ज्ञानेन प्रकाशते जगत्
INDUS UNIVERSITY

ELECTRONICS & COMMUNICATION ENGINEERING
IITE Ahmedabad

# **Power Electronics** (EC0606)

Unit-II

B.Tech (Electronics and Communication)

Semester-VI

**Omkar Pabbati**

Academic Year 2019-2020

# PHASE CONTROLLED RECTIFIERS

- RECTIFIERS CONVERT AC TO DC
- CLASSIFIED AS
  - UNCONTROLLED - DIODES ARED USED
  - CONTROLLED - THYRISTORS ARE USED

# CLASSIFICATION OF RECTIFIERS

- BASED ON INPUT SUPPLY
  - SINGLE PHASE
  - THREE PHASE
- BASED ON QUADRANT OPERATION
  - 1 QUADRANT
  - 2 QUADRANT
  - 4 QUADRANT
- BASED ON NO. OF PULSES
  - ONE PULSE
  - TWO PULSES
  - THREE PULSES
  - SIX PULSES

# APPLICATIONS OF RECTIFIERS

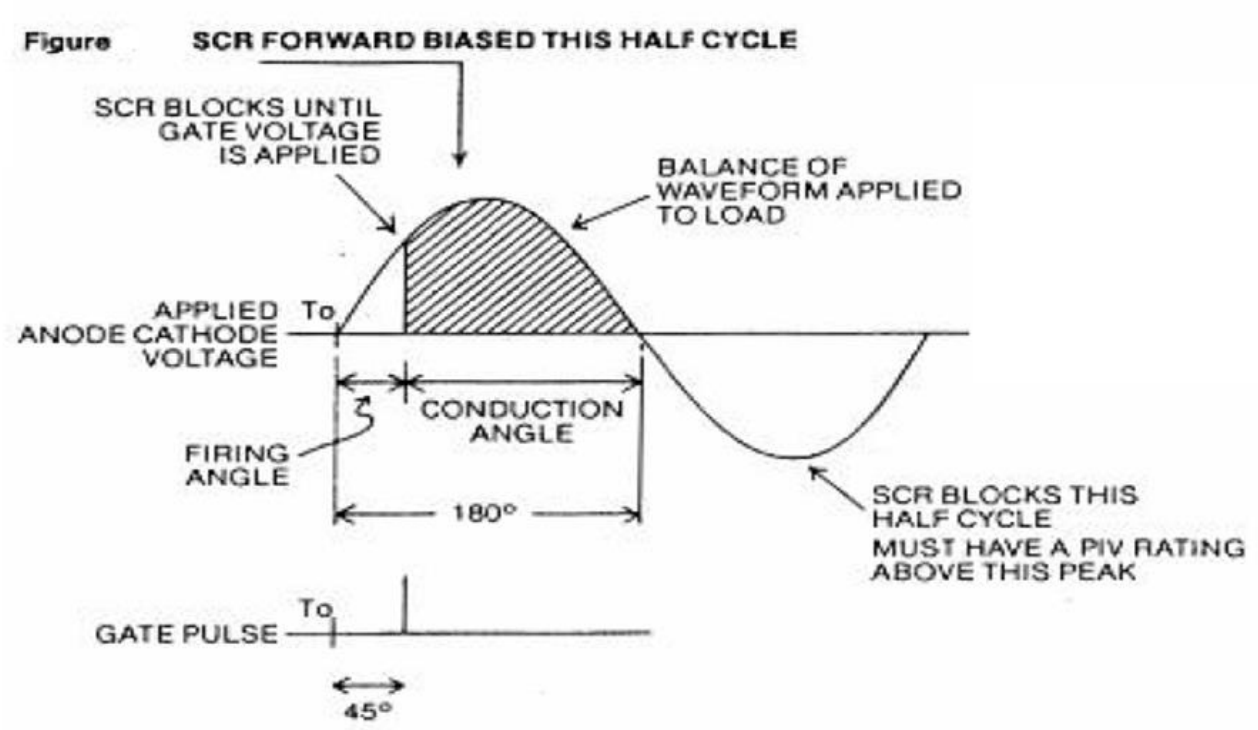
- DC MOTOR SPEED CONTROL
- DC SUPPLY FOR INVERTERS
- ELECTROCHEMICAL PROCESSES
- DC TRACTION
- HVDC TRANSMISSION

# RECTIFIERS

- SINGLE PHASE HALF WAVE RECTIFIER WITH R & RL Load
- SINGLE PHASE FULL WAVE RECTIFIER WITH R & RL Load
- THREE PHASE HALF WAVE RECTIFIER WITH R & RL Load
- THREE PHASE FULL WAVE RECTIFIER WITH R & RL Load

# FIRING ANGLE α

- ANGLE BETWEEN THE ZERO CROSSING OF THE INPUT VOLTAGE AND THE INSTANT THYRISTOR IS FIRED.



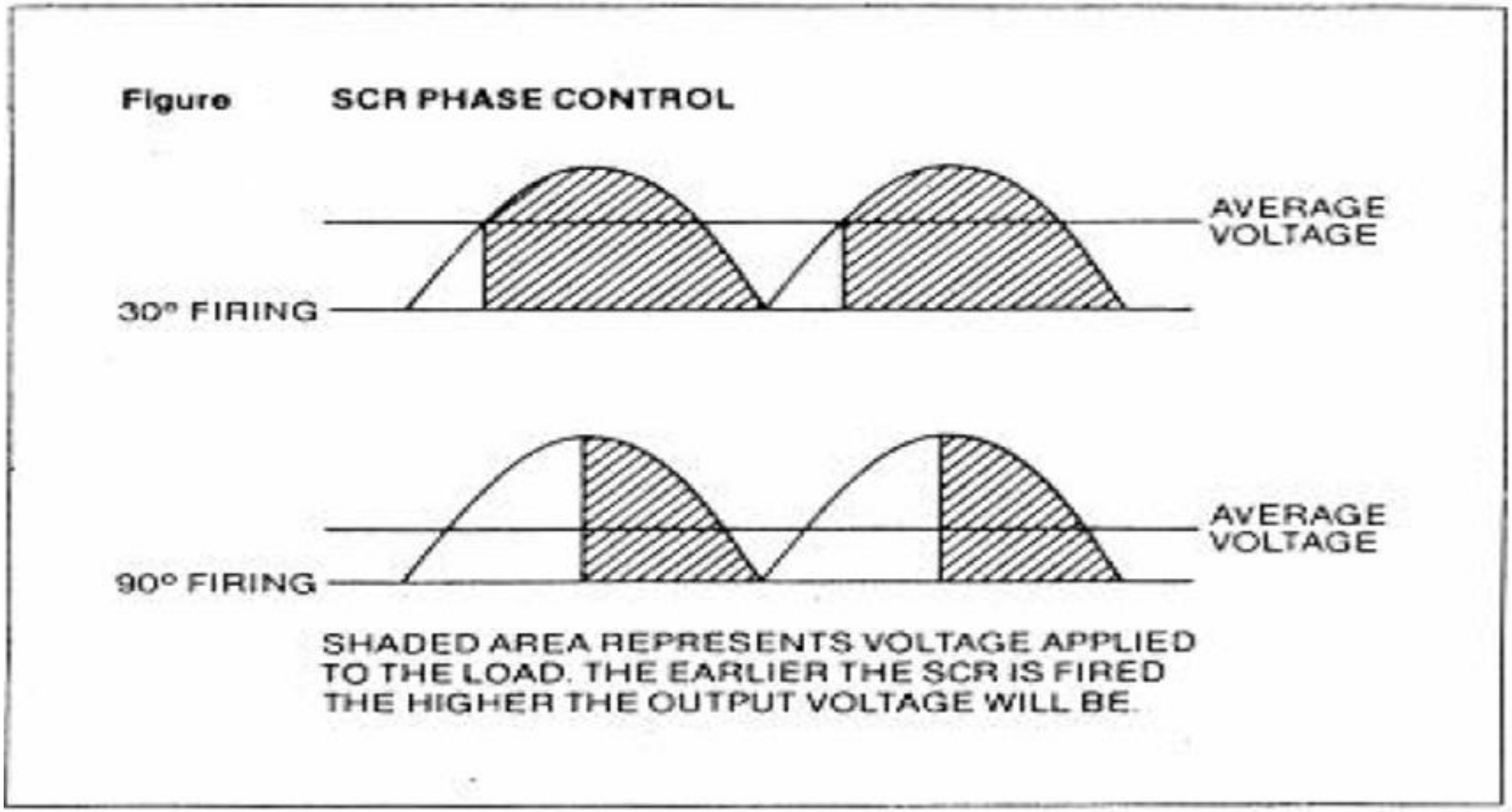
# Contd.

- Figure shows an AC waveform being applied with a gating pulse at 45 degrees. There are 360 electrical degrees in a cycle; 180 degrees in a half-cycle.

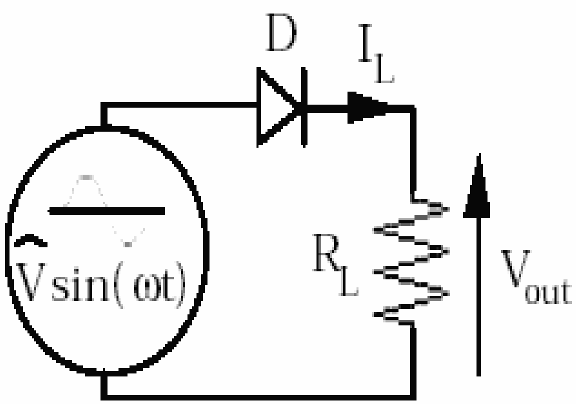
- The number of degrees from the beginning of the cycle until the SCR is gated ON is referred to as the *firing angle.*

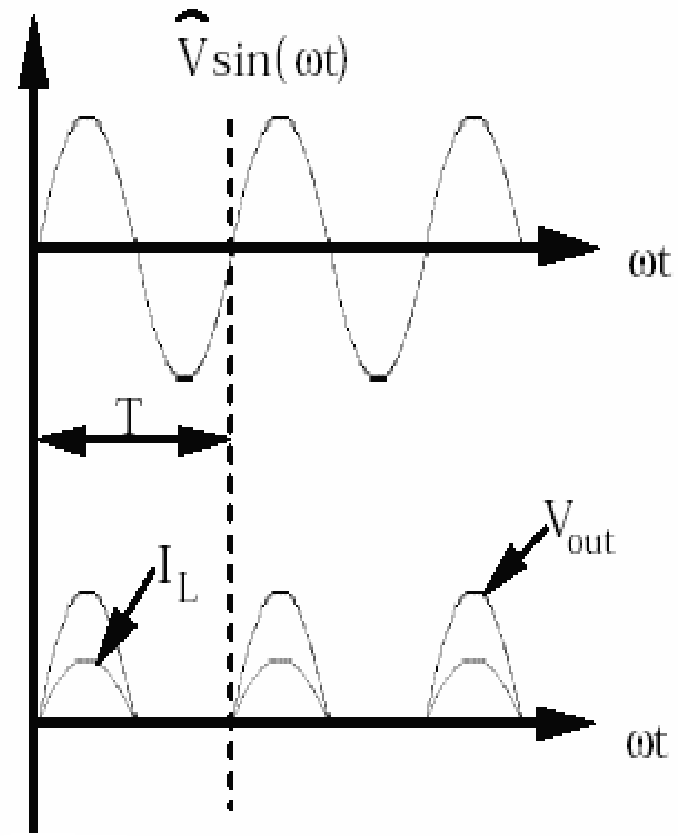
- The number of degrees that the SCR remains conducting is known as the *conduction angle*.

# output voltage applied to the load

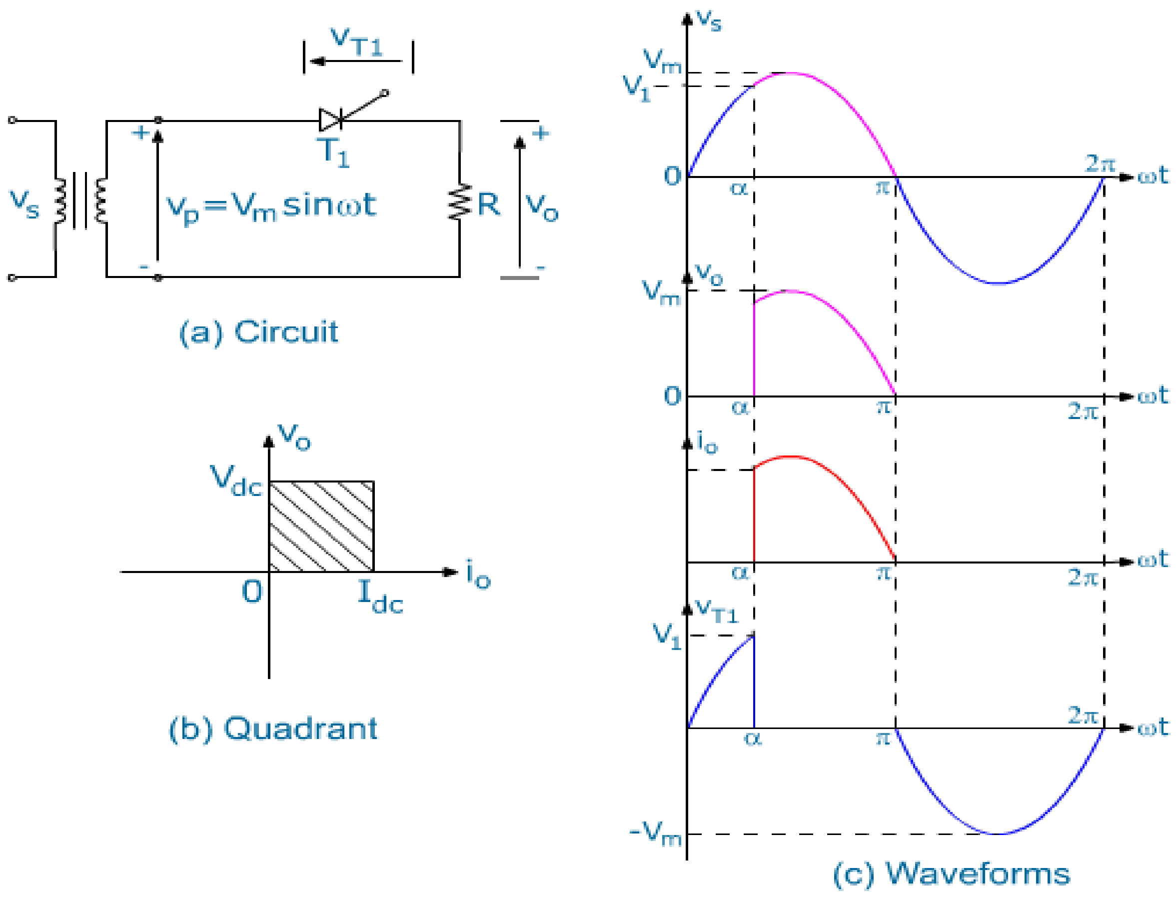


# AC to DC Conversion: Half-Wave Rectifier



# SINGLE PHASE HWR WITH R LOAD



# AVERAGE OUTPUT VOLTAGE OF SINGLE PHASE HWR WITH R LOAD

The average output voltage **$V_{dc}$** is given by

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

$$V_{dc} = \frac{V_m}{2\pi}\left[-\cos\omega t\right]_{\alpha}^{\pi}$$

$$V_{dc} = \frac{V_m}{2\pi}\left(1 + \cos\alpha\right)$$

The output voltage **$V_{dc}$** can be varied from **$V_m$**$/\pi$ to zero as the firing angle $\alpha$ varies from zero to $\pi$.

# RMS OUTPUT VOLTAGE OF SINGLE PHASE HWR WITH R LOAD

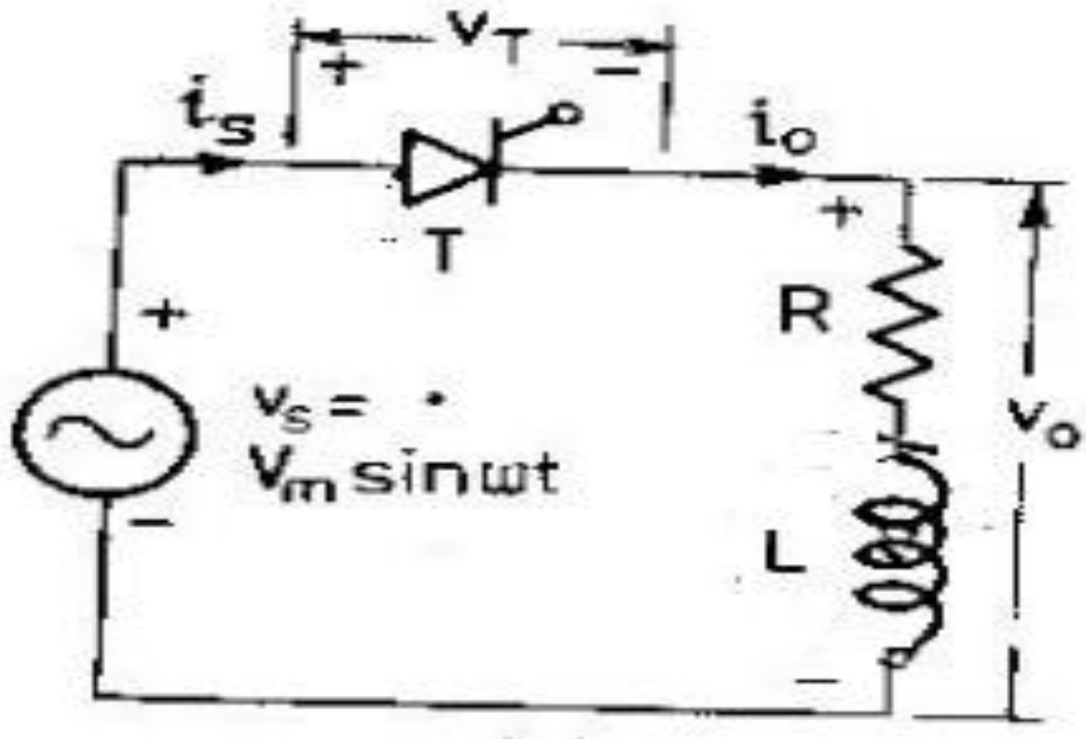
The rms output voltage is given by

$$V_{rms} = \left[ \frac{1}{2\pi} \int_{\alpha}^{\pi} V_m^2 \sin^2 \omega t \, d(\omega t) \right]^{1/2}$$

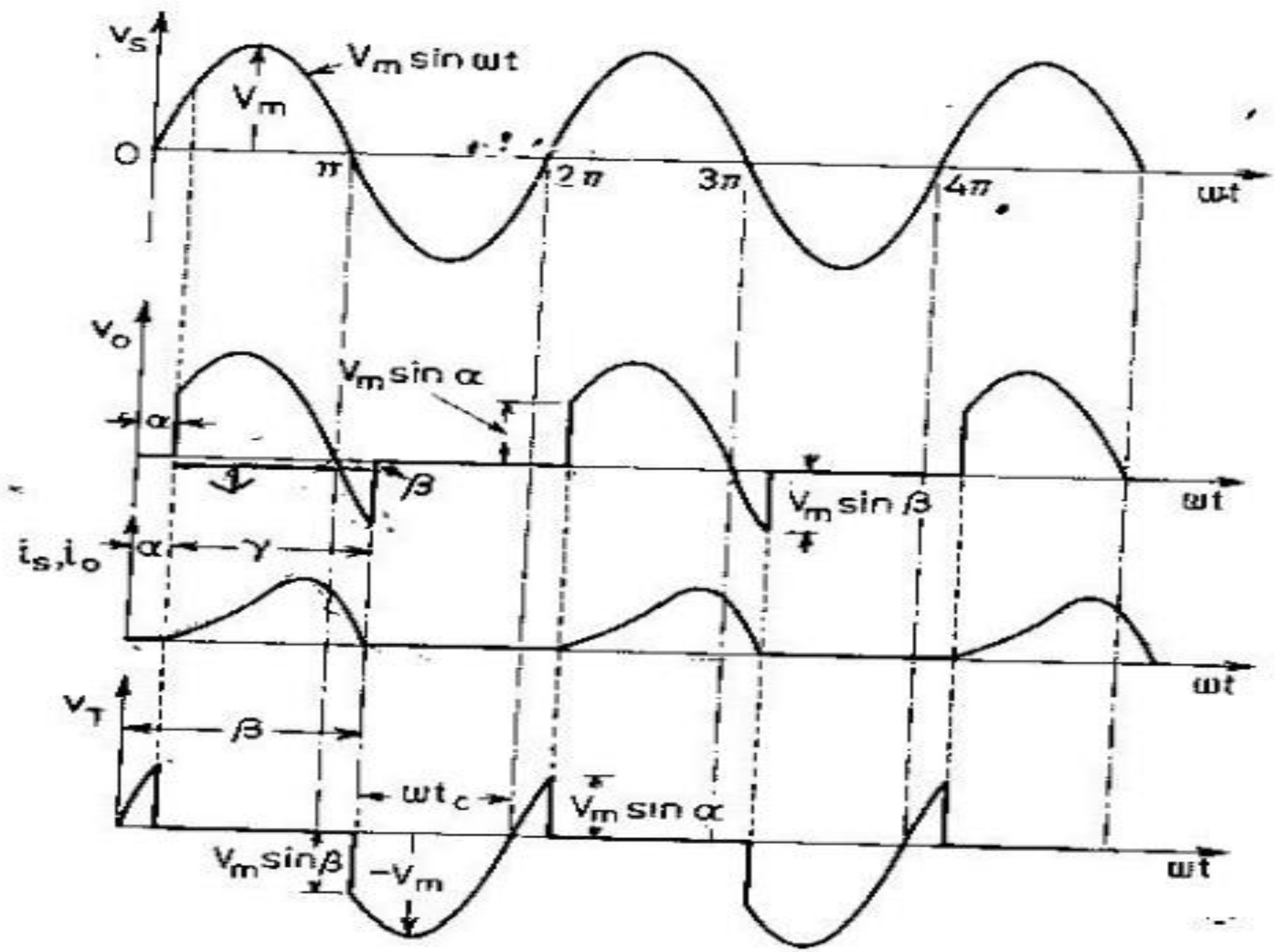
$$V_{rms} = \left[ \frac{V_m^2}{4\pi} \int_{\alpha}^{\pi} (1 - \cos 2\omega t) \, d(\omega t) \right]^{1/2}$$

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

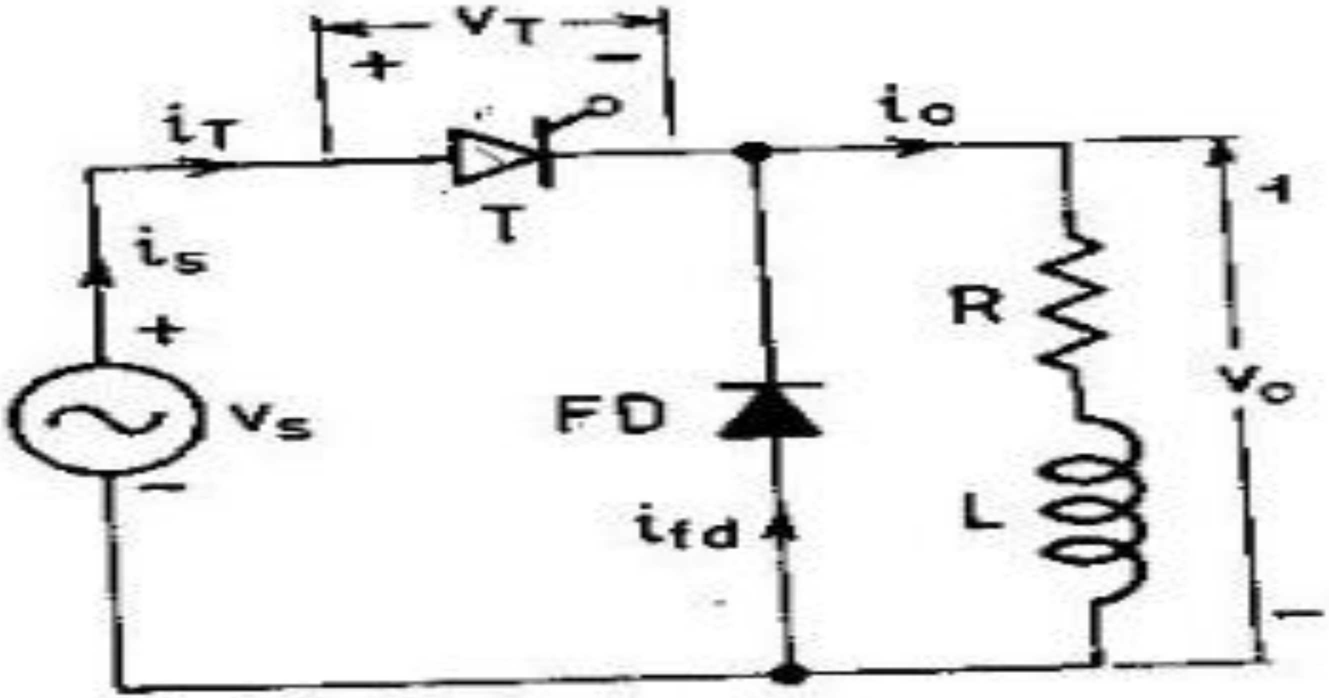
# SINGLE PHASE HWR WITH RL LOAD



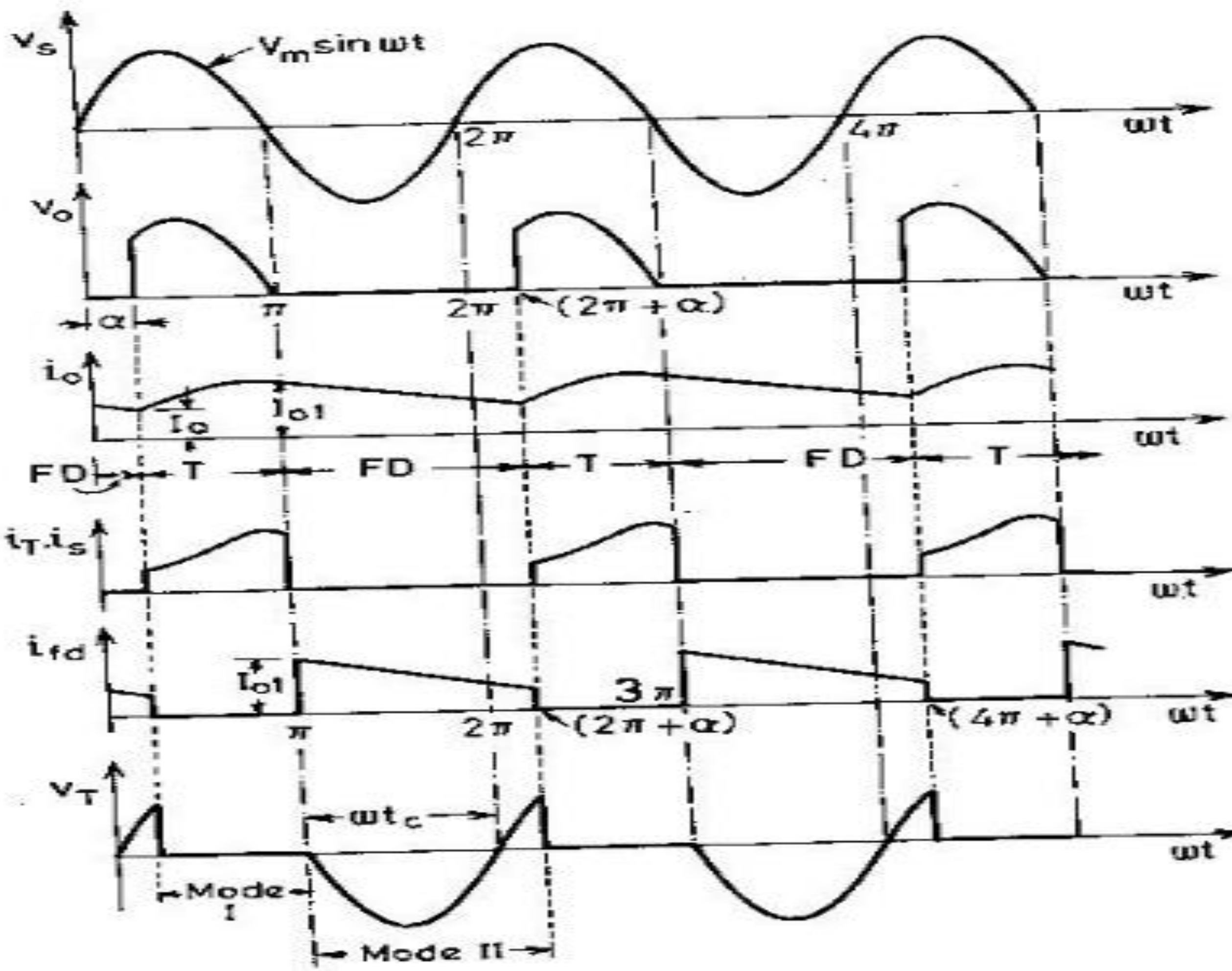
# WAVEFORMS OF HWR SINGLE PHASE WITH RL LOAD



# SINGLE PHASE HWR WITH RL LOAD AND FD



# WAVEFORMS OF SINGLE PHASE HWR WITH RL LOAD AND FD



# Importance of Free-Wheeling Diode

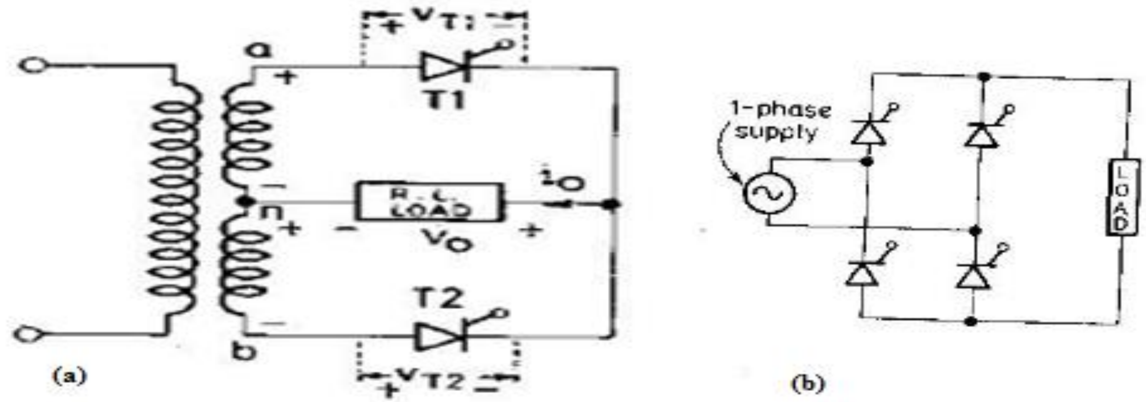
- A "freewheeling diode" is put into a circuit to protect the switching device from being damaged by the reverse current of an inductive load.

✔ This diode serves two main functions

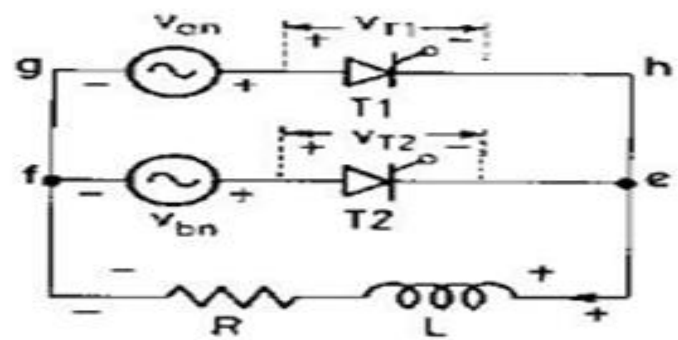
1. To protect/prevent the switching device from being damaged by the reverse current of an inductive load.
2. It transfers load current away from the main rectifier, there by allowing all of its thyristors to regain their blocking states.

Note: with freewheeling diode, thyristor will not be able to conduct beyond 180.

# SINGLE PHASE FULL WAVE CONVERTER WITH RL LOAD AND ITS EQUIVALENT CIRCUIT

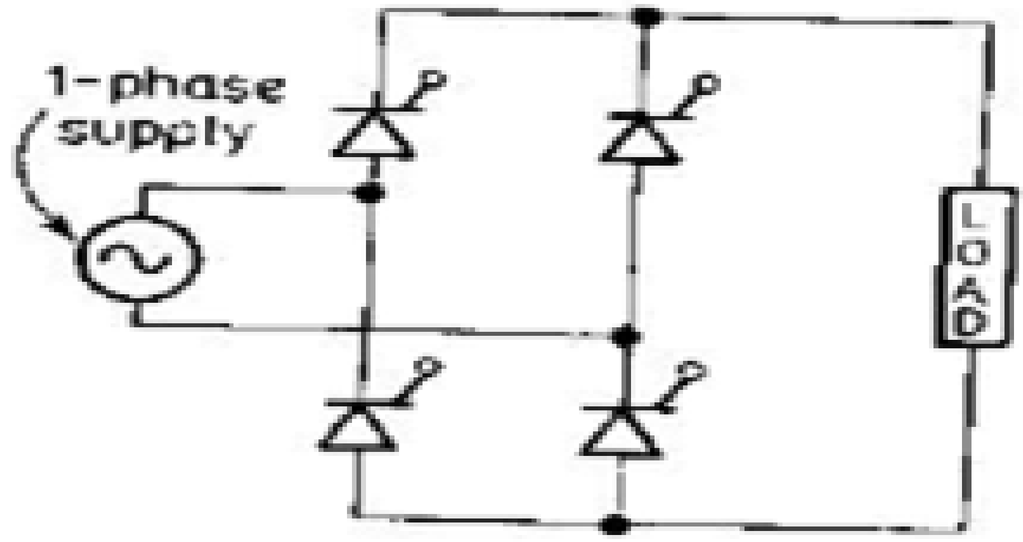



(a)FULL WAVE MID-POINT CONVERTER (b)FULL WAVE BRIDGE CONVERTER

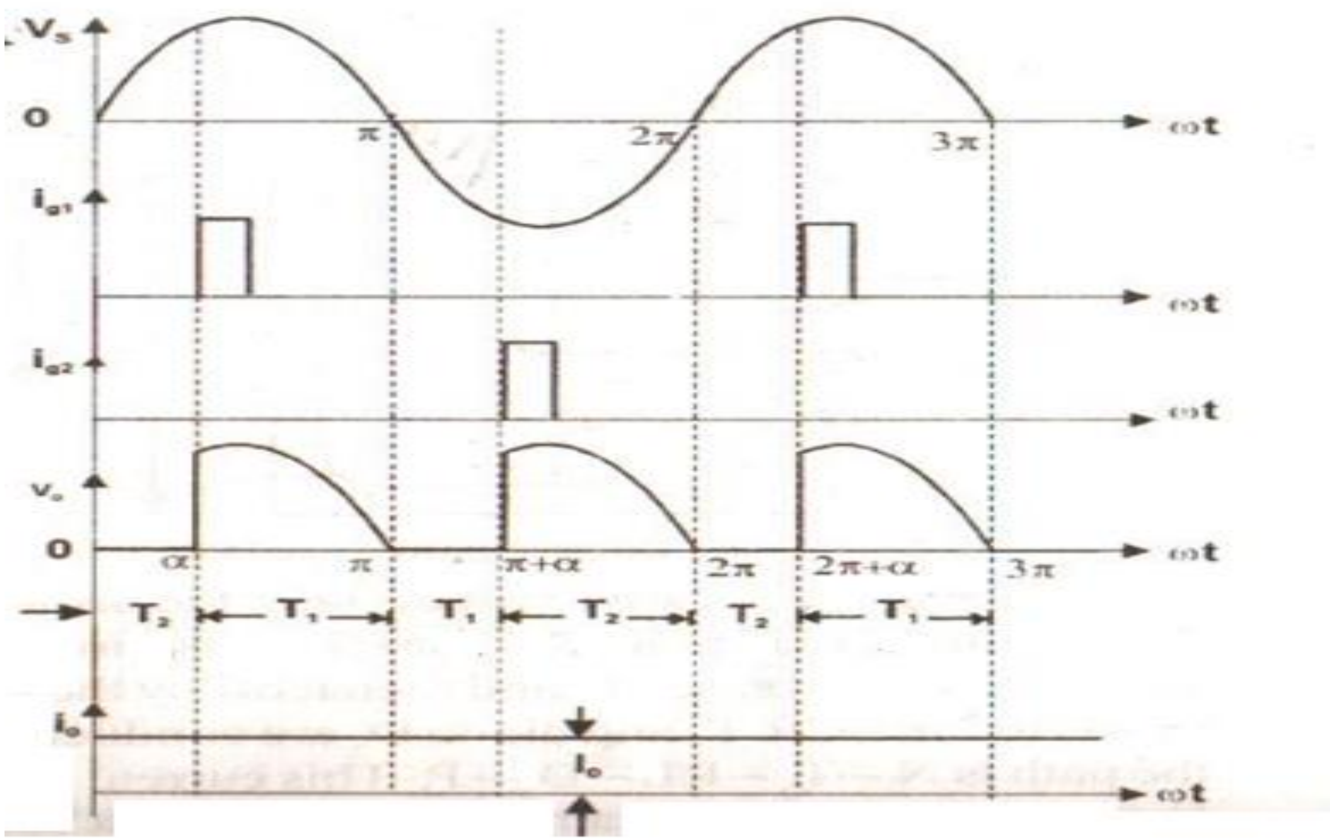



EQUIVALENT CIRCUIT OF FULL WAVE MID-POINT CONVERTER

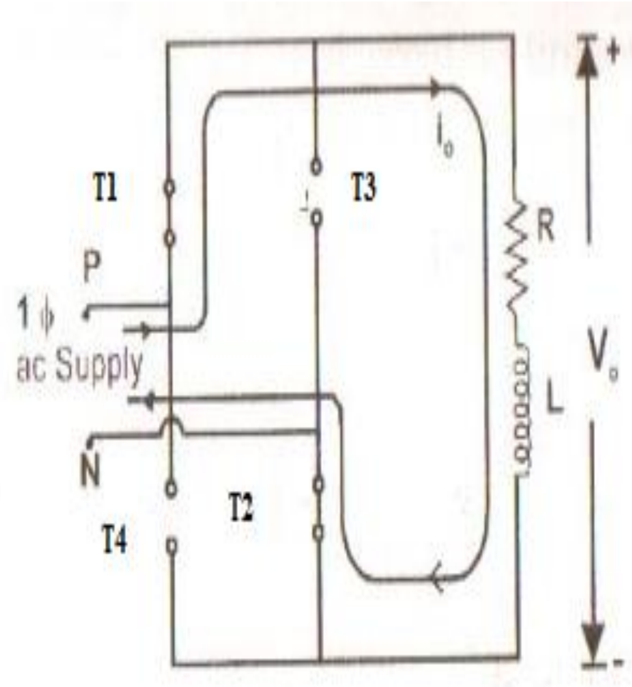
# FULL WAVE RECTIFIER

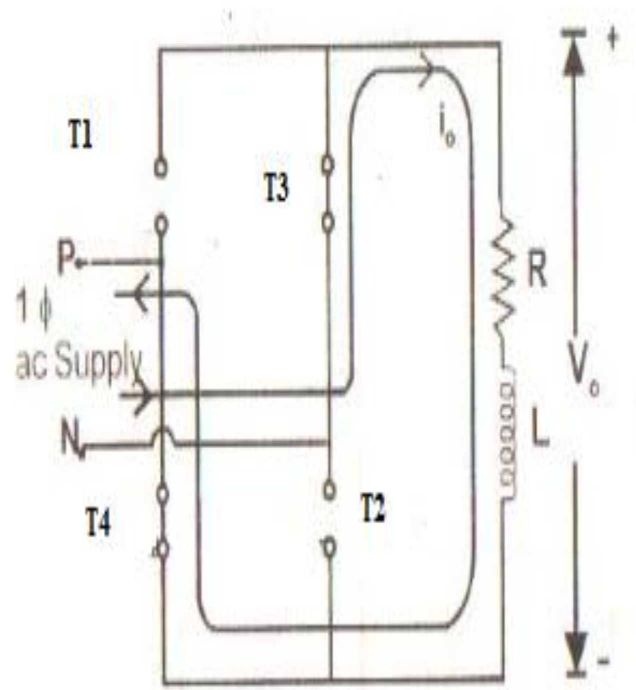


# FULL WAVE RECTIFIER WITH R LOAD

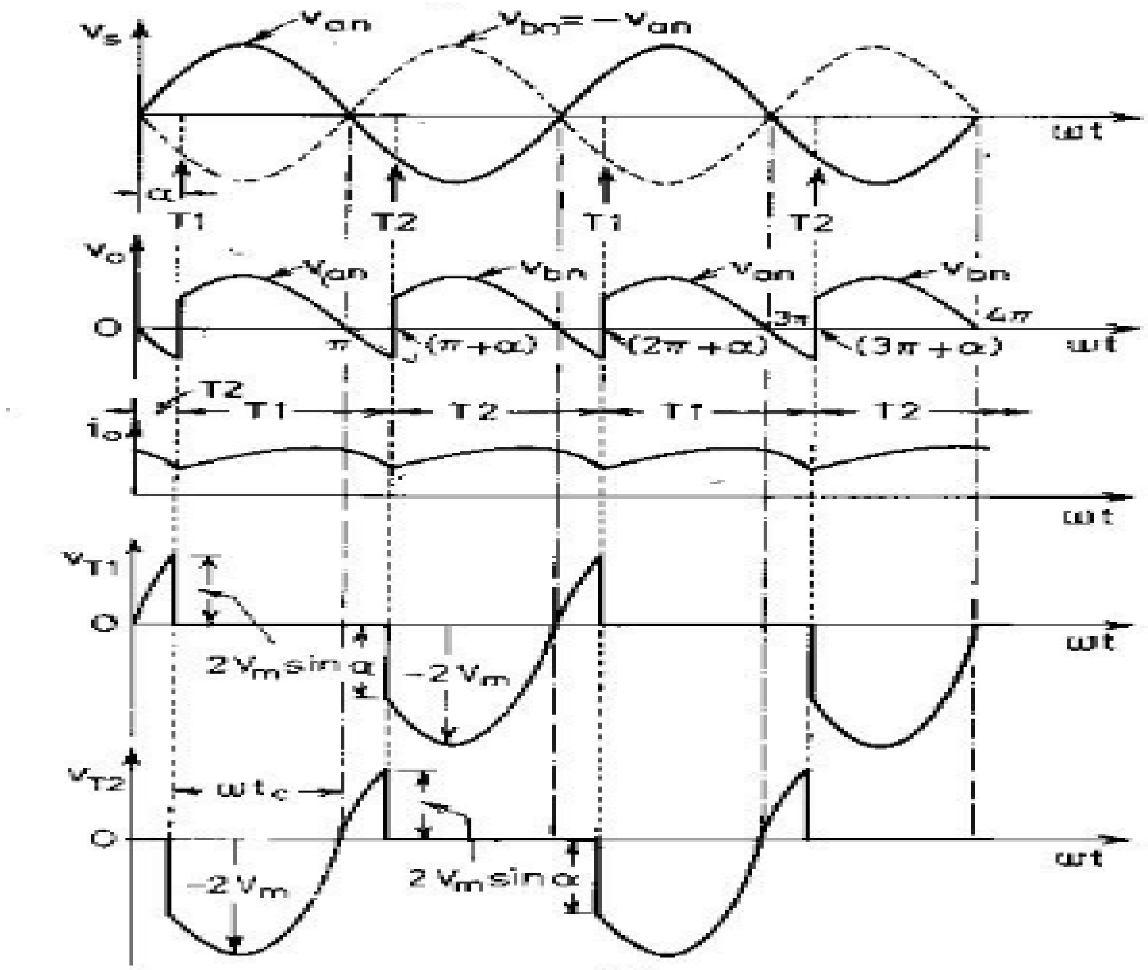


# OPERATION OF FWR WITH RL LOAD



# WAVEFORMS OF FULL WAVE MID-POINT CONVERTER WITH RL LOAD



# SINGLE PHASE FULL WAVE CONTROLLED BRIDGE RECTIFIER WITH R LOAD

**SINGLE PHASE FULL WAVE CONTROLLED BRIDGE RECTIFIER WITH R LOAD**

(i) Average output voltage ($V_{dc}$)

$$V_{dc} = \frac{V_m}{\pi}(1+\cos\alpha)$$

(ii) Average load Current ($I_{dc}$)

$$I_{dc} = \frac{V_m}{\pi R}(1+\cos\alpha)$$

(iii) Rms load Voltage ($V_{rms}$)

$$V_{rms} = [\frac{1}{\pi}\int_{\alpha}^{\pi} V_m^{\,2} \sin^2 \omega t . d\omega t]^{\frac{1}{2}}$$

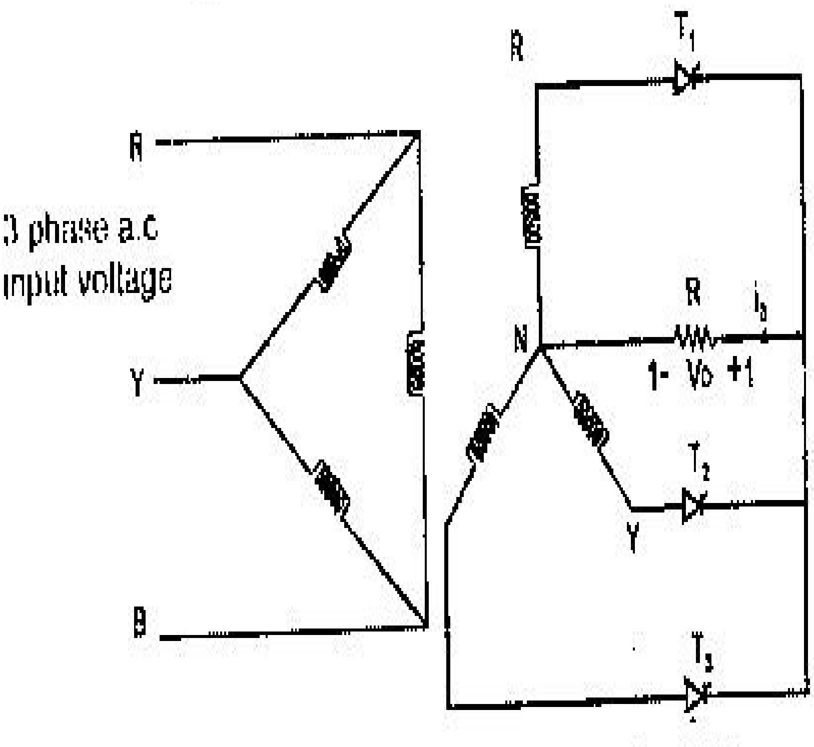
$$V_{rms} = V_m[\frac{\pi-\alpha}{2\pi} + \frac{\sin 2\alpha}{4\pi}]^{\frac{1}{2}}$$

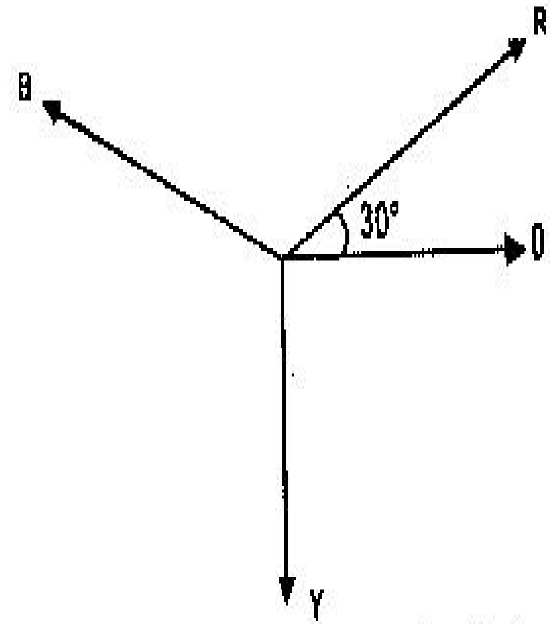
(iv) $I_{rms} = \frac{V_{rms}}{R}$

# THREE PHASE CONTROLLED RECTIFIERS

- ADVANTAGES
  - REDUCED RIPPLE CONTENT IN THE OUTPUT VOLTAGE
  - CAN BE USED FOR HIGH POWER APPLICATIONS
- TYPES
  - THREE PULSE CONVERTERS
  - SIX PULSE CONVERTERS
  - TWELVE PULSE CONVERTERS (HIGHER THE NO.OF PULSES, SMOOTHER IS THE OUTPUT VOLTAGE)

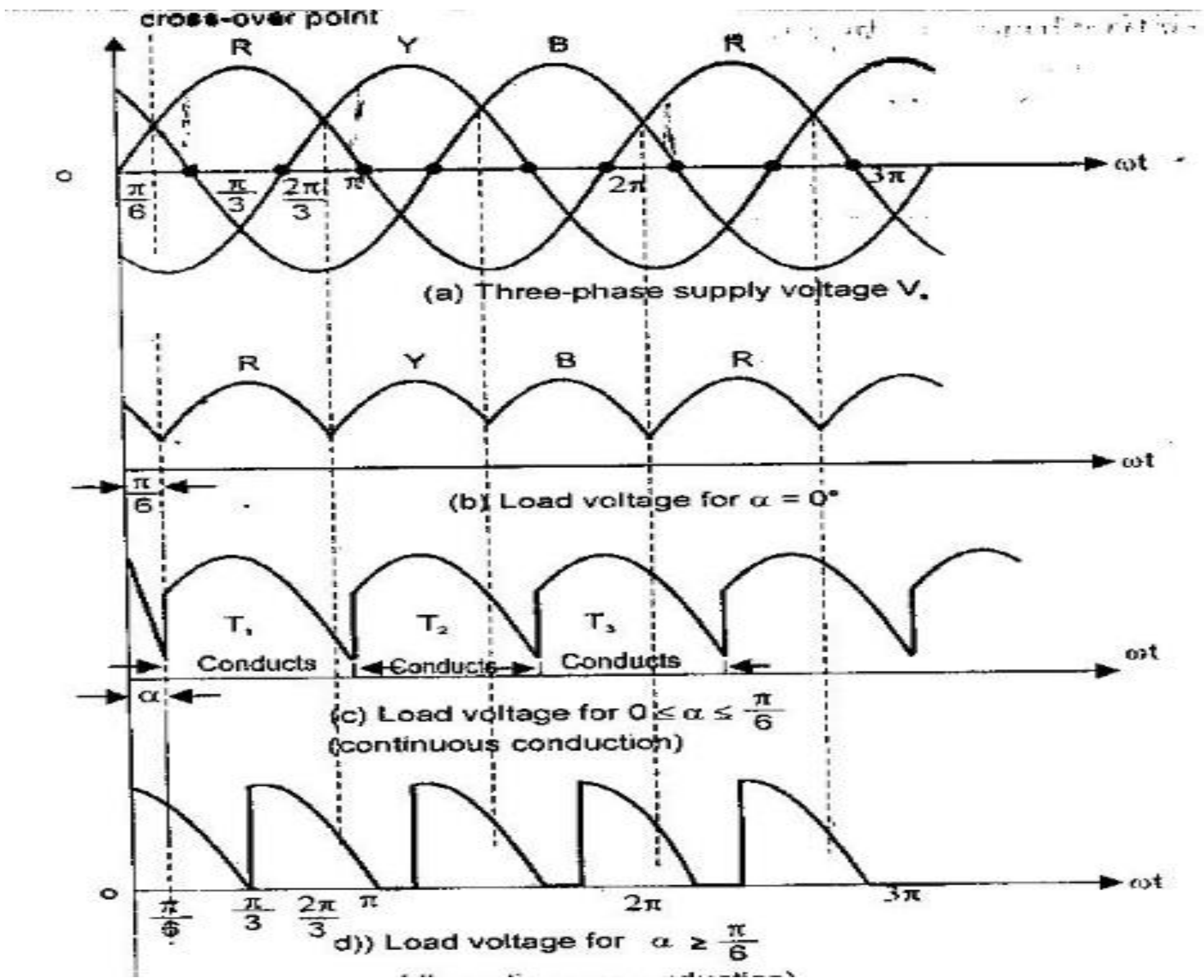
# THREE PHASE HALF WAVE RECTIFIER WITH R LOAD



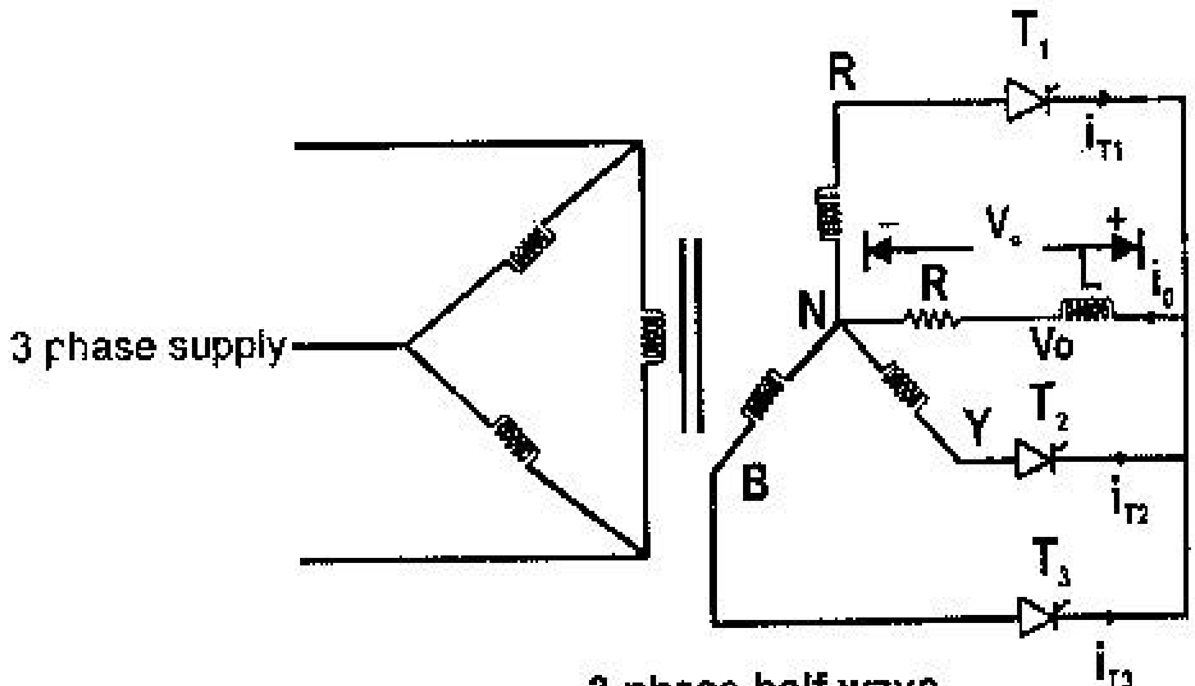




Vector diagram for 3 phase voltage

# WAVEFORMS OF THREE PHASE HWR WITH R LOAD

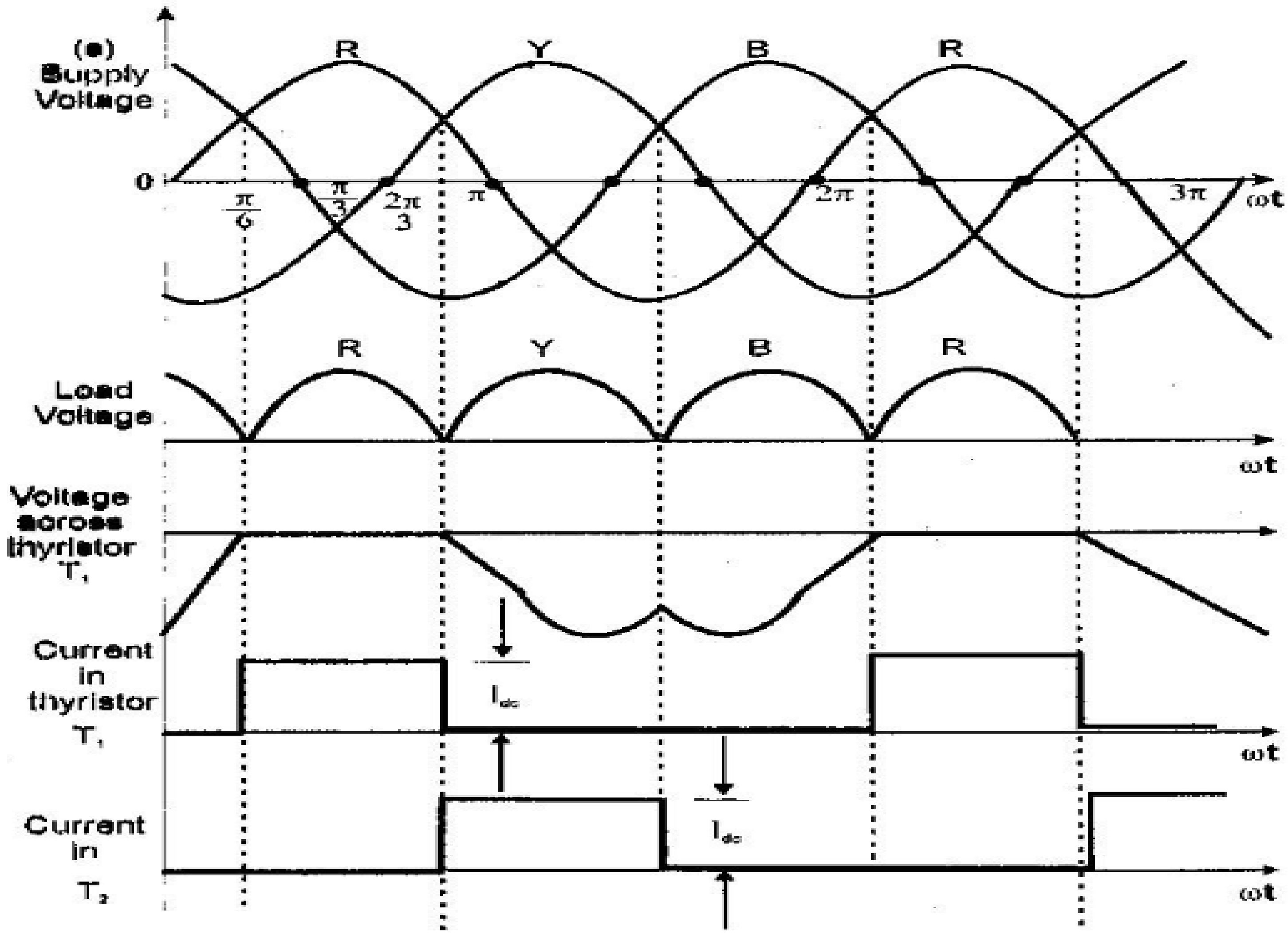


# THREE PHASE HWR WITH RL LOAD

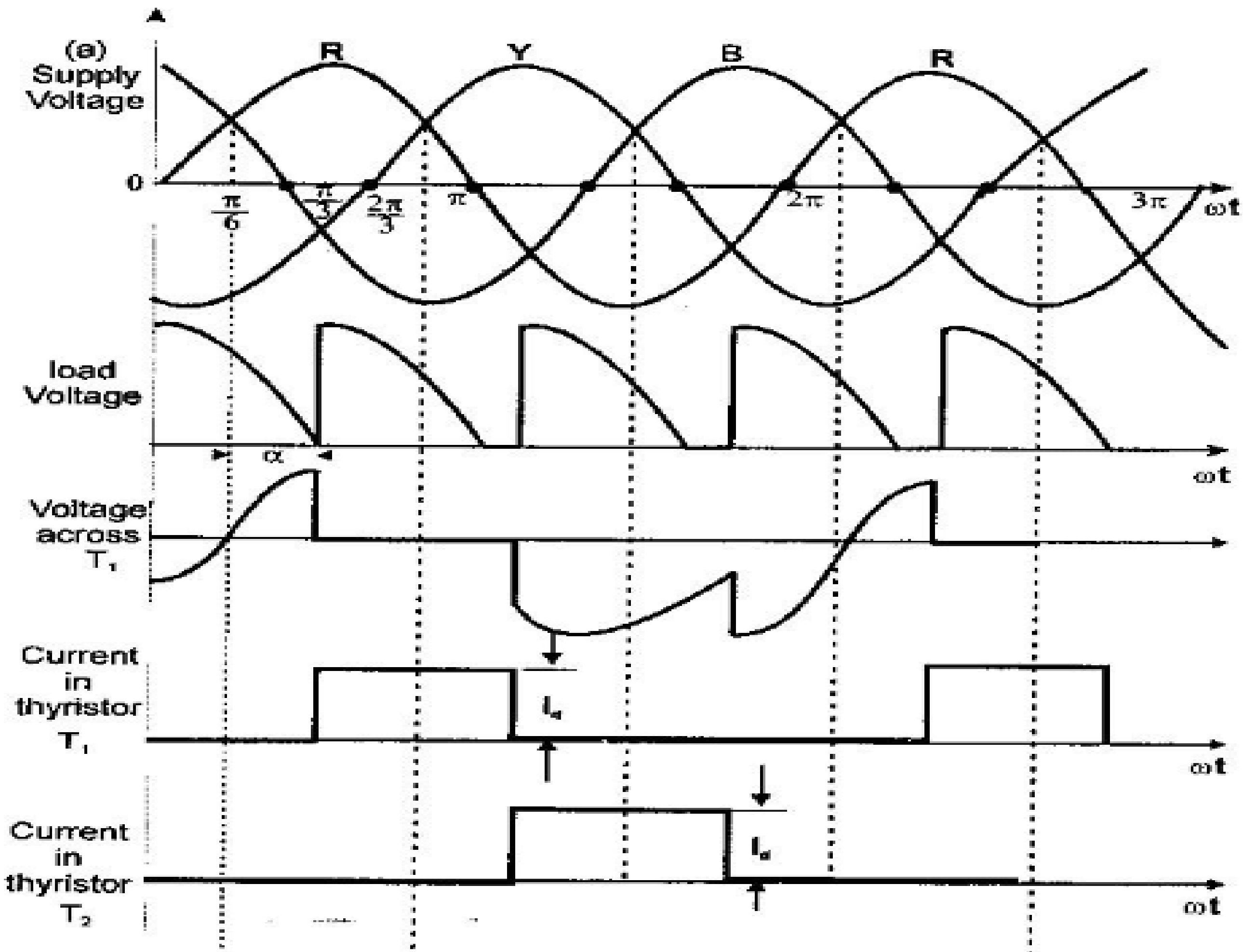



3 phase half wave
controlled rectifier with RL load

# WAVEFORMS OF THREE PHASE HWR WITH RL LOAD ($\alpha = 0^0$)

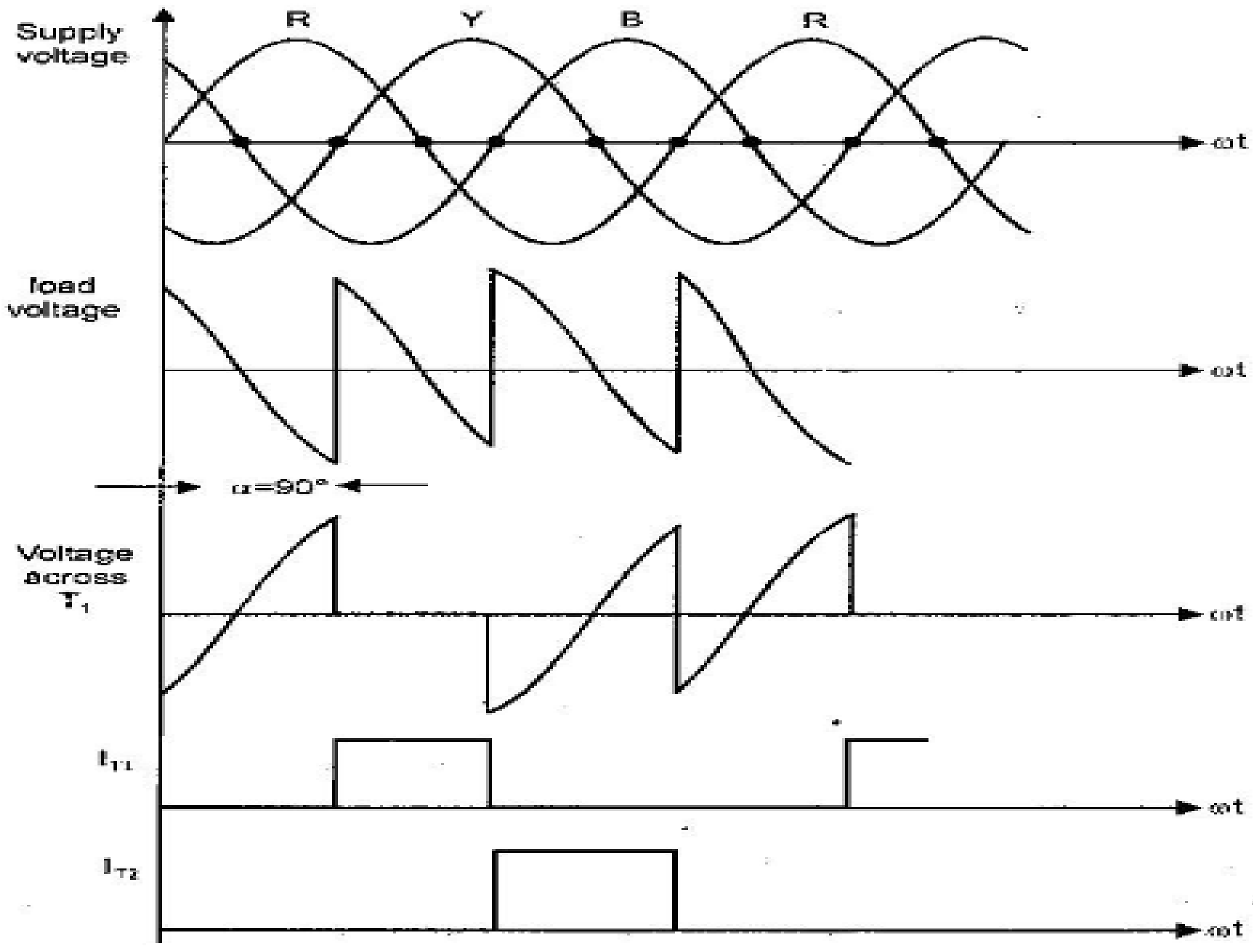


# WAVEFORMS OF THREE PHASE HWR WITH RL LOAD ($\alpha=45^0$)




Voltage and current waveforms for $\alpha=45°$

# WAVEFORMS OF THREE PHASE HWR WITH RL LOAD ($\alpha=90^0$)




Voltage and current waveforms for α=90°

# THREE PHASE HALF WAVE CONTROLLED RECTIFIER WITH R LOAD

**THREE PHASE HALF WAVE CONTROLLED RECTIFIER WITH R LOAD**

(i) Average output voltage ($V_{dc}$)

$$V_{dc} = \frac{3\sqrt{3}}{2\pi} V_m \cos\alpha$$

(ii) Average load Current ($I_{dc}$)

$$I_{dc} = \frac{3\sqrt{3}}{2\pi R} V_m \cos\alpha$$

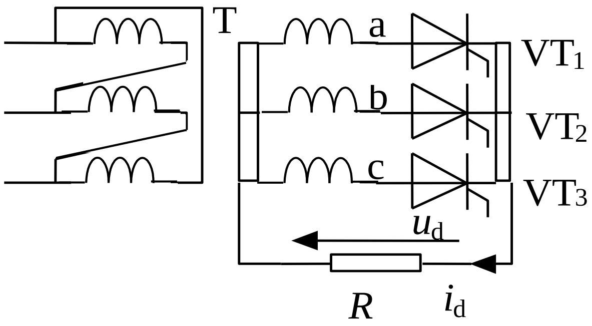
(iii) Rms load Voltage ($V_{rms}$)

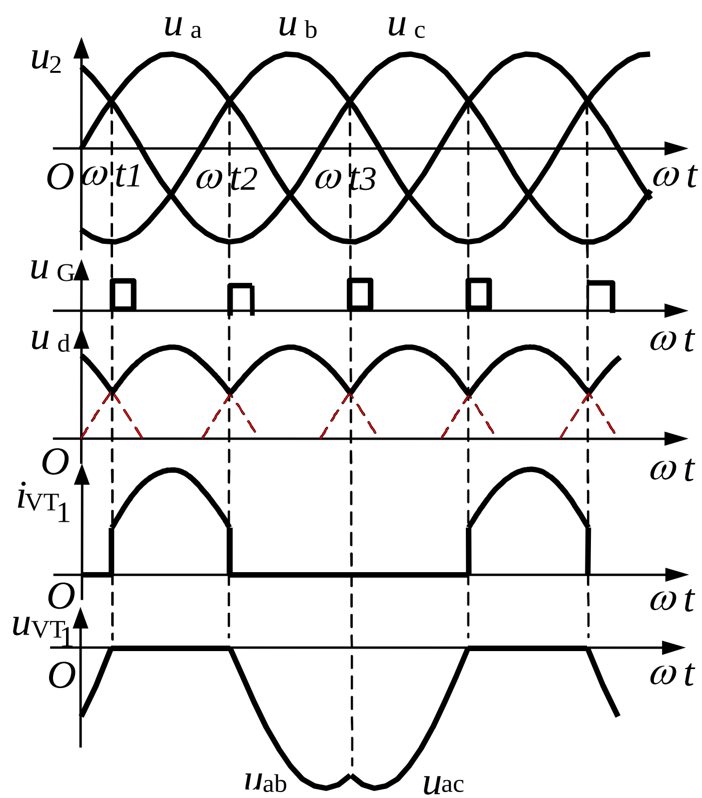
$$V_{rms} = [\frac{1}{2} + \frac{3\sqrt{3}}{8\pi}\cos 2\alpha]^{\frac{1}{2}}$$

# THREE- PHASE HALF WAVE CONTROLLED RECTIFIER

**Three- phase half- wave controlled rectifier**

Resistive load, α= 0º




Common-cathode connection

Natural commutation point

Resistive load, α= 30º