Ajay Kumar Garg Engineering College, Ghaziabad
Department of Electrical & Electronics Engineering

Model Solution ST-2

Course: B.Tech	Semester: V
Session: 2017-18	Section: EN1, EN2
Subject: Power Electronics	Sub. Code: NEE 502
Max. Marks: 50	Time: 2 hours

SECTION-A

Ques: 1: Give classification of SCR commutation techniques. what is load commutation?

Solution: Classification of SCR commutation techniques:

a) Line commutation or natural commutation.

b) Forced commutation

i) Load commutation or Class-A.

ii) Class-B or Resonant pulse commutation.

iii) Class-C or complementary commutation.

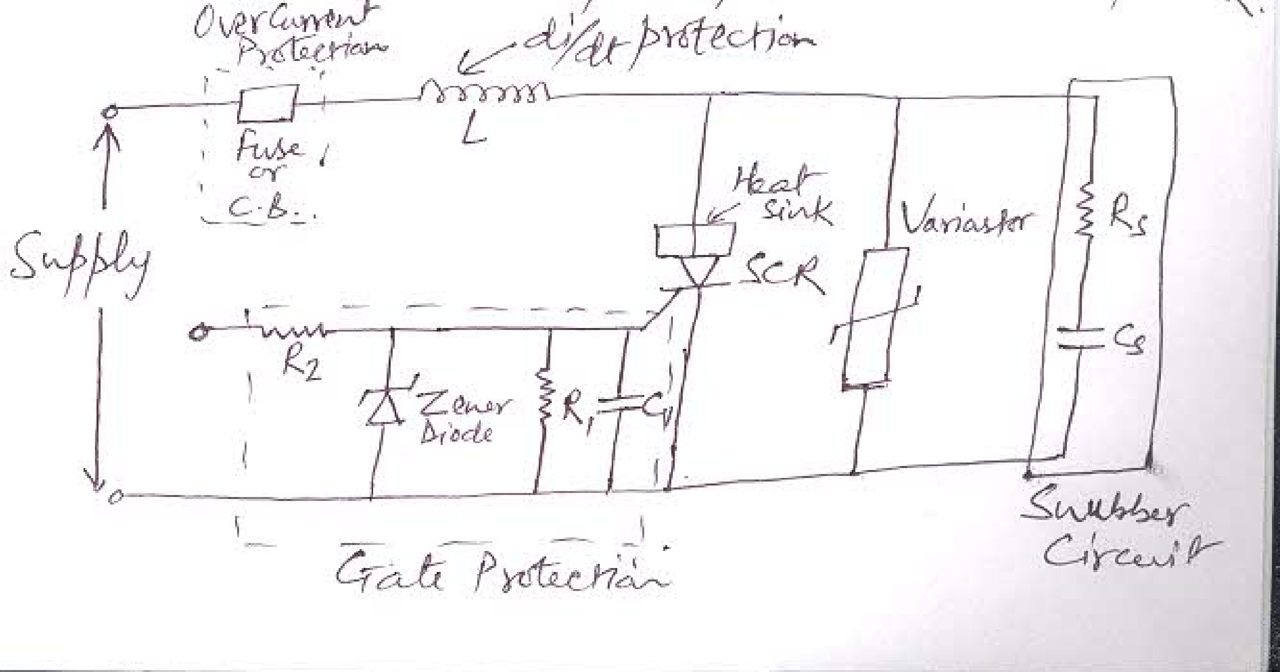
iv) Class-D or Impulse or Voltage Commutation.

v) External pulse commutation or Class-E.

when load elements (R, L, C) support the commutation process it is known as load commutation.

Ques: 2: Draw and label the complete protection circuit for SCR.

Solution:



Ques: 3: Define String Efficiency for a string of series connected SCRs. Why it is less than one?

Solution: String Efficiency:

$$\eta_s = \frac{\text{Total voltage across the string}}{\text{no. of SCR} \times \text{Rated voltage of SCR}}$$

It is always less than unity due to unequal sharing of voltage/current.

Ques: 4: What do you understand by phase control in context with phase controlled converters/rectifiers?

Solution: In a circuit containing controlled, semi-conductor device/component, we can control the turn on & off duration of device and hence we can control the phase of input (AC) which will be reflected in output. Therefore we can control the portion/area of waveform to be processed.

Ques: 5: What are the advantages of using free-wheeling diode in phase controlled rectifier circuits.

Solution: Advantages of free-wheeling diode:

a) It improves the input (supply) power factor.
b) It improves the voltage & current waveforms.
c) It reduces the voltage ripple factor.
d) It improves the performance of converters.

Section-B

Question 6: In a power circuit four SCRs are to be connected in series. Permissible difference in their blocking voltage is 20V for a maximum difference in their blocking currents of 1 mA. Difference in recovery charges is 10 μC. Design suitable equilizing circuit?

Solution: Given:

$\Delta Q = 10\,\mu C$

$\Delta I_b = 1\ mA$

$(n V_{bm} - V_s) = 20V$

$$R = \frac{n V_{bm} - V_s}{(n-1)\,\Delta I_b} = \frac{20}{(4-1)\times 1\times 10^{-3}}$$

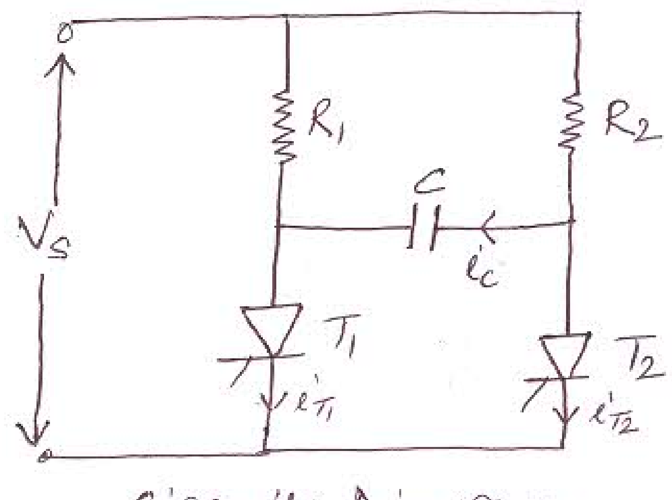
$$R = 6.67\times 10^{3}\,\Omega = 6.67\,K\Omega$$

$$C = \frac{(n-1)\,\Delta Q}{n V_{bm} - V_s} = \frac{(4-1)\times 10^{-6}}{20}$$

$$C = 1.5\times 10^{-7} = 0.15\,\mu F$$

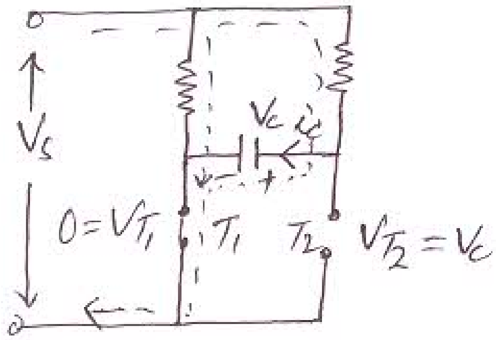
Ques: 7: With the help of relevant circuit and waveform explain class-C commutation circuit?

Solution: Class-C or Complementary commutation:

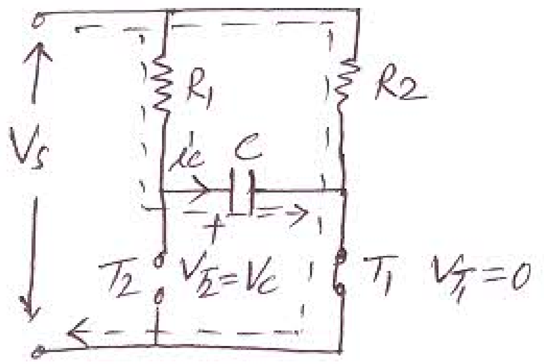


Circuit Diagram

When T_1 is ON



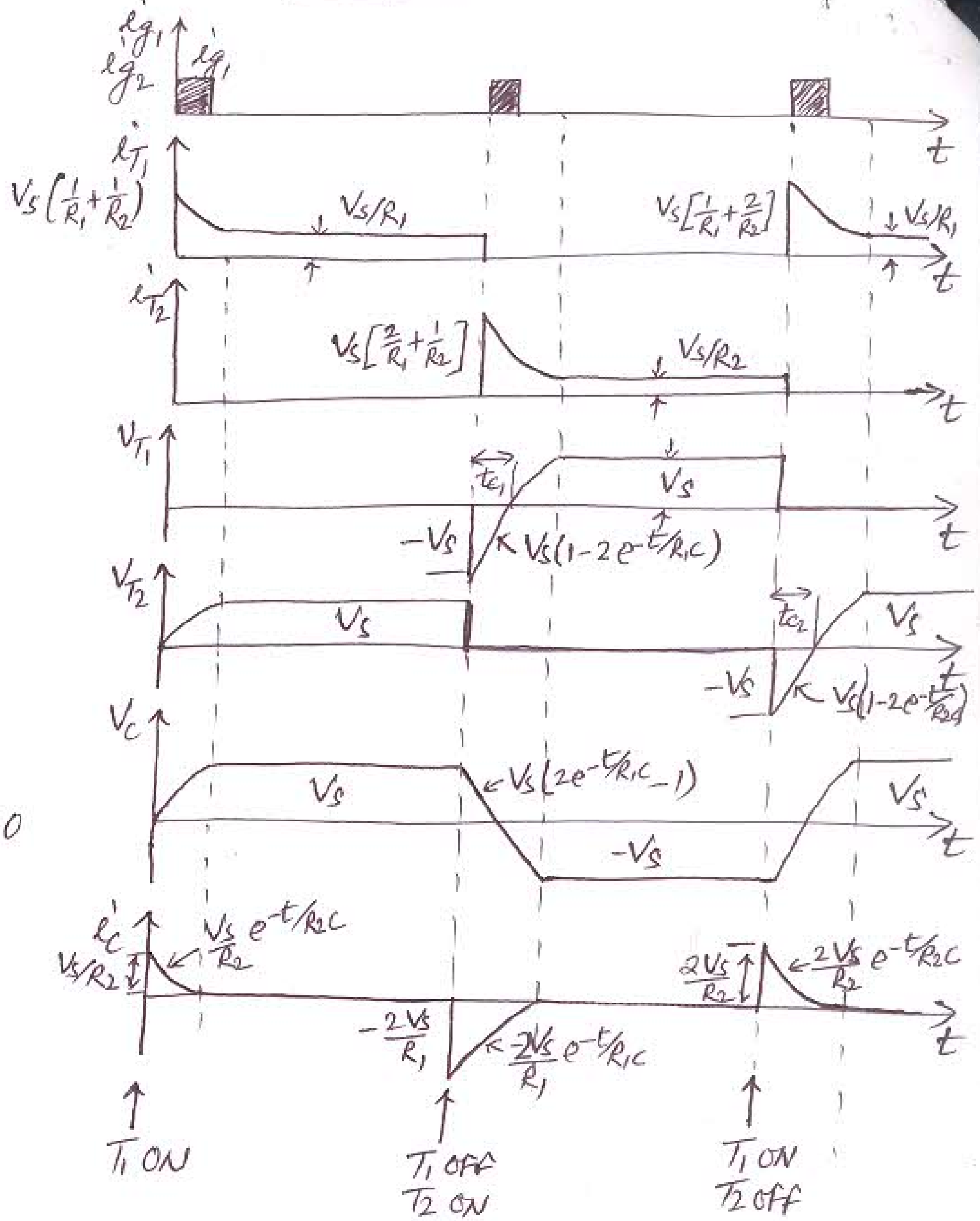
When T_2 is ON



$$t_{c_1} = R_1 C \ln 2$$

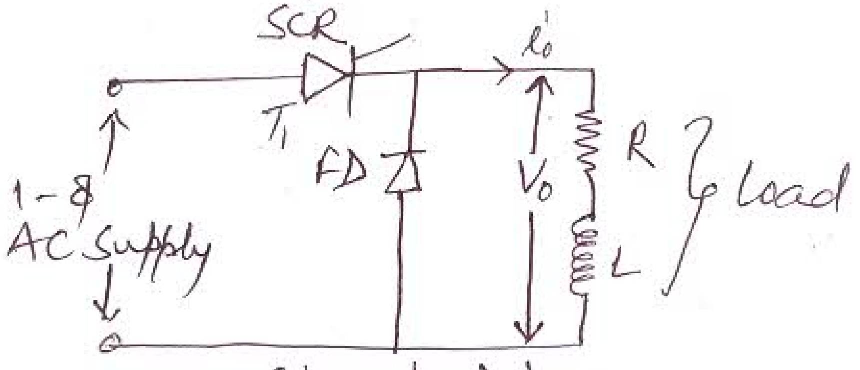
$$t_{c_2} = R_2 C \ln 2$$

Waveform



Ques; 8! A single phase one pulse converter (SCR, controlled) is feeding an RL type of load with freewheeling diode connected across the load. Discuss the operation of circuit with help of relevant waveforms.

Solution! 1-φ one pulse controlled SCR converter!



Circuit Diagram

when T_1 is triggered at $\omega t = \alpha$ the SCR begin the conduction and it get turned on. Inductor stores energy.

when supply voltage is reversed at $\omega t \geq \pi$ the diode get forward biased due to the inductor voltage reversal and SCR get reversed biased and get commutated.

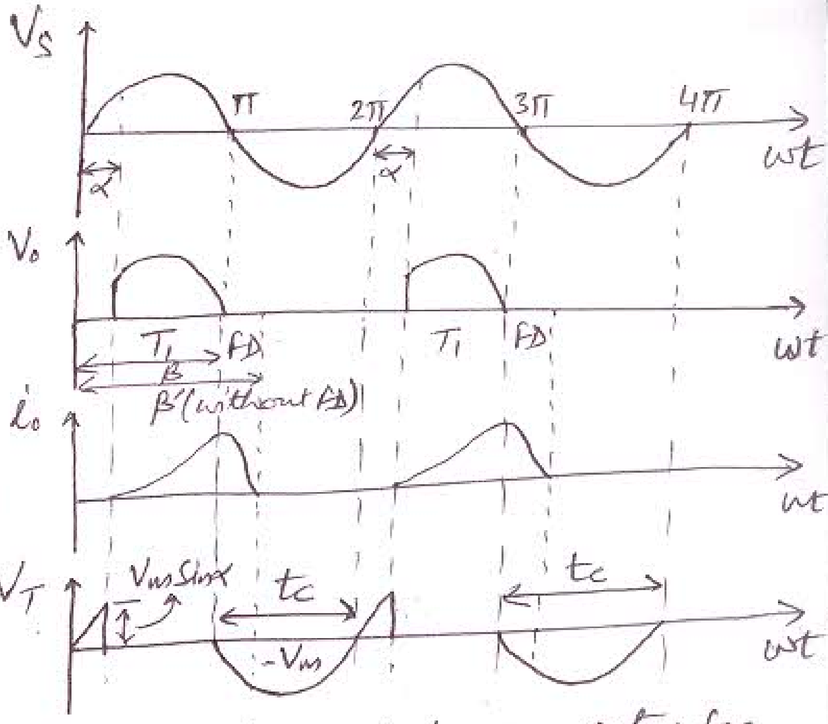
$$V_0 = \frac{1}{T}\int_{\alpha}^{\pi} V_m \sin\omega t \, d\omega t$$

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

$$V_0 = \frac{V_m}{2\pi}(1+\cos\alpha)$$

$$t_c = \frac{\pi}{\omega} \text{ (Circuit turn off time)}.$$

Waveforms



1-ϕ one pulse converter for RL load with free wheeling diode. Discontinous conduction.

Ques: 9! A 1-ϕ full converter bridge is connected to RLE load. The source voltage is 230V, 50 Hz. The average load current of 10A is constant over the working range. For R = 0.4 Ω and L = 2 mH compute the firing angle delay and input power factor of converter if E = 120V.

Solution! Given,

$I_0 = 10A$
$V_s = 230V$
$R = 0.4\,\Omega$
$L = 2mH$
$E = 120V$

For constant load current

$$V_0 = \frac{2V_m}{\pi}\cos\alpha \quad \text{and}$$

$$I_0 = \frac{V_0 - E}{R} \quad (V_m = 230\sqrt{2})$$

$$\therefore \quad 10 = \frac{\frac{2\sqrt{2}\times 230}{\pi}\cos\alpha - 120}{0.4}$$

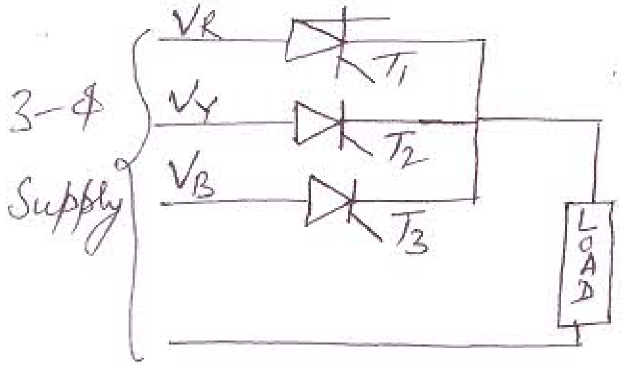
$$\therefore \quad \cos\alpha = \frac{124\times 3.14}{2\sqrt{2}\times 230}$$

$$\alpha = \cos^{-1}\left(\frac{124 \times 3.14}{2\sqrt{2} \times 230}\right) = 53.23^\circ$$

$$\text{Power factor} = \frac{2\sqrt{2}}{\pi}\cos\alpha = 0.5392$$

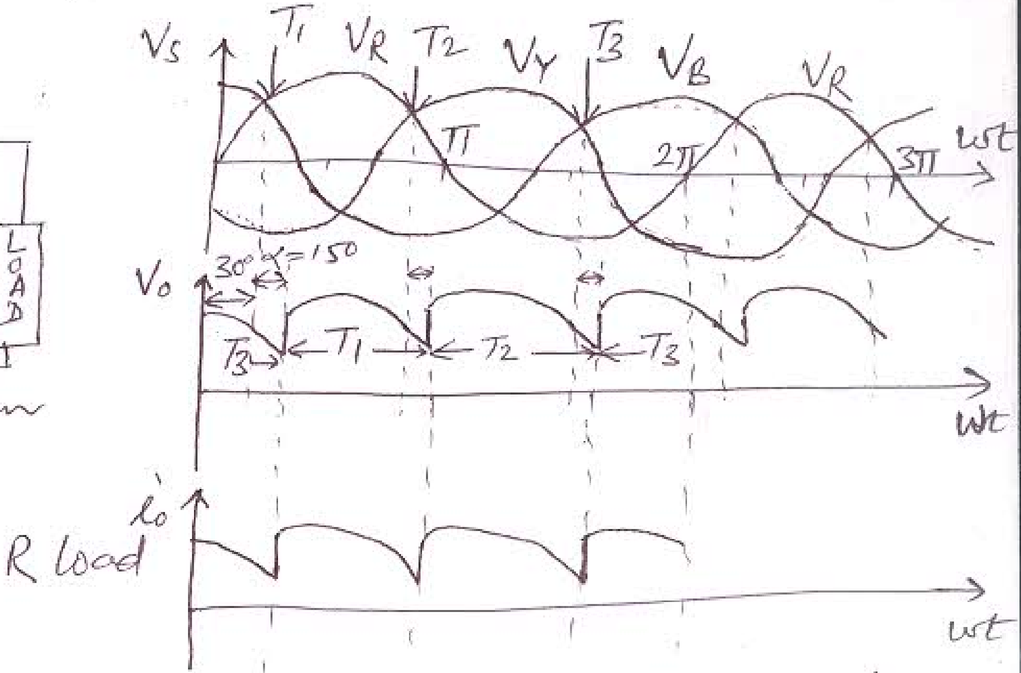
Ques: 10: With the help of relevant circuit and waveform of output voltage and output current explain the operation of a three phase half wave rectifier. Assume the firing angle delay of 15°.

Solution: 3-ϕ half wave rectifier:



Circuit Diagram

$\alpha = 15^\circ$



Each thyristor conduct for 120°. when firing angle $\alpha < 30^\circ$ continuous conduction is obtained.

Continuous Conduction for 3-ϕ Half wave Rectifier

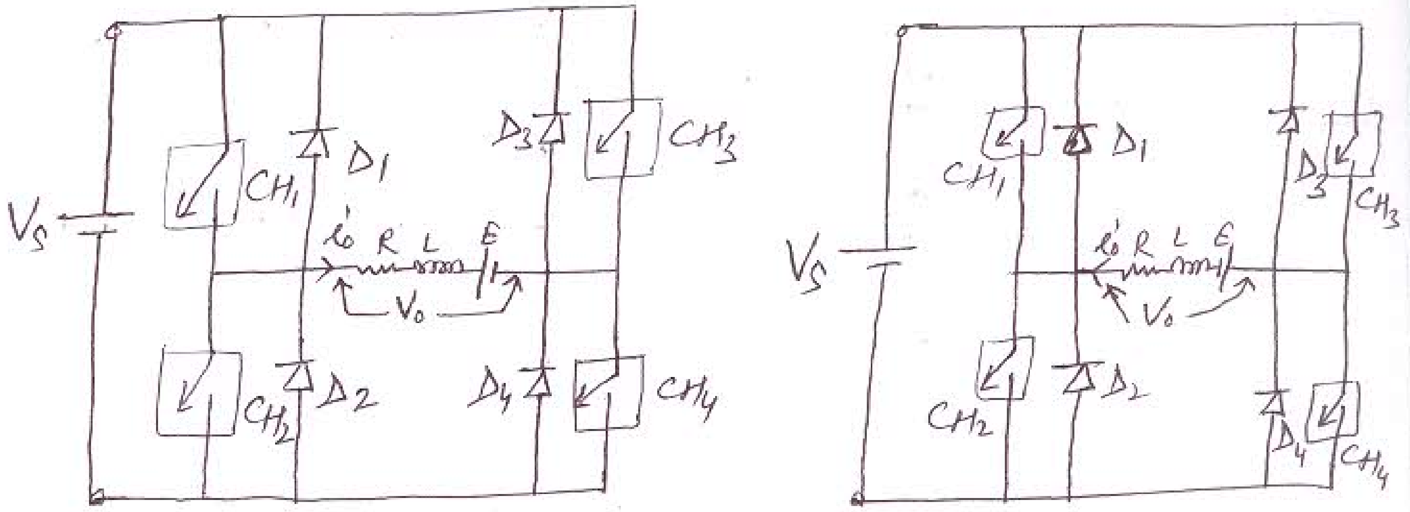
$$V_0 = \frac{1}{\frac{2\pi}{3}} \int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} V_{mph} \sin wt \, dwt$$

$$V_0 = \frac{3\sqrt{3}\, V_{mph}}{2\pi}\cos\alpha = \frac{3 V_{mL}}{2\pi}\cos\alpha$$

Section-C

Question: 11: Describe the operation of E-type chopper with relevant circuit diagrams and its operation in all the four quadrants?

Solution: Type-E chopper: (Four quadrant operation)



(a) Ist & IInd quadrant operation

(b) IIIrd and IVth quadrant operation

Circuit Diagram.

V_0

CH2 operated, CH1, CH3 & CH4 kept off
CH2 - on io is negative.
L stores energy hence $(E + L\frac{di}{dt}) > V_s$
CH2 - off now io flow from load to source through D1 D4.
CH2 on step-up mode.
Power flow from load to source
Vo is positive and io is negative therefore regenerative braking.
2nd quadrant (fig: a circuit diagram)

CH4 is kept on, CH3 kept off, CH1 is operated
2 choppers are on step down
CH1 - CH4 on
CH1 turn off then CH4 - D2 conduct
Vo & io are positive
Power flow from source to load hence
Forward motoring mode
1st quadrant operation.
Fig: a. Circuit diagram

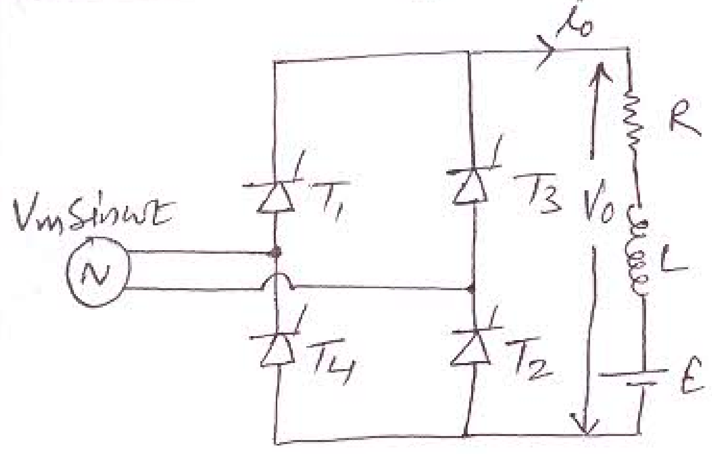
I_0

CH1 kept off, CH2 kept on & CH3 operated
polarity of E must be reversed (fig: b)
CH3 - on load is connected to Vs
therefore Vo & io are negative
CH3 - off negative io free wheels through D4 CH2
2 choppers on step down mode.
Power flow from Source to Load.
Reverse motoring mode.
3rd quadrant operation.

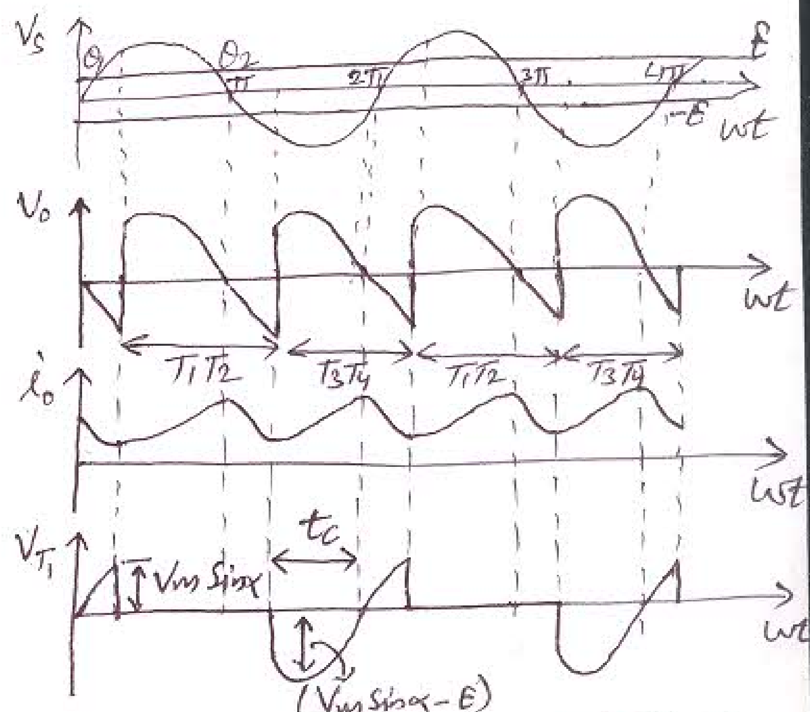
CH4 is operated & other choppers are kept off.
CH4 → on io flow through CH4, D2, L, E.
L stores energy
CH4 - off io flow from load to source through D2 D3.
Vo is negative and io is positive.
Power flow from load to Source.
1 chopper on step-up mode.
Braking mode.
4th quadrant operation (fig: b).

Ques: 12: A single phase controlled converter is feeding RLE type of load. With the help of relevant circuit and the waveforms explain its operation in rectification mode. Also derive the equation for average output voltage.

Solution: $1-\phi$ converter feeding RLE load.



Circuit Diagram



Waveforms for $1-\phi$ full wave RLE load converter in continous conduction

This circuit contains four thyristors divided in two groups.

$T_1 T_2$ conduction occurs when supply voltage waveforms is positive and $T_3 T_4$ conducts for negative supply waveform.

For positive supply voltage $T_1 T_2$ are forward biased and $T_1 T_2$ can be triggered if $V_s \geq E$ therefore minimum firing angle could be is between θ_1 & θ_2.

$\alpha_{min} = \theta_1$, $\alpha_{max} = \theta_2$. (at θ_1, $V_m \sin\theta_1 = E$; at θ_2, $V_m \sin\theta_2 = E$)

In the rectification mode α should not exceed the $wt = 90°$ so that output voltage is positive. therefore firing angle is restricted to max $90°$.

For negative supply voltage $T_3 T_4$ are triggered and outgoing SCR ($T_1 T_2$) get commutated and $T_3 T_4$ (incoming group of SCR) are turned on.

Output average voltage $V_o = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin wt \, dwt$

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