CMR INSTITUTE OF TECHNOLOGY	USN										

Internal Assesment Test II – April 2019							
Sub:	INDUSTRIAL DRIVES & APPLICATIONS					Code:	15EE82
Date:	15/04/2019	Duration:	90 mins	Max Marks:	50	Sem: 8	Section: A & B

Note: Answer any **five FULL** Questions

Sketch neat figures wherever necessary. Answer to the point. **Good luck!**

		Marks	OBE CO	OBE RBT
1	Obtain the thermal model of motor for heating and cooling. Also draw the heating and cooling curve.	[10]	CO2	L2
2	Explain the method of determination short time and intermittent duty loads. Also derive the expression for power rating using over loading factor "K"	[10]	CO2	L2
3 a)	A motor operates on a periodic duty cycle in which it is clutched to its load for 10mins and declutched to run on no load for 20min. Minimum temperature rise is 40^{o}C.Heating and cooling time constants are equal and have a value of 60 mins.when the load is declutched continuously the temperature rise is 15 ^{o}C. Determine i. Maximum temperature during the duty cycle ii. Temperature when the load is clutched continuously	[4]	CO2	L2
b)	A 200V, 1000 RPM, 120A separately excited dc motor has an armature resistance of 0.06Ω. it is fed from a single phase fully controlled rectifier with an ac source voltage of 220V,50Hz. Assuming continuous conduction calculate i. firing angle for rated motor torque and 850 rpm ii. firing angle for half of rated torque and -600rpm iii. motor speed for firing angle 120 and rated torque	[6]	CO3	L2
4	With circuit diagram and waveform, explain the operation of single phase fully controlled rectifier fed separately excited dc motor for continuous mode of operation.	[10]	CO3	L2
5.	With neat circuit diagram and waveforms ,explain the chopper control of separately excited dc motors	[10]	CO3	L2
6	Explain the multi quadrant operation of DC separately excited motor using fully controlled rectifier	[10]	CO3	L2

7 a)	Explain different classes of motor duty	[6]	CO2	L2
b)	The motor rating has to be selected from a class of motors with heating and cooling time constants 60 and 90 min respectively. Calculate the motor rating for the following duty cycle. i. Short time periodic duty cycle consisting of 100KW load for 10mins followed by no load period long enough for the motors to cool down. ii. Intermittent periodic duty cycle consisting of 100KW load period of 10min and no load period of 10 min.	[4]	CO2	L2
8	With circuit diagram and waveform, explain the operation of three phase fully controlled rectifier fed separately excited dc motor for continuous mode of operation.	[10]	CO3	L2

1.

Thermal Model of Motor for heating and Cooling.

Assume m/c to be homogeneous body and cooling medium has the following parameters at time t.

p_1 – heat developed watts / joules/sec.

p_2 – heat dissipated to the cooling medium (watts)

W – weight of the active parts of machine kg.

h = Specific heat, Joules per kg per °c.

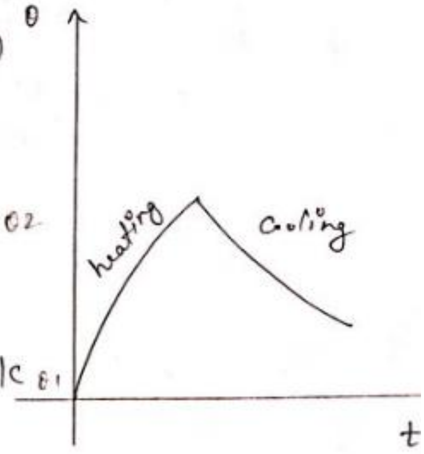
A = Cooling surface, m^2

d_1 – Co-efficient of heat transfer or specific heat dissipation, joules/sec/m²/°c

θ – mean temp rise, °c.

Heat absorbed = Heat developed - Heat dissipated.

Heat developed = heat absorbed + heat dissipated.



$$p_1 \, dt = Wh \, d\theta + p_2 \, dt \quad - (1)$$

$$\boxed{p_2 = \theta \, d_1 A}$$

Sub P_2 in (1)

$$p_1 \, dt = Wh \, d\theta + \theta \, d_1 A \, dt$$

assume $Wh = C \rightarrow$ thermal capacity of m/c in watts/°c.

$dA = D$ heat dissipation const.

$$\therefore \; p_1 \, dt = Wh \, d\theta + \theta D \, dt$$

$$p_1 \, dt = c \, d\theta + \theta D \, dt. \qquad \boxed{c \frac{d\theta}{dt} = P_1 - D\theta} \quad - (I).$$

$$c \, d\theta = p_1 \, dt - \theta D \, dt \Rightarrow$$

$$c \, d\theta = dt \, (p_1 - \theta D)$$

$$\frac{dt}{c} = \frac{d\theta}{p_1 - \theta D} \quad - (2)$$

(2) × $\frac{1}{D}$

$$\frac{dt}{c/D} = \frac{d\theta}{\frac{p_1}{D} - \theta}$$

$$\boxed{\frac{dt}{\tau} = \frac{d\theta}{\frac{p_1}{D} - \theta}} \quad - (3).$$

when steady state is reached,

heat gen = heat dissipated

$$p_1 \cancel{dt} = \theta_{ss}\, dA\, \cancel{dt}$$

$$\theta_{ss} = \frac{p_1}{dA} = \frac{p_1}{D}$$

$$\boxed{\theta_{ss} = \frac{p_1}{D}} \quad - \ (4).$$

(4) in (3),

$$\frac{dt}{\tau} = \frac{d\theta}{\theta_{ss} - \theta}$$

where $\tau - \frac{C}{D}$; $\theta_{ss} = \frac{p_1}{D}$

$$\frac{1}{\tau}\int dt = \int \frac{d\theta}{\theta_{ss} - \theta}$$

$$\boxed{\frac{t}{\tau} = -\log(\theta_{ss} - \theta) + K} \quad - \ (5)$$

To find K, at $t=0$, $\theta = \theta_1$

$$0\ \cancel{\frac{t}{\tau}} = -\log(\theta_{ss} - \theta_1) + K$$

$$\boxed{K = \log(\theta_{ss} - \theta_1)} \quad - \ (6).$$

(6) in (5),

$$\frac{t}{\tau} = -\log(\theta_{ss} - \theta) + \log(\theta_{ss} - \theta_1)$$

$$\frac{t}{\tau} = \log\frac{(\theta_{ss} - \theta_1)}{(\theta_{ss} - \theta)}$$

$$e^{t/\tau} = \frac{\theta_{ss} - \theta_1}{\theta_{ss} - \theta}.$$

$$\theta_{ss} - \theta = \frac{\theta_{ss} - \theta_1}{e^{t/\tau}}$$

$$\theta_{ss} - \theta = (\theta_{ss} - \theta_1)\, e^{-t/\tau}$$

$$\theta_{ss} - \theta = \theta_{ss}\, e^{-t/\tau} - \theta_1 e^{-t/\tau}$$

$$\theta = \theta_{ss} - \theta_{ss} e^{-t/\tau} + \theta_1 e^{-t/\tau}$$

$$\boxed{\theta_h = \theta_{ss}(1 - e^{-t/\tau}) + \theta_1 e^{-t/\tau}} \quad - ④.$$

where τ = heating or thermal time const.

at $t \to \infty$, $\theta = \theta_{ss}$

i.e θ_{ss} - steady state temp of the m/c when it is continuously heated by power p_1.

i.e at this temp, all the heat produced in m/c is dissipated to the surrounding medium.

Now if the load is thrown off after its temp rise θ_2, heat loss will reduce to a small value. Let it be p_1' and cooling operation of the motor will begin.

$\therefore$ Using ⑦,

$$c \frac{d\theta}{dt} = p_1' - D'\theta \quad - ⑧.$$

solving ⑧,

$$\boxed{\theta_c = \theta_{ss}' (1 - e^{-t/\tau'}) + \theta_2 e^{-t/\tau'}} \quad - ⑨.$$

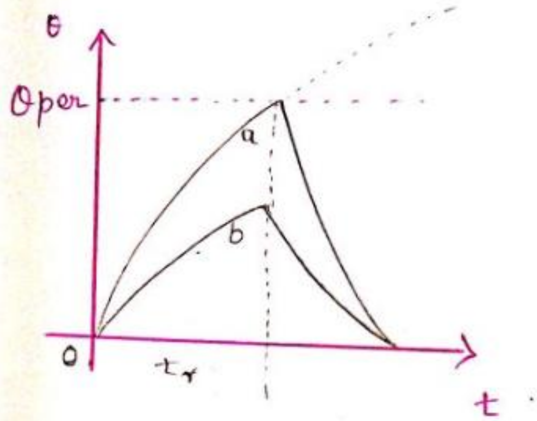
where $\theta_{ss}' = \frac{p_1'}{D'}$; $\tau' = \frac{c}{D'}$

τ' - cooling time const, θ_{ss}' steady state operation for new cond of operation

2. Over loading factor k :

Determination of motor rating:

SHORT TIME DUTY.



a → with power KP_r
b → with power P_r.

$$\theta_{per} = \theta_{ss}\left(1 - e^{-t_r/\tau}\right) \quad — ①$$

$$\frac{\theta_{ss}}{\theta_{per}} = \frac{1}{1 - e^{-t_r/\tau}} \quad — ②$$

θ_{ss} – steady state temp of the motor (on continuous duty) with power KP_r.

θ_{per} – steady state temp of the motor (on continuous duty) with power P_r

Let P_{lr} and P_{ls} be the motor power losses with ratings P_r and KP_r.

$\theta_{ss} \rightarrow KP_r \rightarrow P_{ls}$

$\theta_{per} \rightarrow P_r \rightarrow P_{lr}$.

Under steady - state condn,

heat gen = heat dissipated.

Let $\theta = \theta_{ss} \Rightarrow$ steady state temp.

$$\theta_{ss} = \frac{P_{ls}}{D} \quad -(3) \; ; \quad \theta_{per} = \frac{P_{lr}}{D} \quad -(4)$$

Combining (2), (3) & (4),

$$\frac{\theta_{ss}}{\theta_{per}} = \frac{P_{ls}}{P_{lr}} = \frac{1}{1-e^{-t_r/\tau}} \quad — (5).$$

Let $P_{lr} = P_c + P_v$

$= P_c + P_{cu}$

Let $\alpha = \frac{p_c}{p_{cu}}$

$$\therefore P_{lr} = P_{cu}\left[1 + \frac{p_c}{p_{cu}}\right]$$

$$P_{lr} = p_{cu}\left[1+\alpha\right] \quad (6)$$

$$P_{ls} = P_c + K^2 P_{cu}$$

$$P_{ls} = P_{cu}\left[K^2 + \alpha\right] \quad --- (7).$$

Substituting ⑥ & ⑦ in ⑤,

$$\frac{\alpha + K^2}{1+\alpha} = \frac{1}{1-e^{-t_r/\tau}}.$$

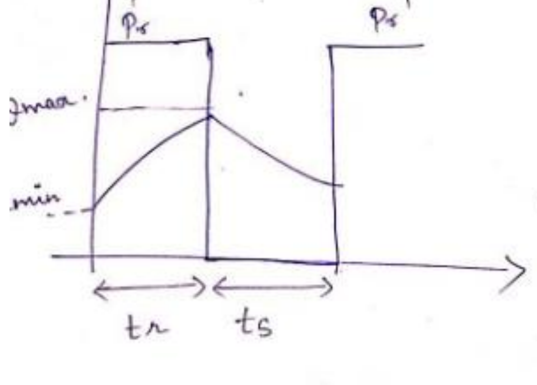
$$K^2 = \frac{1+\alpha}{1-e^{-t_r/\tau}} - \alpha$$

$$K = \sqrt{\frac{1+\alpha}{1-e^{-t_r/\tau}} - \alpha}$$

where K is the overloading factor. K can be calculated if constant and cu losses are known seperately

INTERMITTENT PERIODIC DUTY

Equivalent T, current and P method cannot be employed where speed changes in wide limits.



Consider a simple intermittent load, where the motor is alternately subjected to a fixed magnitude of P_r' load duration t_r and standstill cond of ~~loa~~ duration t_s.

W.K.T, $\theta = \theta_{ss}(1-e^{-t/\tau}) + \theta_1 e^{-t/\tau}$ — ①

Here, $\theta = \theta_{max}$, $\theta_1 = \theta_{min}$, $t = t_r$, $\tau = \tau_r$

$$\theta_{max} = \theta_{ss}(1-e^{-t_r/\tau_r}) + \theta_{min} e^{-t_r/\tau_r} \quad \text{— ②} \quad \text{(during } t\text{}$$

$$\theta_{min} = \theta_{max} e^{-t_s/\tau_s} \text{ — ③}$$ (during t_s or fall in temp or at the end of stand still

③ in ②,

$$\theta_{max} = \theta_{ss}(1-e^{-t_r/\tau_r}) + \theta_{max} e^{-t_s/\tau_s} e^{-t_r/\tau_r}$$

$$= \theta_{ss}(1-e^{-t_r/\tau_r}) + \theta_{max} e^{-(t_s/\tau_s + t_r/\tau_r)}$$

$$\theta_{max} - \theta_{max} e^{-(t_s/\tau_s + t_r/\tau_r)} = \theta_{ss}(1-e^{-t_r/\tau_r})$$

$$\theta_{max}\left[1 - e^{-(t_s/\tau_s + t_r/\tau_r)}\right] = \theta_{ss}(1-e^{-t_r/\tau_r})$$

$$\frac{\theta_{ss}}{\theta_{max}} = \frac{1 - e^{-(t_s/\tau_s + t_r/\tau_r)}}{1 - e^{-t_r/\tau_r}}$$

$\theta_{max} = \theta_{per}$ — for full utilization of motor.

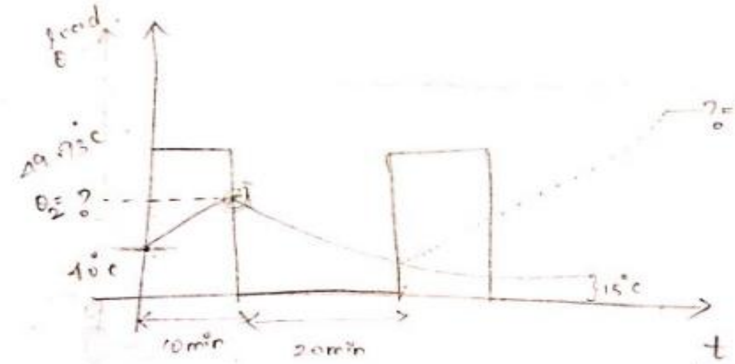
Let p_{lr} and p_{ls} be losses for load values of p_r and p_r', then

$$\frac{p_{ls}}{p_{lr}} = \frac{\theta_{ss}}{\theta_{per}} = \frac{1 - e^{-\left(\frac{t_s}{\tau_s} + \frac{t_r}{\tau_r}\right)}}{1 - e^{-t_r/\tau_r}} = \frac{K^2 + \alpha}{1 + \alpha}$$

$$K^2+\alpha = (1+\alpha)\frac{1-e^{-\left(\frac{t_s}{\tau_s}+\frac{t_r}{\tau_r}\right)}}{1-e^{-t_r/\tau_r}}$$

$$K = \sqrt{(1+\alpha)\frac{1-e^{-\left(\frac{t_s}{\tau_s}+\frac{t_r}{\tau_r}\right)}}{1-e^{-t_r/\tau_r}} - \alpha}.$$

3 a



$\tau = \tau' = 6$

heating

$$\theta = \theta_{ss_1}(1-e^{-t/\tau}) + \theta_1 e^{-t/\tau}$$

θ_1 - initial temp rise.

$\theta_{ss_1} \rightarrow \theta_{max}$

$$\theta = \theta_{ss_1}(1-e^{-10/60}) + 40\, e^{-10/60}.$$

$$\theta = \theta_{max}(0.1535) + 33.86.$$

$$\boxed{\theta = 0.15\,\theta_{max} + 33.86}. \quad -(1).$$

(4)

$\theta = \theta_{ss} (1 - e^{-t/\tau'}) + \theta_2 e^{-t/\tau'}$

$\theta = 15 \left(1 - e^{-20/60}\right) + \theta_2 e^{-20/60}$.

$40 = 4.25 + \theta_2 (0.716)$

$0.716 \theta_2 = 35.75$

$\boxed{\theta_2 = 49.93^\circ C}$

θ- mean temp rise at particular time

$\theta = 40^\circ$ during cooling

-ake ①

$\theta = \theta_2$ b'coz mean temp during heating

$49.93 = \theta_{max} (0.1535) + 33.86$.

$0.1535 \theta_{max} = 16.07$.

$\boxed{\theta_{max} = 104.69}$

3 b

(i) E_1 - rated $E_1 = V - i_a R_a = 200 - \ldots$

$E_1 = 191V$, $N_1 = 875$ rpm. $\frac{E_1}{E_2} = \frac{N_1}{N_2}$

$E_2 = ?$ $N_2 = 750$ rpm

$$E_2 = E_1 \frac{N_2}{N_1} = 191 \times \frac{750}{875} = 163.71\,V$$

$$\frac{2V_m}{\pi} \cos\alpha = V_a$$

$$V_a = E_2 + i_a R_a = 163.71 + (150 \times 0.06) = 172.71$$

$$V_m = \cancel{2V} V_L\sqrt{2} = 220\sqrt{2} = 311.13\,V$$

$$\cos\alpha = \frac{V_a \pi}{2V_m} = \frac{172.71\,\pi}{2 \times 311.13} = 0.8719$$

$$\boxed{\alpha = 29.31^\circ}$$

(ii) E_2 at -500 rpm, $= 191 \times \frac{-500}{875} = -109.14$.

$$V_a = E_2 + i_a R_a \Rightarrow -109.14 + (150 \times 0.06) = -100.14.$$

$$\cos\alpha = \frac{-100.14\,(\pi)}{2 \times 311.13} = -0.5055$$

$$\boxed{\alpha = 120.369}$$

(iii) $\alpha = 160^\circ$,

$$\frac{2V_m}{\pi} \cos\alpha = V_a$$

$$V_a = \frac{2(311.13)}{\pi} \cos 160 = -186.12\,V.$$

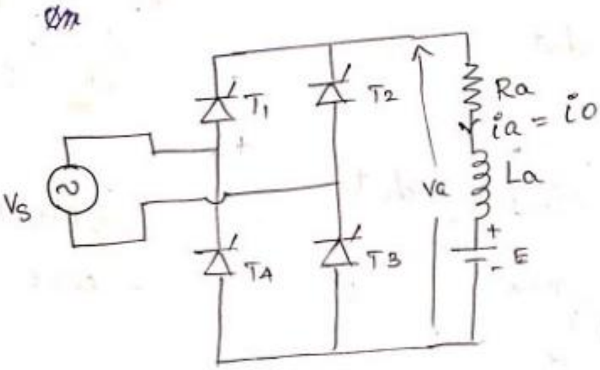
$E_2 = V_a - i_a R_a$. $E_2 = -186.12 - (150 \times 0.06)$

$$E_2 = -195.126$$

$E_2 = E_1 \frac{N_2}{N_1}$; $N_2 = \frac{E_2}{E_1} N_1 = \frac{-195.126}{191} \times 875$

(exercise) $\boxed{N_2 = -893.90}$ rpm.

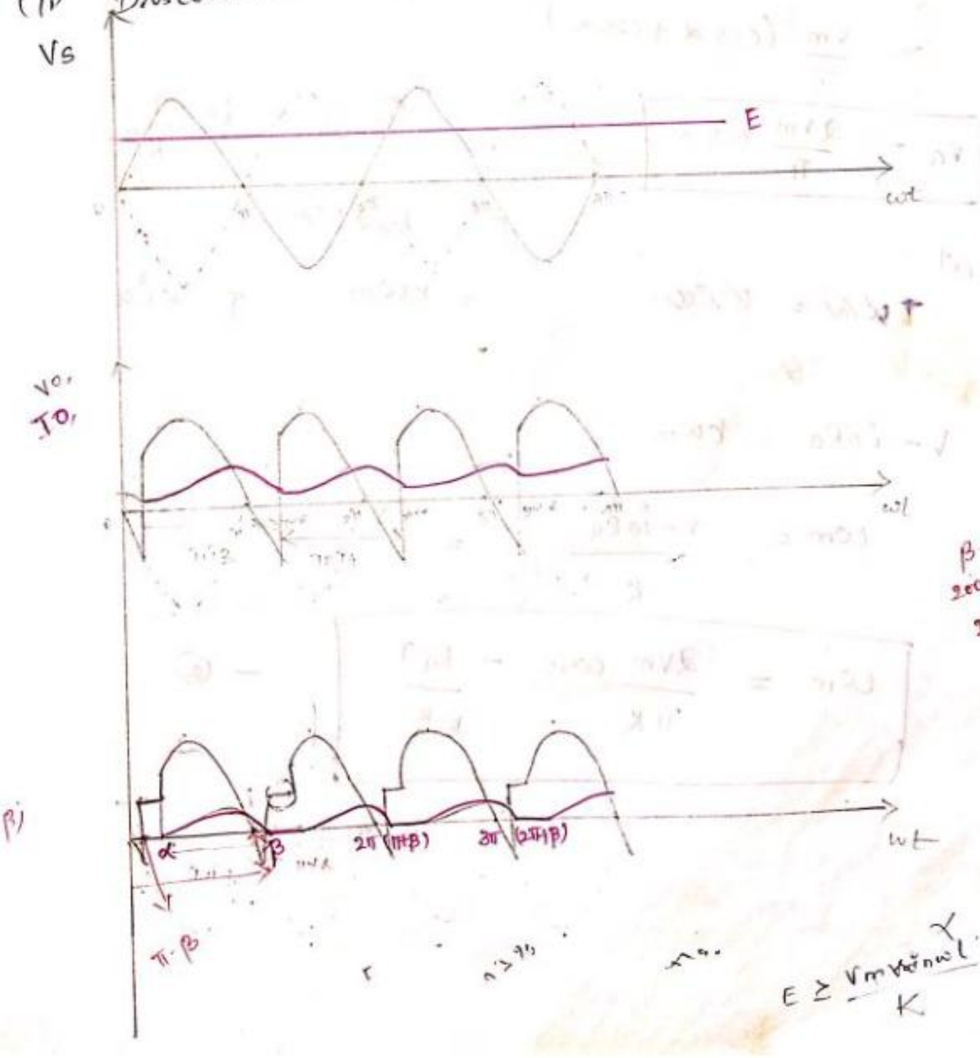
1φ Fully controlled Rectifier control of dc separately excited motor



CONTROLLED rectifier fed dc drives are known as Static Ward - Leonard drives.

(i) Continuous (current) mode

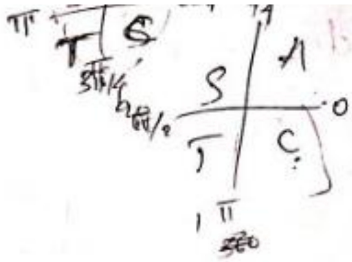
(ii) Discontinuous (current) mode



$\beta - \pi$

$E \geq \frac{V_m \sin \omega t}{K}$

Continuous mode.



$V_s = V_m \sin \omega t$

$$V_a = \frac{1}{\pi} \int_{\alpha}^{\pi+\alpha} v_s \, d\omega t$$

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

$$-\cos(\pi + \theta) = \cos\theta.$$

$$= \frac{V_m}{\pi} (-\cos \omega t)_{\alpha}^{\pi+\alpha}$$

$$= \frac{V_m}{\pi} (-\cos(\pi+\alpha) + \cos\alpha)$$

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

$$\boxed{V_a = \frac{2V_m}{\pi} \cos\alpha.} \quad — ①$$

$$i_a = \frac{T}{K^2}$$

$$E = K_e \phi \omega_m$$

$$= K\omega_m. \qquad T = K i_a.$$

sep ext $T \cancel{\omega m} = \cancel{E I \alpha}$.

$V - i_a R_a = K\omega_m$

$$\omega_m = \frac{V - i_a R_a}{K} = V -$$

$$\boxed{\omega_m = \frac{2V_m}{\pi K}\cos\alpha - \frac{R_a T}{K^2}} \quad — ②$$

$$V_a = \frac{1}{\pi}\left[\int_{\alpha}^{\beta} v_a + \int_{\beta}^{\pi+\alpha} E\right] d\omega t$$

$$= \frac{1}{\pi}\left[\int_{\alpha}^{\beta} V_m \sin \omega t \; d\omega t + \int_{\beta}^{\pi+\alpha} E \; d\omega t\right]$$

$$= \frac{1}{\pi}\left[V_m \left(-\cos \omega t\right)_{\alpha}^{\beta} + E \left(\omega t\right)_{\beta}^{\pi+\alpha}\right]$$

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

$$V_a = \frac{V_m\left(\cos\alpha - \cos\beta\right) + \left(\pi+\alpha-\beta\right)E}{\pi}$$

$i_a R_a$

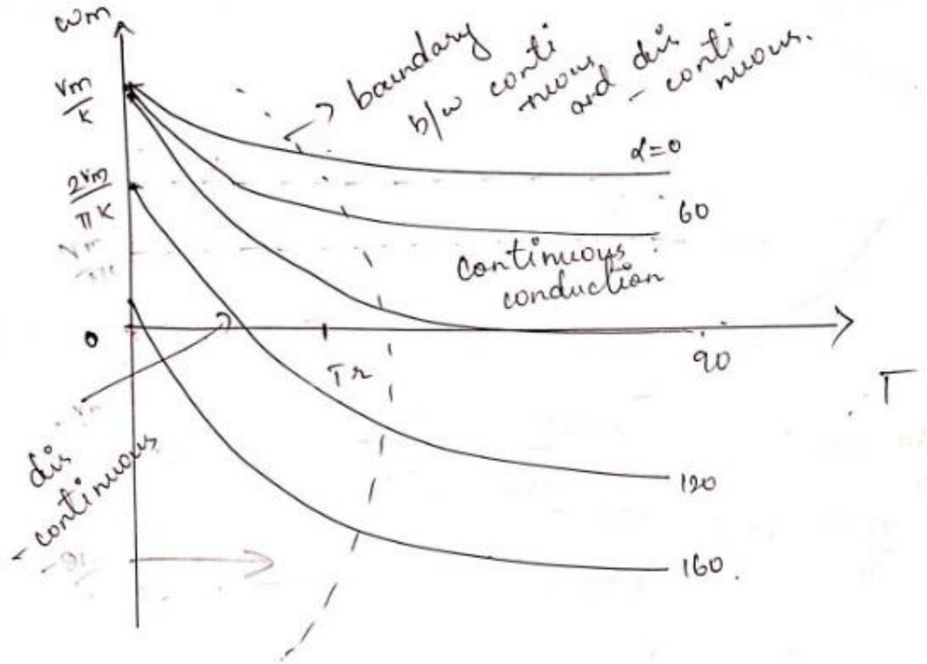
$T = K i_a$

$$\omega_m = \frac{V - i_a R_a}{K}$$

$$= \frac{V_m(\cos\alpha - \cos\beta) + (\pi+\alpha-\beta)E}{\pi K} - \frac{i_a R_a}{K}$$

$$\omega_m = \frac{V_m(\cos\alpha - \cos\beta) + (\pi+\alpha-\beta)K\omega_m}{\pi K} - \frac{R_a T}{K^2}$$

$$\omega_m - \frac{\cancel{K}\omega_m(\pi+\alpha-\beta)}{\pi \cancel{K}} = \frac{V_m(\cos\alpha - \cos\beta)}{\pi K} - \frac{R_a T}{K^2}$$



$$\omega_m \left[1 - \frac{(\pi+\alpha-\beta)}{\pi}\right] = \frac{V_m(\cos\alpha-\cos\beta)}{\pi K} - \frac{R_a T}{K^2}$$

$$\rightarrow \frac{\cancel{\pi}-\cancel{\pi}-\alpha+\beta}{\pi}$$

$$\omega_m \frac{-(\alpha-\beta)}{\pi} = \frac{V_m(\cos\alpha-\cos\beta)}{\pi K} - \frac{R_a T}{K^2}$$

$$\times\frac{\pi}{(\alpha-\beta)}$$

$$\omega_m = \frac{V_m(\cos\alpha-\cos\beta)}{K-(\alpha-\beta)} - \frac{R_a T}{K^2}$$

$$\omega_m \frac{(\beta-\alpha)}{\pi} = \frac{V_m(\cos\alpha\cdot\cos\beta)}{\pi K} - \frac{R_a T}{K^2}$$

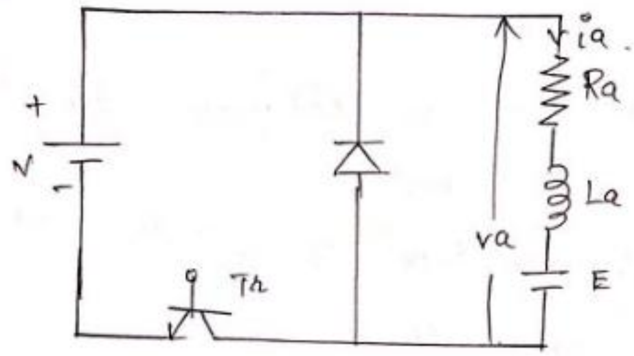
$$\boxed{\omega_m = \frac{V_m(\cos\alpha-\cos\beta)}{K(\beta-\alpha)} - \frac{R_a T\pi}{K^2(\beta-\alpha)}}$$

Chopper – dc to dc
↳ variable dc is obtained from fixed ac.

Chopper control of separately excited dc motor

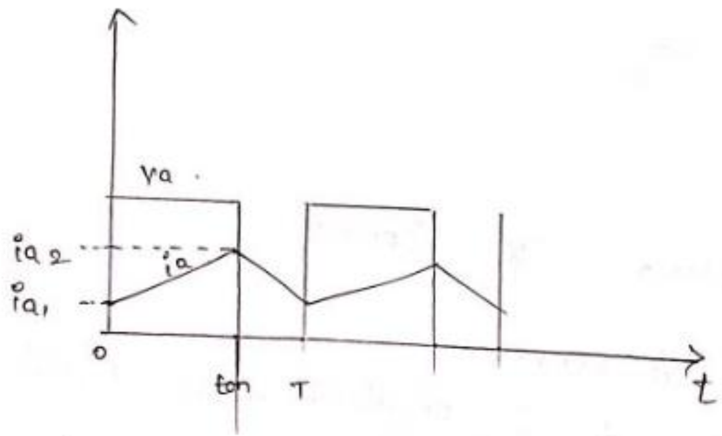
* Motoring control
* Regenerative braking
* Motoring and regenerative braking
* Dynamic braking

Motoring Control



→ Tr is operated periodically with period T and remains on for duration ton.

→ ~~The~~ Present day choppers operate at high fre to ensure continuous conduction.



Operation :- i) Duty interval $0 \le t \le t_{on}$

ii) Freewheeling interval $t_{on} \le t \le T$.

i) Duty interval:-

$$i_a R_a + L_a \frac{di_a}{dt} + E = V$$

$$V_a = \frac{1}{T} \int_0^{t_{on}} V\, dt \quad -(1)$$

Duty ratio or duty cycle:- δ

$$\delta = \frac{\text{duty interval}}{T} = \frac{t_{on}}{T}$$

$$\boxed{\delta = \frac{t_{on}}{T}} \quad - (2)$$

$$V_a = \frac{V}{T}(t)_0^{t_{on}} \Rightarrow \frac{V}{T} t_{on} = V\delta$$

$$\boxed{V_a = V\delta}$$

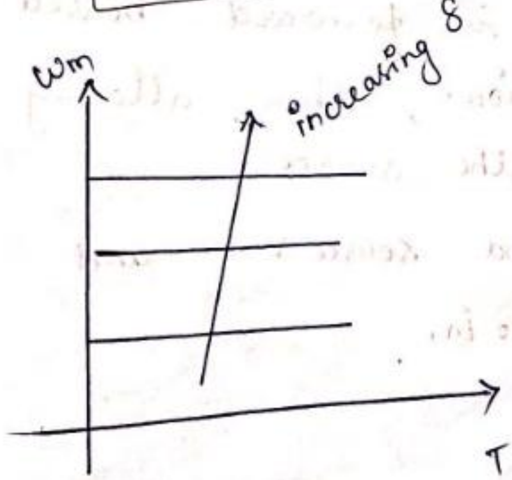
$V_a = i_a R_a + E$.

$$i_a = \frac{V_a - E}{R_a} = \frac{\delta V - E}{R_a}.$$

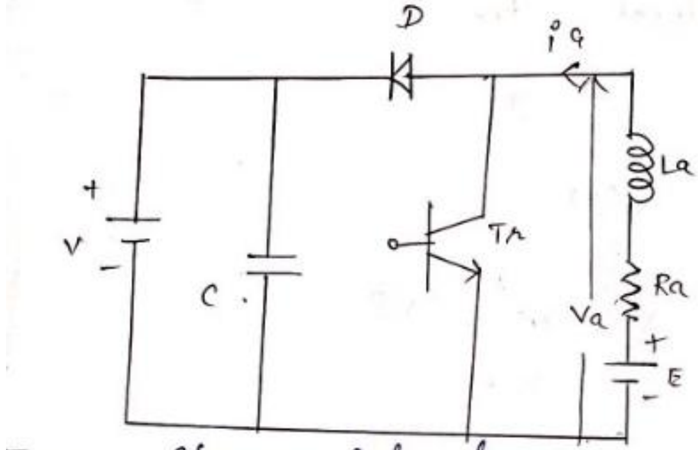
$$\boxed{i_a = \frac{\delta V - E}{R_a}.}$$

$$\omega_m = \frac{V_a - i_a R_a}{K} = \frac{\delta V - i_a R_a}{K}.$$

$$\boxed{\omega_m = \frac{\delta V}{K} - \frac{R_a T}{K^2}} \qquad \boxed{\because T = K i_a}$$



Regenerative Braking.



Energy Storage interval

> When T_r is on ($0 \le t \le t_{on}$), the o/p voltage is zero. $\boxed{v_0 = v_a = 0}$

> Though $v_a = 0$, voltage E drives current thro L_a and T_r.

→ L_a stores energy during t_{on}.

→ i_a ↑s from i_{a_1} to i_{a_2}.

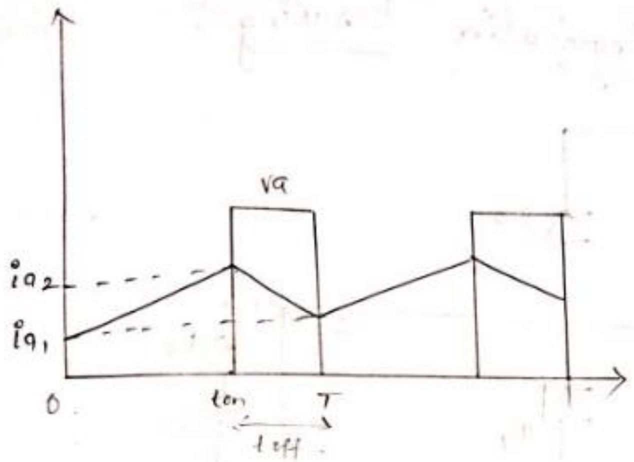
Duty interval :- ($t_{on} \le t \le T$)

> When ~~t~~ T_r is off, $v_0 = E + L_a \frac{di_a}{dt} = V$

∴ ~~$V_0 > V$~~

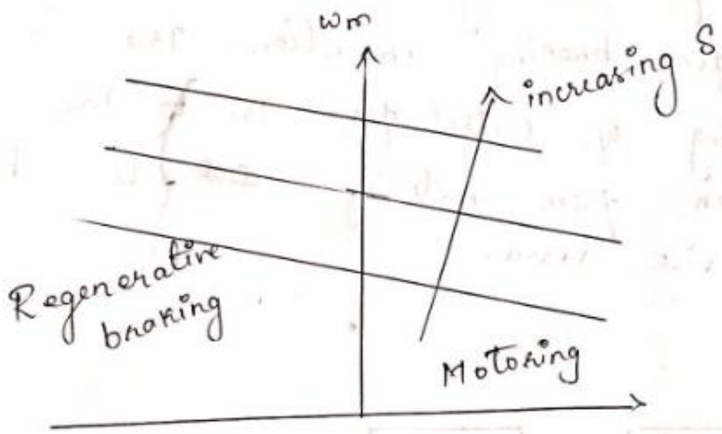
bcoz of this, D is forward biased and begins conduction, thus allowing power flow to the source.

> i_a flows thro D, and source V and reduces from i_{a_2} to i_{a_1}.



$$\delta = \frac{\text{duty interval}}{T} = \frac{t_{off}}{T} = \frac{T - t_{on}}{T}$$

$$V_a = \frac{1}{T}\int_{t_{on}}^{T} \qquad V_a = \frac{1}{T}\int_{t_{on}}^{T} v\, dt = \frac{V}{T}(T - t_{on})$$



$$\cancel{V_a} = V\left(1 - \frac{t_{on}}{T}\right) \cancel{=} V(1-\delta) \qquad V_a = V\delta$$

where $\delta = 1 - \frac{t_{on}}{T}$.

$E_g = K\omega_m$

$T = -KI_a$ ($\because I_a$ is reversed)

$$\omega_m = \frac{V_a + i_a R_a}{K} = \frac{V(1-\delta)}{K} + \frac{R_a T}{K^2}$$

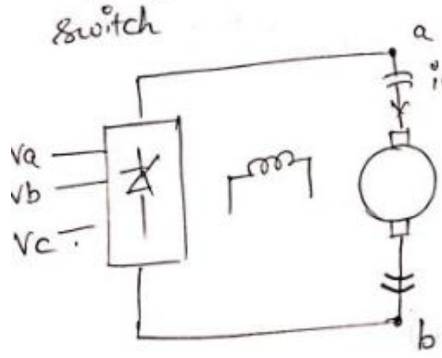
$$\omega_m = \frac{V\delta}{K} + \frac{R_a T}{K^2}$$

Multi-quadrant operation of separately excited dc motor fed from fully controlled rectifier.

a) 1ϕ fully controlled rectifier with a reversing switch
b) Dual converter
c) 1ϕ fully controlled rectifier in the armature with field current reversal.

Fully controlled converter - quadrant I & IV

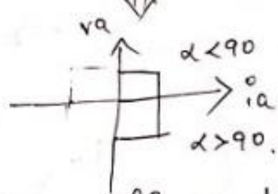
1ϕ fully controlled rectifier with a reversing switch



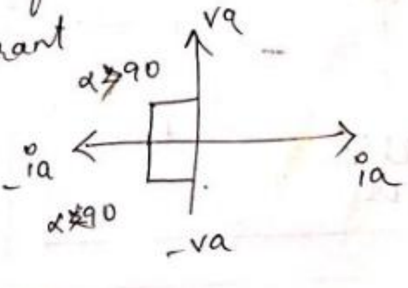
→ Reversing switch RS is used to reverse the arm connection w.r.t to rectifier

→ FCC → I and IV

⇓



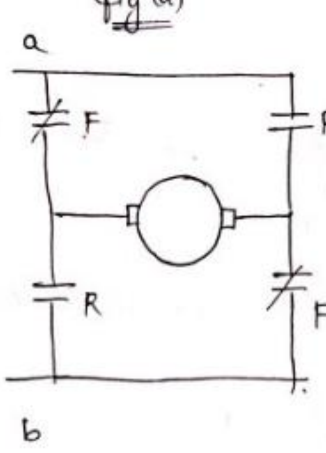
> The reversal of armature connection provides II and III quadrant

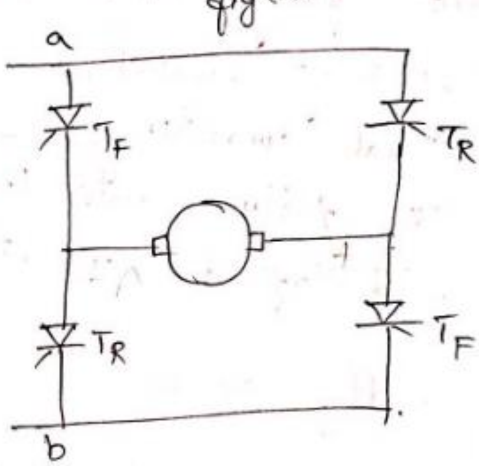


The switch can be relay - operated contactor with 2 normally NO and NC closed contactors. (fig

OR

using thyristors fig (b)





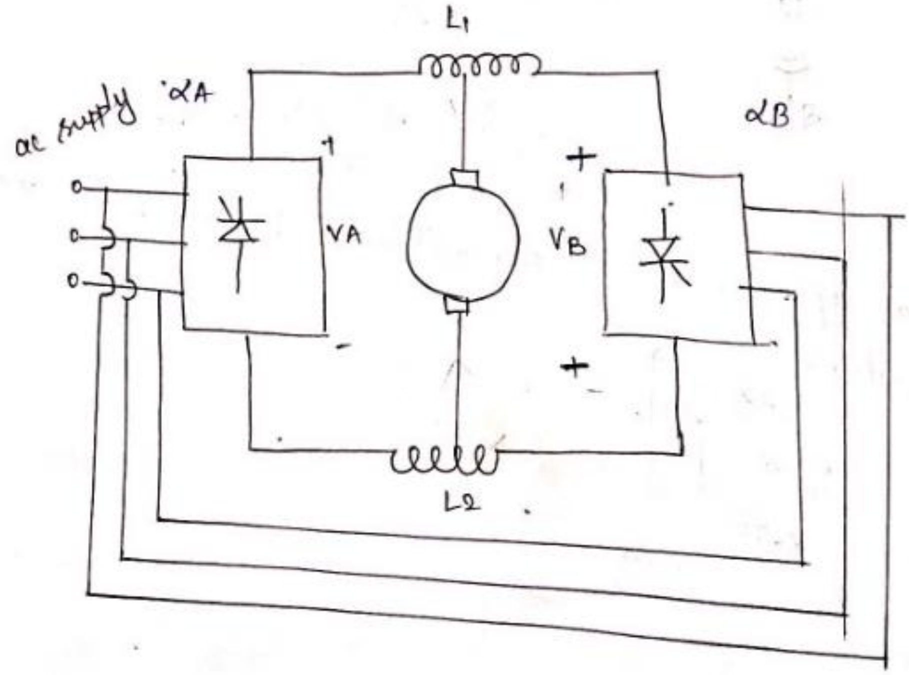
NO - a - F - M - F - b ⇒ I & IV

relay operates NC - a - R - M - R - b.

TF-ON (TR-OFF) - I & IV

TR-ON (TF-OFF) - III & II.

Dual Converter:-



→ 2 fully controlled converters connected in anti-parallel across the armature.

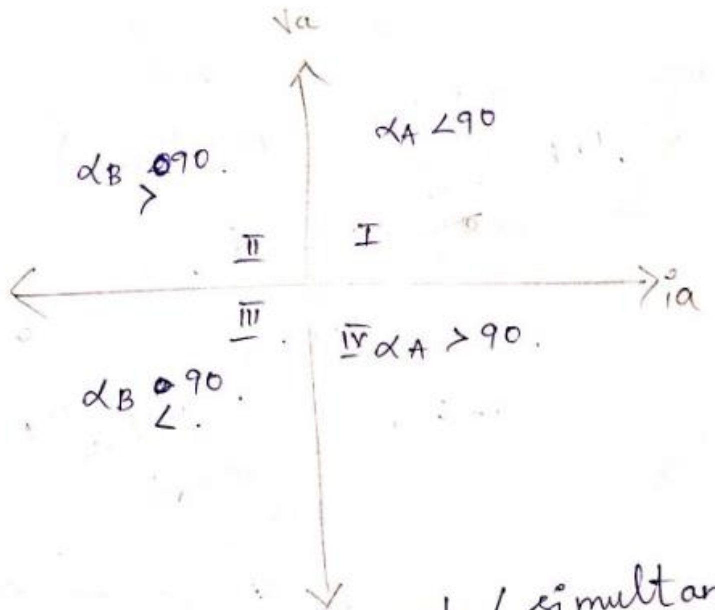
→ Rectifier A – +ve current and $+V_A$ and $-V_A$

$\therefore$ I and IV quadrant

→ Rectifier B – –ve current and $+V_B$ and $-V_B$.

$\therefore$ III and II quadrant. E =

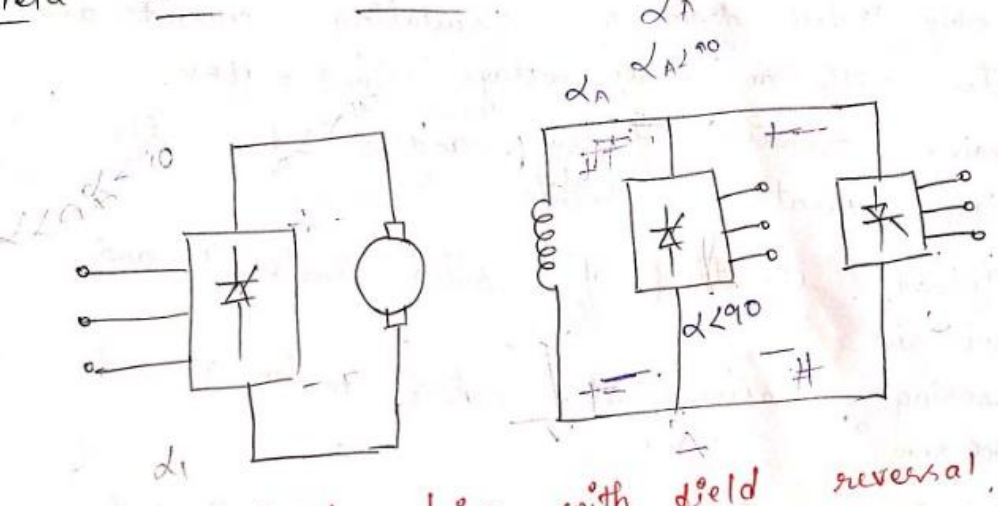
Refer Bimbra.



i) circulating current mode / simultaneous mode.

$$\alpha_A + \alpha_B = 180.$$

Field current Reversal



Four quadrant drive with field reversal.

* With I_f in one direction, → Quadrants I and IV
* When I_f is reversed → Quadrants II and III.

→ The dual converter operates with non-simultaneous control.

7 a

CLASSES OF MOTOR DUTY. (5)

According to IS - there are eight standard classes of duty.

(1) Continuous duty
(2) Short time duty
(3) Intermittent periodic duty
(4) Intermittent periodic duty with starting
(5) Intermittent periodic duty with starting and braking.
(6) Continuous duty with intermittent periodic loading
(7) Continuous duty with starting and braking.
(8) Continuous duty with periodic speed changes.

Assume loss to be proportional to $(\text{power})^2$.

$\alpha = 0$.

continuous

$P_r' = K P_r$

$P_r = \frac{p_r'}{K}$

(i) $$K = \sqrt{\frac{1+\alpha}{1-e^{-t_r/\tau}} - \alpha}$$

$$K = \sqrt{\frac{1}{1-e^{-10/60}}} = 2.55$$

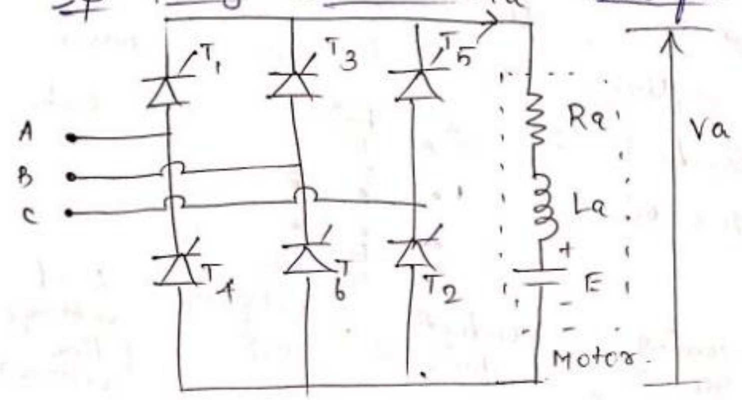
Motor rating $= \frac{100K}{2.55} = 39.21\,KW$.

(ii) $$K = \left((1+\alpha) \frac{1-e^{-\left(\frac{t_s}{\tau_s} + \frac{t_r}{\tau_r}\right)}}{1-e^{-t_r/\tau_r}} - \alpha \right)^{1/2}$$

$$K = (1) \frac{1-e^{-\left(10/90 + 10/60\right)}}{1-e^{(-10/60)}} = 1.2569.$$

Motor rating $= \frac{100}{1.2569} = 79.56\,KW$.

3φ Fully Controlled Rectifier.



* SCRS T_1, T_3 and T_5 form a +ve group - turned on when the supply voltages are +ve.
* SCRs T_4, T_6 and T_2 form a -ve group - turned on when the supply voltages are -ve.

If only a single gate pulse is used, no current will flow, as the other SCR in the current path will be in the off state.
Hence in order to start the cRt functioning 2 thyristors must be fired at the same time in order to commence current flow, one of the upper arm and one of the lower arm.

1) Each device should be triggered at a desired firing angle α
2) Each SCR can conduct for 120°.
3) SCRS must be triggered in the sequence T_1, T_2, T_3, T_4, T_5 and T_6

phase shift b/w the triggering of the two adjacent SCRs is 60°

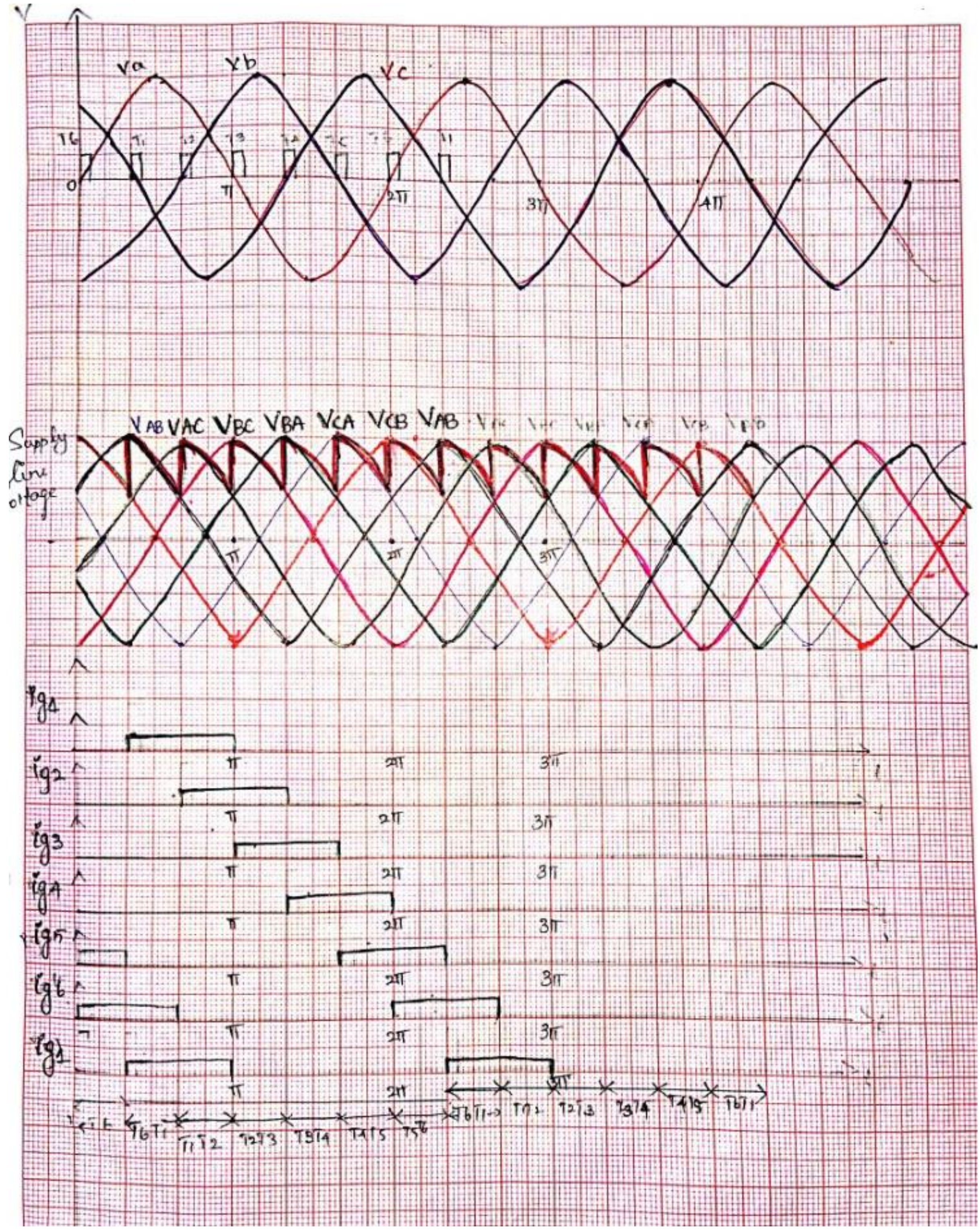
5) At any instant, two SCRs should conduct and there are 6 such pairs.

6) Each SCR conducts in 2 pairs and each pair conducts for 60°.

A	B	C
1	3	5
4	6	2
-A	-B	-C

S.NO	ωt	Incoming SCR	conducting pair.	outgoing SCR	Load voltage (line voltage)
1	$30+\alpha$	T_1	T_6, T_1	T_6	V_{AB}
2	$90+\alpha$	T_2	$T_1 - T_2$	T_1	V_{AC}
3	$150+\alpha$	T_3	$T_2 - T_3$	T_2	V_{BC}
4	$210+\alpha$	T_4	$T_3 - T_4$	T_3	V_{BA}
5	$270+\alpha$	T_5	$T_4 - T_5$	T_4	V_{CA}
6	$330+\alpha$	T_6	$T_5 - T_6$	T_5	V_{CB}.

When 2 SCRs are connecting, one from +ve and one from -ve group, the corresponding line voltage is applied across the load.



Va
Vb
Vc
VAB VAC VBC VBA VCA VCB VAB
Supply line voltage
ig1
ig2
ig3
ig4
ig5
ig6

$$V_0 = \frac{6}{2\pi} \int_{\alpha+30}^{\alpha+90} V_{AB} \; d\omega t$$

$$= \frac{3}{\pi} \int_{\alpha+30}^{\alpha+90} \sqrt{3}\, V_{ml} \sin(\omega t + 30) \cdot d\omega t$$

$$= \frac{3\sqrt{3}\, V_{ml}}{\pi} \Big[-\cos(\omega t + 30) \Big]_{\alpha+30}^{\alpha+90}$$

$$= \frac{3\sqrt{3}\, V_{ml}}{\pi} \Big[-\cos[\alpha+120] + \cos(\alpha+60) \Big]$$

$$= \frac{3\sqrt{3}\, V_{ml}}{\pi} \Big[-(-\cos(60-\alpha) + \cos(60+\alpha) \Big]$$

$$= \frac{3\sqrt{3}\, V_{ml}}{\pi} \Big[\cos(60-\alpha) + \cos(60+\alpha) \Big]$$

$$= \frac{3\sqrt{3}\, V_{ml}}{\pi} \times 2 \cos 60 \cos\alpha$$

$$= \frac{3\sqrt{3}\, V_{ml}}{\pi} \cos\alpha \qquad \boxed{\because \cos 60 = 1/2}$$