CHAPTER 3

Phase Controlled Rectifier
(Marks - 14)

Contents:

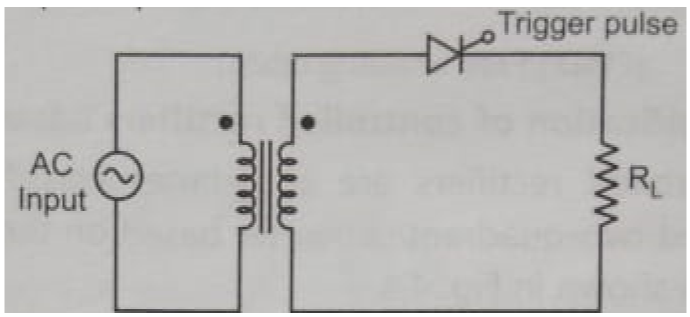
Phase Controlled parameters

Firing Angle (α)- In AC circuits, the SCR can be turned ON by the gate at any angle α with respect to the applied voltage. This angle α is called as the firing angle.

Conduction angle (Ø) - Conduction angle in SCR is the complete angle through which the SCR conducts through it. It can be varied by firing the SCR earlier with the help of a firing pulse at its gate terminal

Single Phase half wave controlled rectifier with Resistive Load

Circuit Diagram :

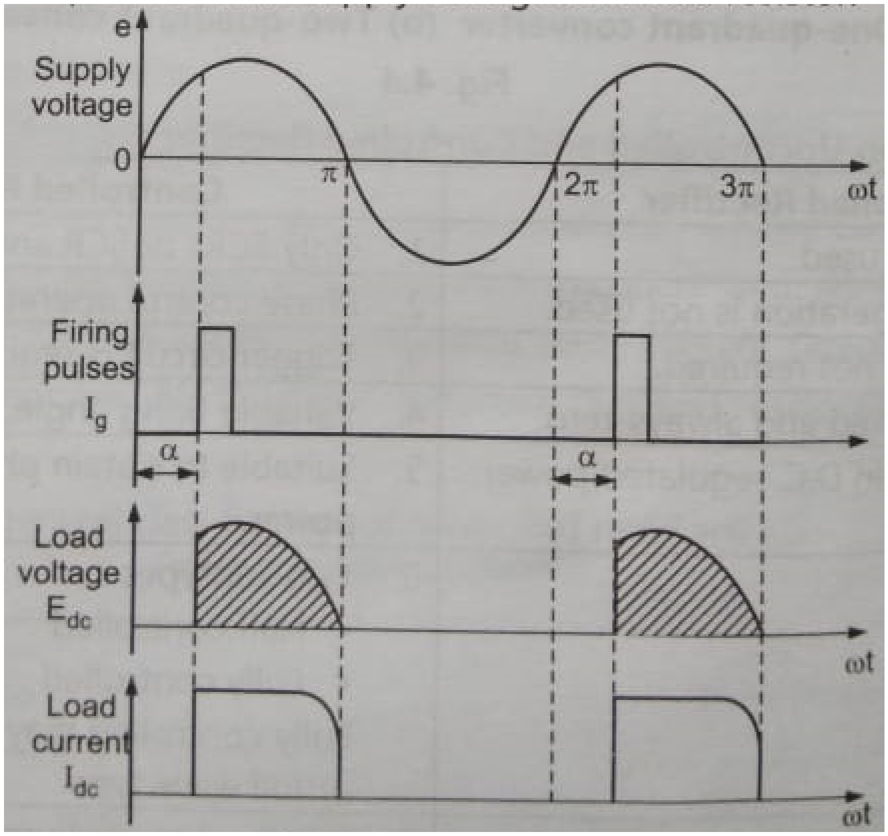


Explanation :

As per the circuit diagram a single Thyristor is connected in series with the load R_L

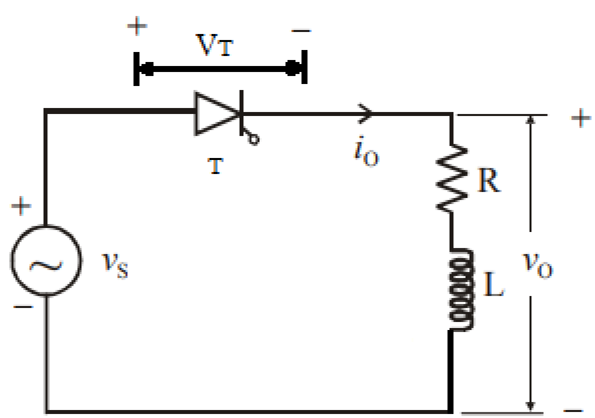
- During the positive half cycle of supply voltage the anode of SCR is positive w.r.t. Cathode, but till the gate pulse is not applied SCR blocks the load current.
- When the SCR is fired at α , SCR starts conducting and full input voltage appears at the load. As load is purely resistive, once SCR is on the load, current is similar to the supply voltage.
- The SCR conducts until the supply voltage is reversed at π. The angle of conduction can be given as $\beta = \pi - \alpha$.
- During negative half cycle of the supply voltage, SCR does not conduct as it is reverse biased and the load current is zero.

Waveforms:



Single Phase half wave controlled rectifier with <u>RL load</u>

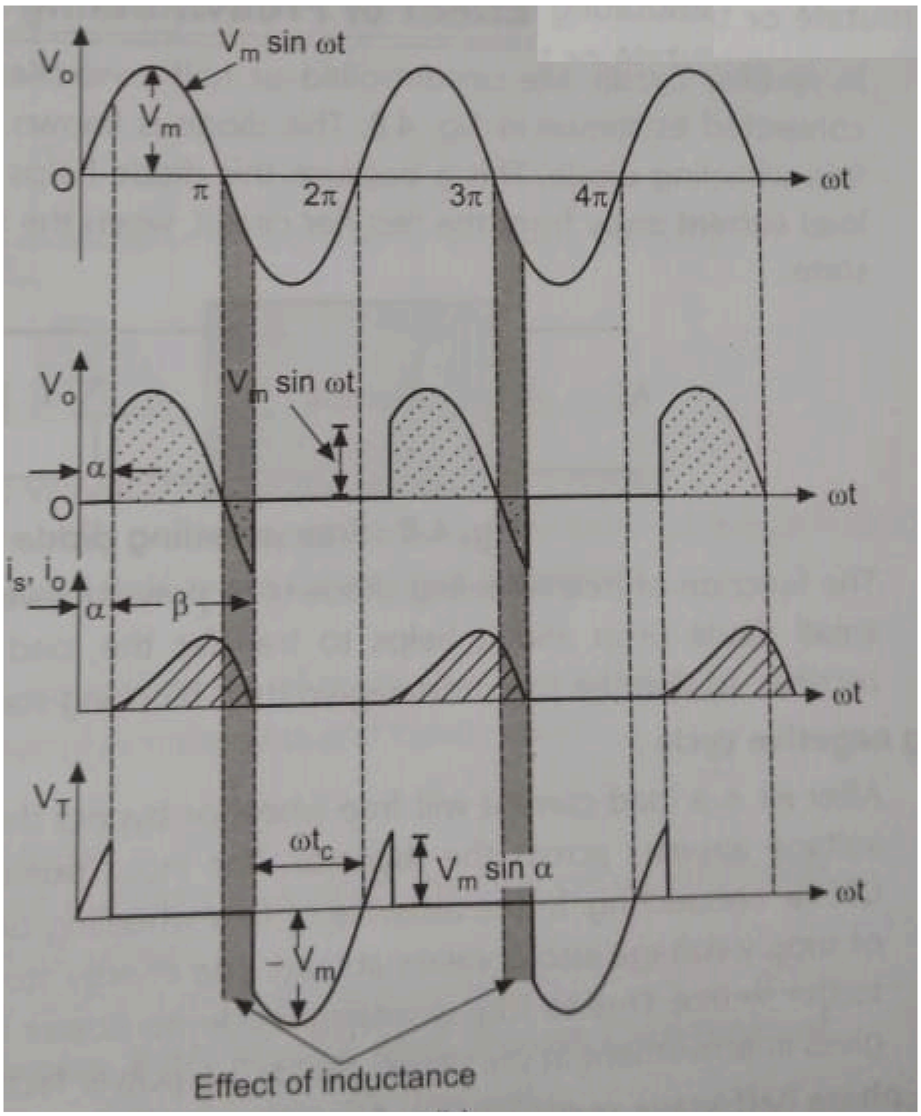
Circuit Diagram:



- The SCR "T" is turned ON at phase angle α called as firing angle. Because of the load inductance, it continues to conduct even after π i.e. even after supply voltage goes negative. The back e.m.f. generated in the inductor maintains the load current in the same direction. Therefore, output voltage is negative but output current is positive for a short duration after π.

- The nature of output current or load current Io is not exactly same as output voltage Vo because of the inductive load.
- The inductor has a property of opposing any change in current. The output current Io, slowly builds up and decays.
- At some angle after π the load current reduces to zero and SCR turns OFF as it is already reverse biased,

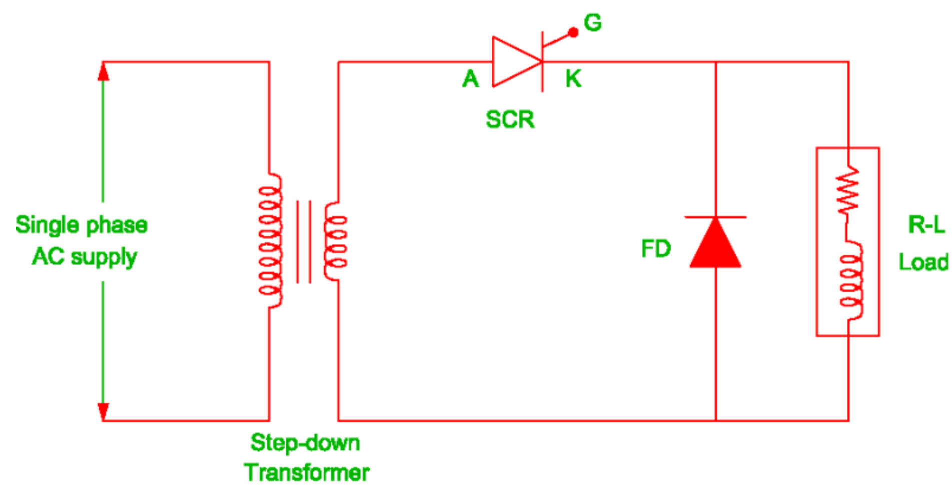
Waveforms:



Effect of Freewheeling Diode on Half Wave controlled Rectifier

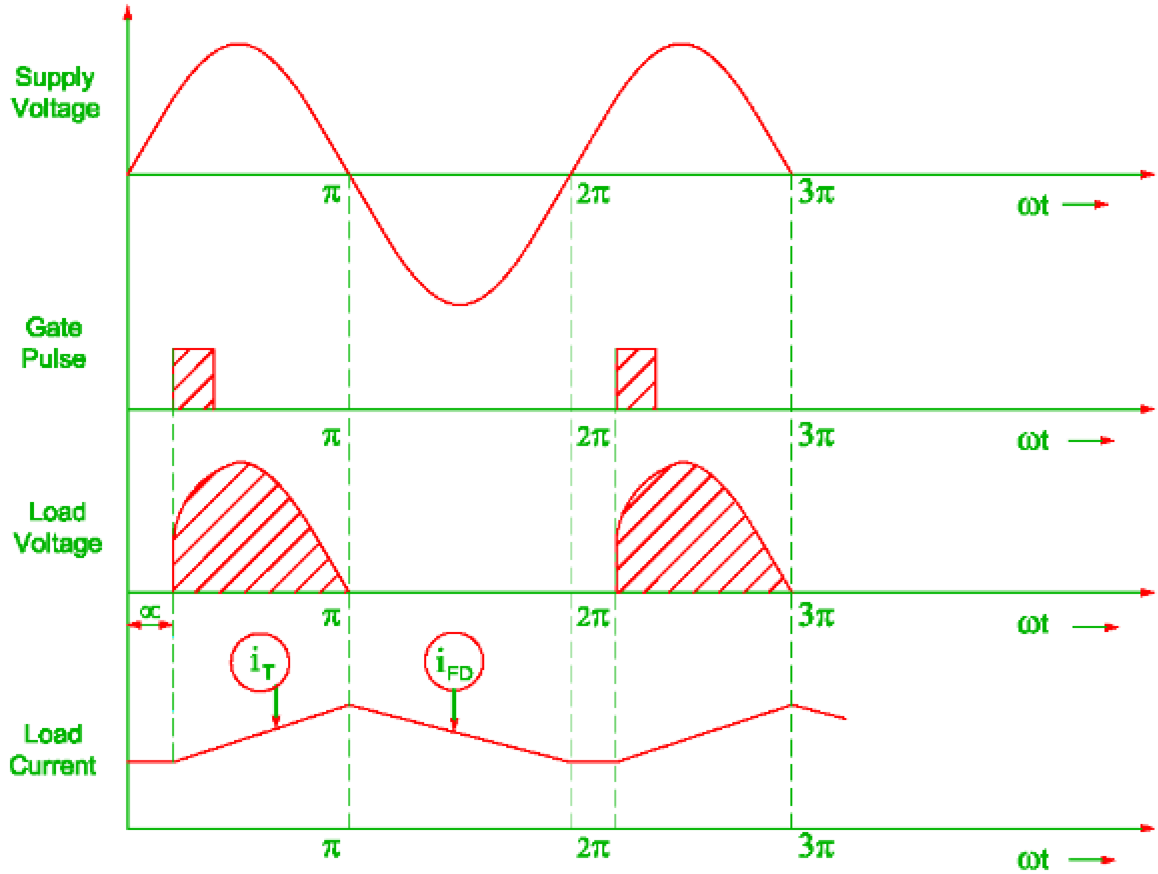
- The diode is connected across load in the controlled or uncontrolled converter circuit. This diode is called as freewheeling diode or flywheel diode.
- The freewheeling diode is connected across R – L load in the half controlled rectifier circuit as shown in the figure below

Circuit Diagram :



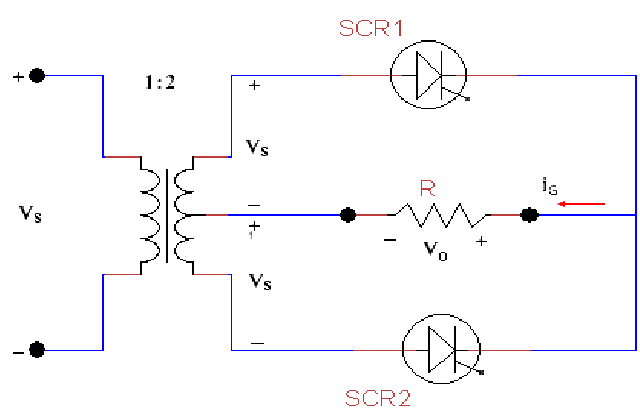
- As the SCR T1 is turned on during positive half cycle of alternating supply, the load current flows through load.
- The energy stored in the inductor due to current passes through it.
- The stored energy of the load dissipates through freewheeling diode during negative half cycle of the alternating supply.
- If there is no freewheel diode, the stored energy of load back to the input supply.

Waveforms:



Single phase centre tapped full wave controlled rectifier with R load

Circuit Diagram



Waveforms -

Working

Case 1:

- During the positive half cycle, SCR1 is forward biased and SCR2 becomes reverse biased.
- Initially SCR1 does not conduct because Vm is less than VBO. At $\Theta = \alpha$, gate current is given to SCR1 and it becomes ON.
- Hence remaining +ve half cycle from α to π appears across RL as Vo.

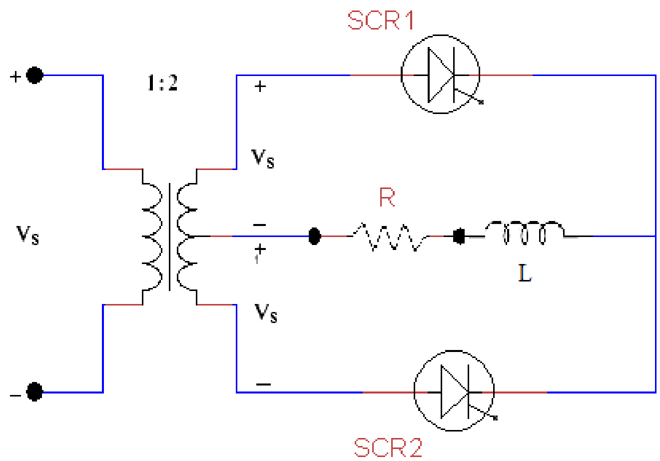
Case 2:

- During the negative half cycle, SCR1 is reversed biased and SCR2 is forward biased , both SCRs are off from π to $\pi+\alpha$. Hence at $\Theta = \pi+\alpha$, SCR2 is triggered due to which Vo = Vin.
- IL is unidirectional , hence Vo is unidirectional pulsating DC voltage.
- The load current IL is now supplied by SCR2.

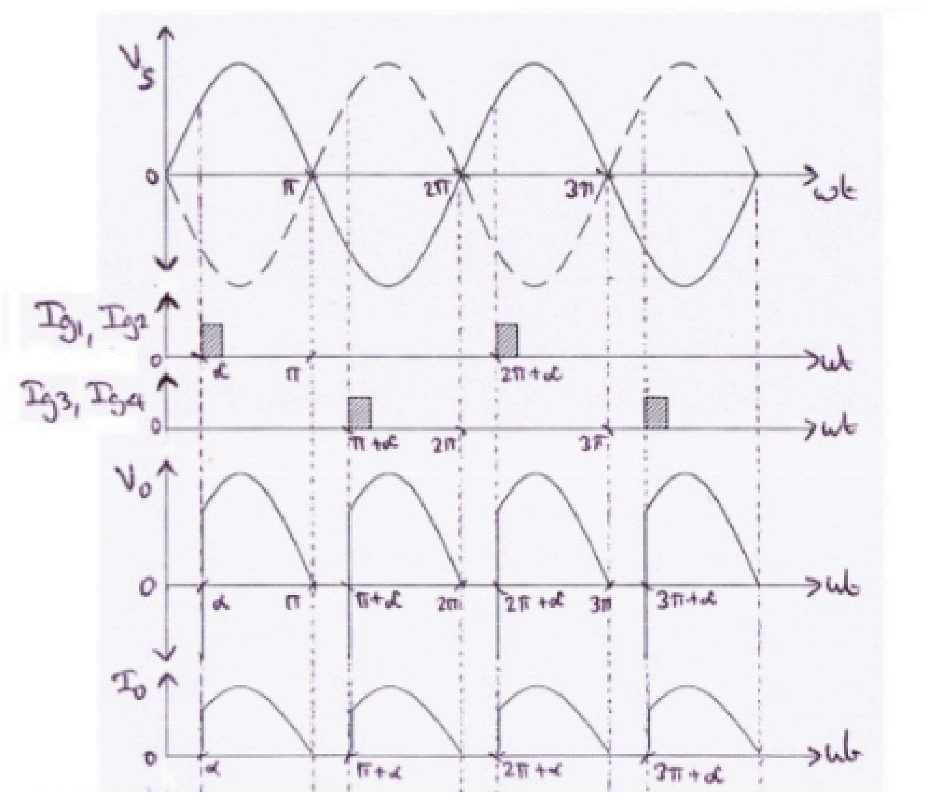
Since both the half cycles are appearing at the output voltage Vo hence it is a full wave controlled rectifier.

Single phase centre tapped full wave controlled rectifier with RL load

Circuit Diagram-



Waveforms-



Working -

Time Period → $\alpha \leq \Theta \leq \pi$

SCR2 is reversed biased and act as open switch SCR1 is forward biased and at $\Theta = \alpha$, it starts conducting because Ig1 is given at this instant neglecting voltage drop across ON SCR1. The output voltage follows i/p AC +ve half cycle from α to π current to the load and is supplied by ON SCR1 and electrical energy is stored in the inductive part of the load.

Time Period → $\pi < \Theta < \pi + \alpha$.

Since -ve half cycle starts SCR1 will try to go off and will try to make load current IL = 0. But this is opposed by the energy stored in the inductor, hence polarity of back emf reverses and continues to flow through SCR1 which is still forward biased.

Time Period → $\pi + \alpha \leq \Theta \leq 2\pi$.

SCR1 is reverse biased, while SCR2 is FB and it is also triggered at $\pi + \alpha$ by giving Ig2 at this instant. Hence SCR2 now sends current in load from right to left i.e. in the same direction.

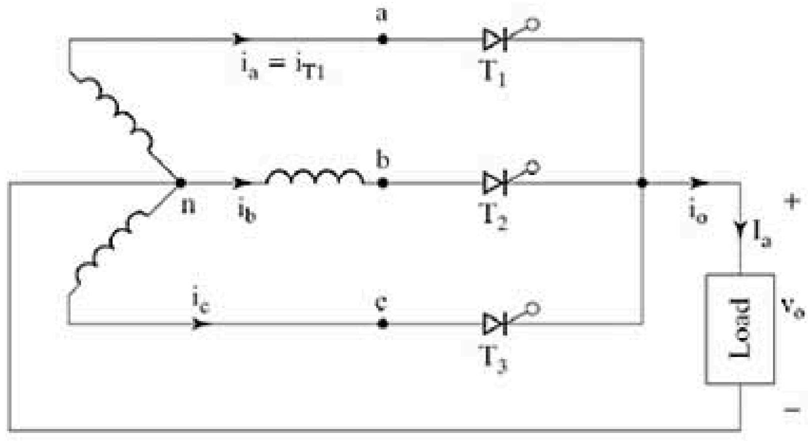
Time Period → $2\pi < \Theta < 2\pi + \alpha$

For SCR2 -ve half cycle starts, hence it starts to go off due to which load current IL tries to become zero, but this is opposed by the energy stored in inductor for the previous time period from $\pi + \alpha$ to 2π. The polarity of back e.m.f. reverses due to which current continues to flow in load in the same direction and this current also flows in SCR2 and hence it is ON for this time period.

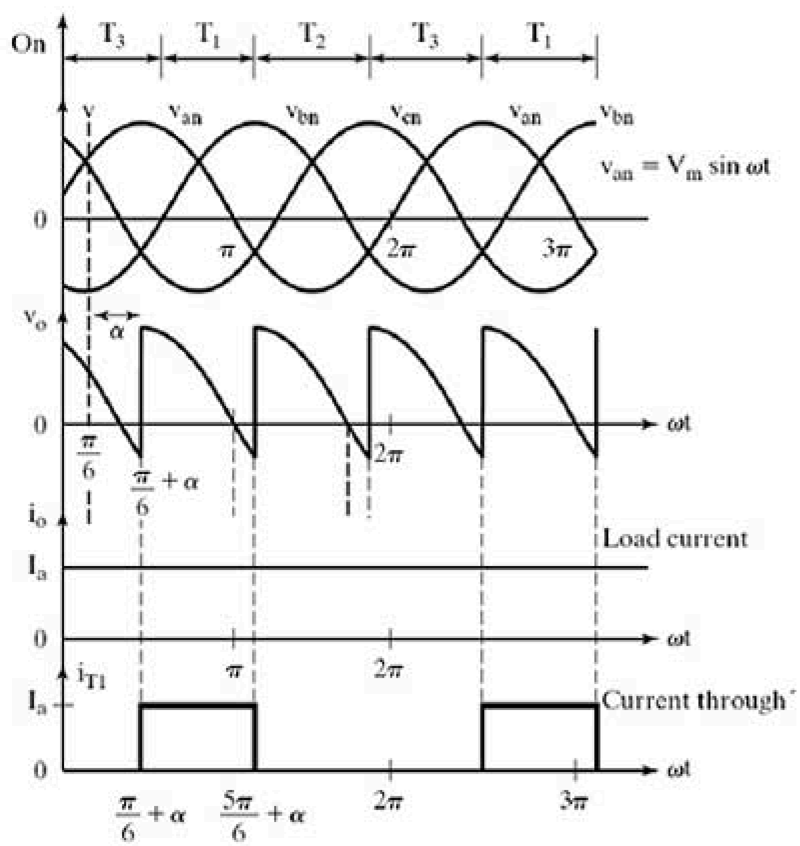
Basic three phase half wave controlled rectifier

Three single phase half-wave converters are connected together to form a three phase half-wave converter as shown in the figure below.

Circuit Diagram :



Waveforms:



Working :

The 3-PHASE HALF WAVE CONVERTER combines three single phase half wave controlled rectifiers in one single circuit feeding a common load. The thyristor T1 in series with one of the supply phase windings 'a-n' acts as one half wave controlled rectifier. The second thyristor T2 in series with the supply phase winding 'b-n' acts as the second half wave controlled rectifier. The third thyristor T3 in series with the supply phase winding acts as the third half wave controlled rectifier.

The 3-phase input supply is applied through the star connected supply transformer as shown in the figure. The common neutral point of the supply is connected to one end of the load while the other end of the load connected to the common cathode point.

When the thyristor T1 is triggered at ωt=(∏/6 + α)=(30° + α) , the phase voltage Van appears across the load when T1 conducts. The load current flows through the supply phase winding 'a-n' and through thyristor T1 as long as T1 conducts.

When thyristor T2 is triggered at ωt=(5∏/6α), T1 becomes reverse biased and turns-off. The load current flows through the thyristor and through the supply phase winding 'b-n' . When T2 conducts the phase voltage vbn appears across the load until the thyristor T3 is triggered .

When the thyristor T3 is triggered at ωt=(3∏/2 + α)=(270°+α) , T2 is reversed biased and hence T2 turns-off. The phase voltage Van appears across the load when T3 conducts.

When T1 is triggered again at the beginning of the next input cycle the thyristor T3 turns off as it is reverse biased naturally as soon as T1 is triggered. The figure shows the 3-phase input supply voltages, the output voltage which appears across the load, and the load current assuming a constant and ripple free load current for a highly inductive load and the current through the thyristor T1.

For a purely resistive load where the load inductance ‘L = 0’ and the trigger angle α >(∏/6) , the load current appears as discontinuous load current and each thyristor is naturally commutated when the polarity of the corresponding phase supply voltage reverses. The frequency of output ripple frequency for a 3-PHASE HALF WAVE CONVERTER is fs, where fs is the input supply frequency

Q - Compare single phase half wave controlled rectifier and single phase full wave controlled rectifier.

Parameter	Single Phase Half wave controlled rectifier	Single Phase Full wave controlled rectifier
No. of SCR used	One SCR	Two/ Four SCR
Firing circuit complexity	Easier	Complicated
Average Load voltage	Vm/2π * (1+ cosα)	Vm/π * (1+ cosα)
Ripple frequency	50 Hz	100 Hz
Application	In small battery chargers	In DC motor speed control
Waveforms