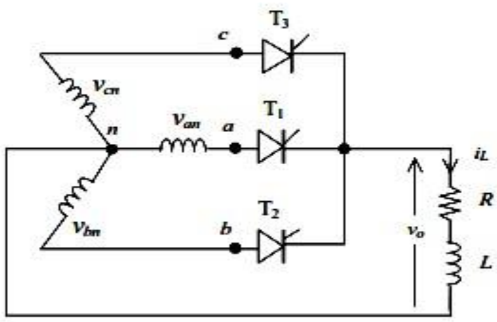
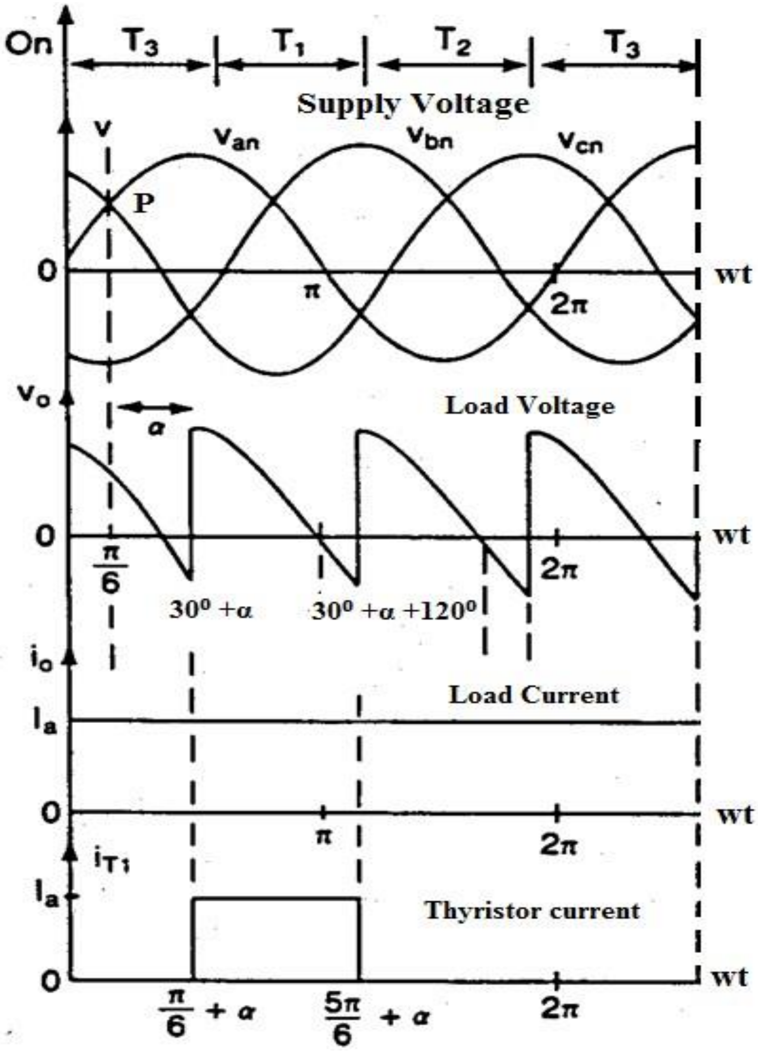
3.2 Three-phase Controlled Rectifier

3.2.1 Three-phase half wave Controlled Rectifier

The Three- phase half – wave controlled rectifier is shown in Fig. 3.3.As for the half – wave 3-phase uncontrolled diode rectifier, the load is connected between the converter positive terminal (cathodes of all thyristors) and the supply neutral. The diode with the highest voltage ,the neutral conducts. As the voltage of another diode becomes the highest, the load current is transferred to that device, and the previously conducting device is reverse biased and naturally commutated. The waveforms for the supply voltage, output voltage, and load current are shown in Fig.3.3 .





α is usually measured from point P

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NOTES:

1. Circuit Configuration

- The circuit consists of **three thyristors (SCR1, SCR2, SCR3)**.
- Each thyristor is connected to a different phase of the AC supply.
- The load is connected between the common cathode terminal and the neutral of the supply.

2. Firing Angle Control (α):

- The conduction of each thyristor is controlled by adjusting its **firing angle (α)**.
- The thyristors turn on at **α** and remain on for **120°** per cycle.

3. Waveforms

- The output voltage consists of **three overlapping pulses** per cycle.
- As **α increases**, the average **DC output voltage decreases**.
- The waveform has **high ripple**, requiring filtering for smooth DC output.

4. Advantages:

- Simple design (only 3 thyristors)
- Easier control compared to full-wave rectifiers
- Suitable for low-power applications

4. Disadvantages:

- High ripple and poor DC output quality
- Low efficiency compared to full-wave rectifiers
- Causes unbalanced loading on the transformer

Let $v_{an} = V_m \sin \omega t$

$V_{bn} = V_m \sin(\omega t - 2\pi/3)$

$V_{cn} = V_m \sin(\omega t - 4\pi/3)$

The average value of the load voltage wave is

$$V_{dc} = \frac{1}{\frac{2\pi}{3}} \int_{30°+\alpha}^{30°+\alpha+120°} V_m \; sin\omega t \; d\omega t = \frac{3V_m}{2\pi} [-cos\omega t] \begin{matrix} 150° + \alpha \\ 30° + \alpha \end{matrix}$$

$$= \frac{3V_m}{2\pi} [-(\cos(150° + \alpha) - \cos(30° + \alpha)] = \frac{3V_m}{2\pi} \left[-\left(-\frac{\sqrt{3}}{2} - \frac{\sqrt{3}}{2} \right) cos\alpha \right]$$

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

The load current I_{dc} is:

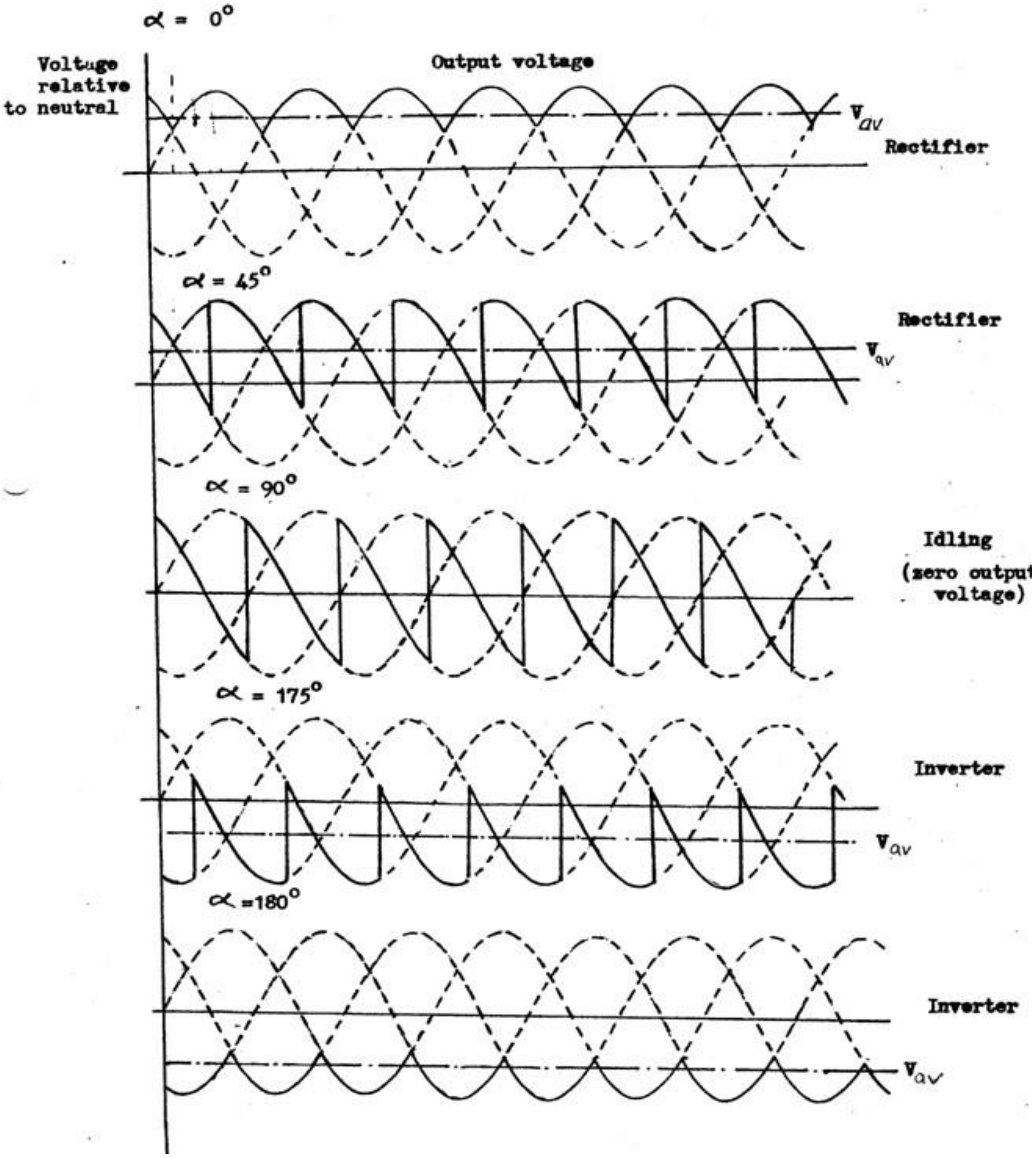
$$I_{dc} = \frac{3\sqrt{3}.Vm}{2\pi R} cos\alpha$$

The operation of the 3 – phase half – wave rectifier with different values of α is illustrated in Fig.7.4.It can be seen that this converter can operate either as a rectifier or as an inverter as

For $0° < \alpha < 90°$ ⟶ Rectifier

$90° < \alpha < 180°$ ⟶ Inversion

Fig.7.4 Output voltage waveform of the 3-phase half-wave rectifier for different values of firing angle α. Case of R-L load.



Example: The load in Fig.1 consists of a resistance and a very large inductance. The inductance is so large that the output current I_L can be assumed to be continuous and ripple-free. For $\alpha = 60°$:

Determine the average value of the output voltage, if phase voltage $V_{an} = 120V$.

Solution:

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

$$\alpha = 60°$$

$$V_m = \sqrt{2}\,V_{an} = \sqrt{2} \times 120 \text{ V}$$

$$\therefore V_{av} = \frac{3\sqrt{6}\,V_{an}}{2\pi} \cos 60$$

$$= \frac{3\sqrt{6} \times 120}{2\pi} \times \frac{1}{2} = 70.2\text{ V}.$$

H.W 1: Assume a three-phase half wave controlled rectifier with resistive load 10 Ω and high inductive load, the phase voltage 230 V,f=50 Hz and the firing angle: α=30, calculate DC voltage and current.

H.W2: Repeat the example for different firing angles while keeping the other parameters constant.

1. **α=0**
2. **α=60**
3. **α=90**
4. **α=120**