns Ratio) = $\frac{N_1}{N_2}$ = 2:1

$V_p = 230\sqrt{2}\ \sin(\omega t)$

$V_s = 115\sqrt{2}\ \sin(\omega t)$

$\frac{V_p}{V_s} = \frac{N_1}{N_2} = a$

$V_s = \frac{V_p}{a} \Rightarrow V_p = \frac{230\sqrt{2}}{2} \sin \omega t$

$V_s = 115\sqrt{2}\ \sin \omega t$ ..

Resistive Load ⊕ $V_{o(av)} = I_{o(av)} R$

$I_{o(av)} = \frac{V_{o(av)}}{R}$ max.

max

$V_{o(av)} = \frac{V_m}{\pi} (1 + \cos \alpha)$.

DCM

$\boxed{\beta = 0 \text{ Resistive load}}$

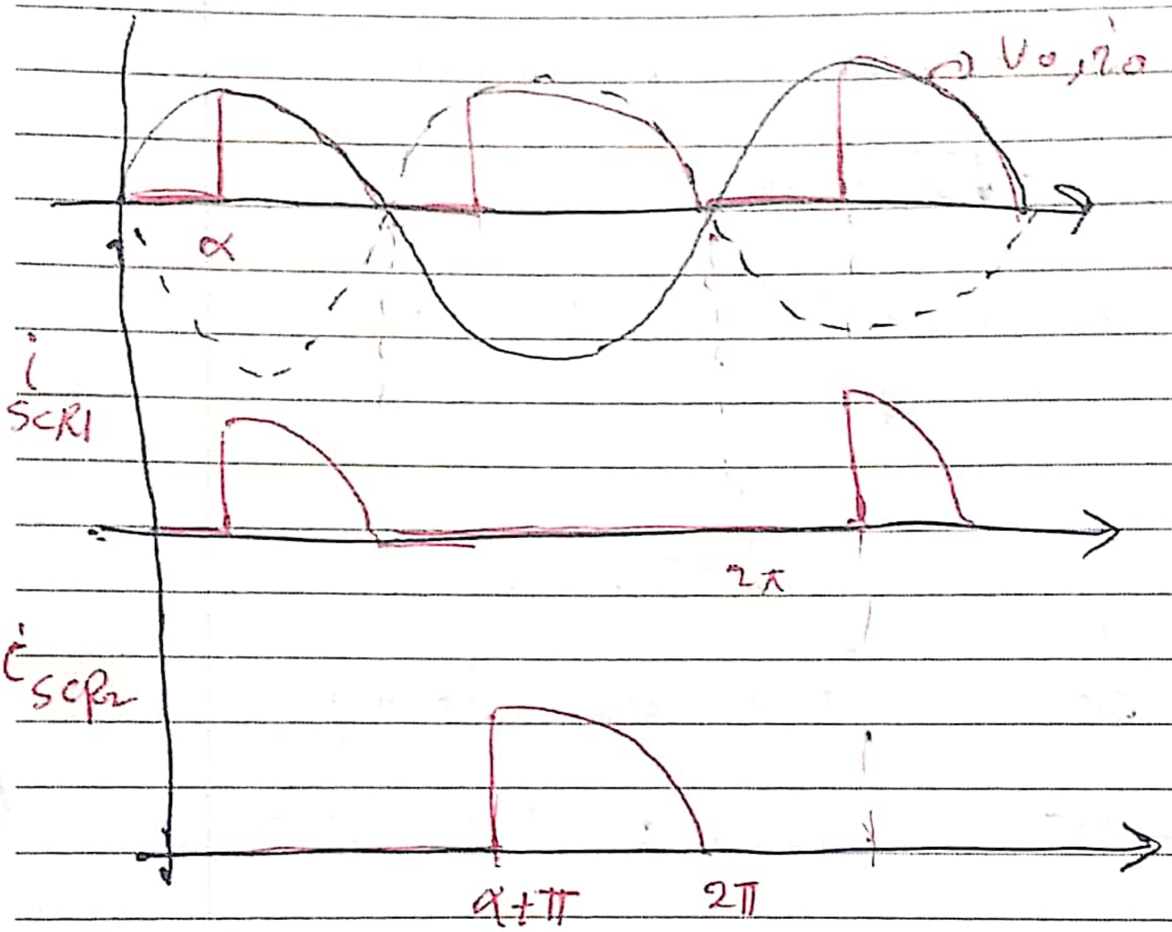
$V_{o(av)\,max} = \frac{115\sqrt{2}}{\pi} (1 + \cos 0°)$ to find max.

$V_{o(av)}$ max = $\frac{2 \cdot 115 \cdot \sqrt{2}}{\pi} = 103.5$ V

$I_{av\,max} = \frac{103.5}{15} = 6.9$ A

Rated values → at maximum possible case.

$I_{rms} = \frac{V_{o(rms)}}{R}$ (Load is Resistive).



$I_{SCR(av)} = \frac{I_{o(av)}}{2}$ A   3.45A

$V_{o(rms)}$ Resistive $= \sqrt{\frac{V_m^2}{2\pi}\left(\pi + \overset{0}{\cancel{\beta}} - \alpha + \frac{1}{2}\sin(2\alpha)\right)}$

$I_{SCR}(rms) = \sqrt{\frac{I_m^2}{4\pi}(\pi - \alpha + \frac{1}{2}\sin 2\alpha)}$.

Form factor ?

$I_m = \frac{V_m}{Z}$ $\frac{\sqrt{2}(115)}{15}$ =

$\alpha = 0, I_{SCR} = \frac{I_m}{2} = 5.42\,A$
(rms)
rating

$I_{SCR\ peak} = I_m = 10.84\,A$

PIV (peak inverse Volt

Rect	PIV
HW single-phase	V_m
FW single-ph	V_m
centre tapped	$2V_m$
3-phase Rect.	$\sqrt{3}V_m$

SCR Voltage Ratings

(2→3) PIV → 2 V_m

Ex centretapped

9 $V_m = \sqrt{2}(115)(2)$

$VSCR = (2 \to 3) * (\sqrt{2})(115)(2)$

VSCR ( )

$(648 \to 972)$

$\alpha = ?$ $I = 5A$

$V_{o(av)} = R I_{o(av)} = 10 * 15 = 150V$

$150 = \int$

$150 = \frac{V_m}{\pi}(1 + \cos\alpha)$.

$\alpha = \cos^{-1}\left(\frac{150\pi}{\sqrt{2} * 115} - 1\right)$

[redacted] ③

$\cos\alpha = 1.89$

if 5A

$\cos\alpha = 0.448$

$\alpha = 63.8^\circ$

if $\alpha = 45^\circ$

find pF

$$V_o(av) = \frac{115\sqrt{2}}{\pi}(1+\cos 45^\circ)$$

$V_o(av) = 88.3\,V$

$I_o(av) = V_o(av)/R = 5.8\,A$

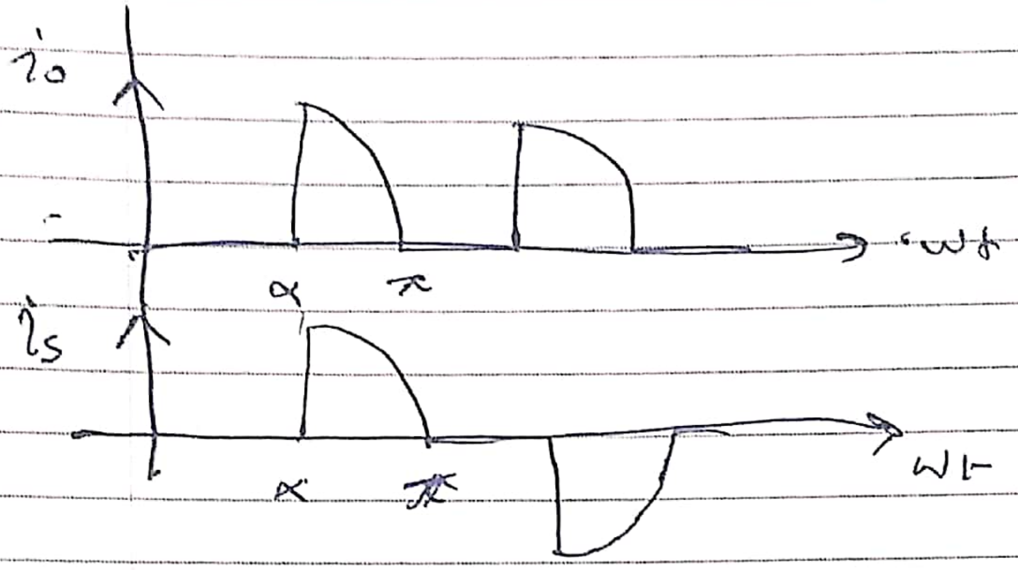
$$pF = \frac{\overset{\boxed{I_o^2(rms)\,R}}{P_{out}(W)}}{\underset{\text{in}}{S(VA)}} =$$

$I_s(rms)\;V_s(rms)$

$$I_o(rms) = \sqrt{\frac{I_m^2}{2\pi}\left(\pi-\alpha+\frac{1}{2}\sin 2\alpha\right)}$$

$I_o(rms) =$

$I_s(rms) = I_o(rms)$



Cater Thyristor is more expensive
triggering circuit is Cheeper

Transformer is a must (drawbacks).

they are Same Core, but the copper is more
so, it's wieght is larger.

Power ~~Gross~~ loss → Bridge Better.