

5.Poly- phase uncontrolled rectification

For most industrial applications poly – phase rectifier circuits are use. The circuit employed may gives either half – wave or full – wave, controlled or uncontrolled rectifier circuits.

1. Three –Phase Half -Wave Uncontrolled Rectifier

Fig.5.1 shows a 3-phase half-wave uncontrolled rectifier with resistive load. The rectifier is fed from an ideal 3 – phase supply through delta –star 3- phase transformer. The principle of operation of this convertor can be explained as follows:

- Diode 1 which has a more positive voltage at its anode conducts for the period from $\pi/6$ to $5\pi/6$. In this period D2 and D3 are off. The neutral wire provides a return path to the load current.
- Similarly, diode 2, and 3, whichever has more positive voltage at its cathode conducts.
- The conduction pattern is: **D1 ,D2, D3.**

The output voltage and current waveforms are shown in Fig.5.2.

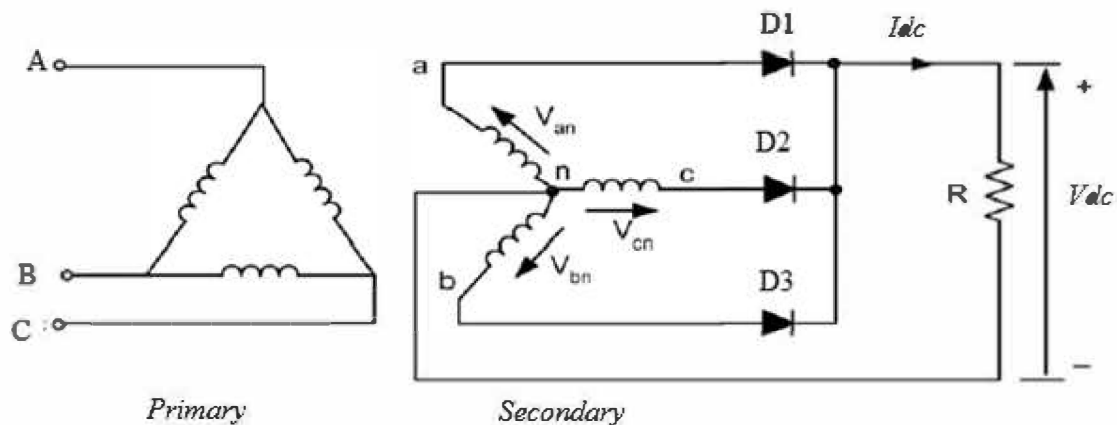


Fig.5.1 A 3-phase half-wave uncontrolled rectifier with resistive load.

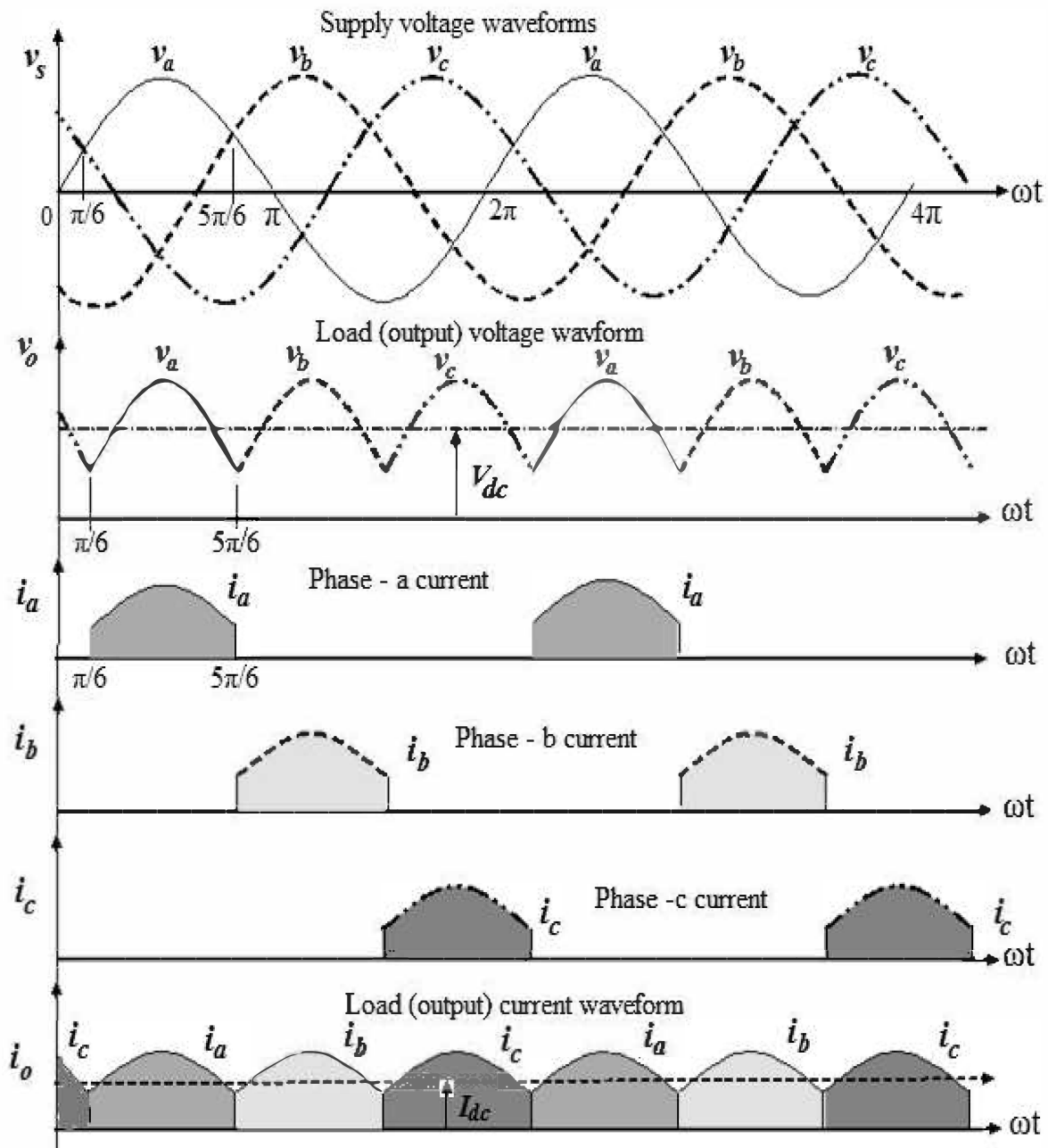
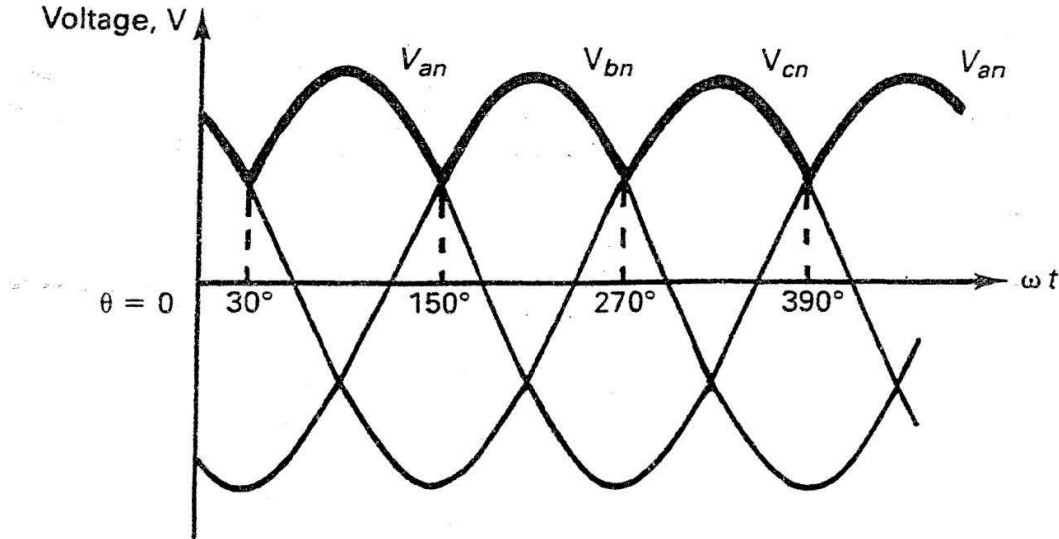


Fig .5.2 Load voltage and current waveforms for the 3 – phase half – wave uncontrolled rectifier.

Analytical properties of the output voltage waveform

The average value of the voltage waveform in Fig.5.3 can be found as follows:



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

$$\begin{aligned} V_{dc} &= \frac{1}{2\pi} \int_{\pi/6}^{5\pi/6} V_m \sin \omega t \, d\omega t = \frac{3V_m}{2\pi} [-\cos \omega t]_{\pi/6}^{5\pi/6} \\ &= \frac{3V_m}{2\pi} \left[-\left(\cos \frac{5\pi}{6} - \cos \frac{\pi}{6} \right) \right] = \frac{3V_m}{2\pi} \left[-\left(-\frac{\sqrt{3}}{2} - \frac{\sqrt{3}}{2} \right) \right] = \frac{3\sqrt{3}V_m}{2\pi} \end{aligned}$$

The load current I_{dc} is:

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

Note that the secondary windings of the supply transformer carry unidirectional currents, which leads dc magnetization of the transformer core. This implies that the transformer cores have dc flux, so that for the same ac voltage and hence flux swing, it must have larger core size than is necessary. This problem of dc magnetization is avoided using bridge rectifier circuit.

2.Three –Phase Full-Wave Uncontrolled Bridge Rectifier

Fig.5.4 shows a 3-phase full-wave uncontrolled bridge rectifier with resistive load. The rectifier is fed from an ideal 3 – phase supply through delta –star 3-phase transformer. The principle of operation of this convertor can be explained as follows:

Each three-phase line connects between pair of diodes .One to route power to positive (+) side of load, and other to route power to negative (-) side of load.

- Diode 1, 3 and 5, whichever has a more positive voltage at its anode conducts.
- Similarly, diode 2, 4 and 6, whichever has more negative voltage at its cathode return the load current.
- The conduction pattern is: **12-16-36-34-54-52-12.**
- Each diode conducts for 120° in each supply cycle as shown in Fig.5.5.

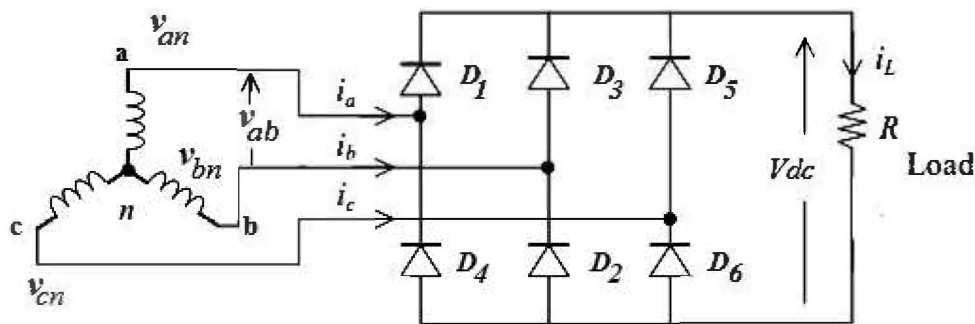


Fig.5.4 The rectifier

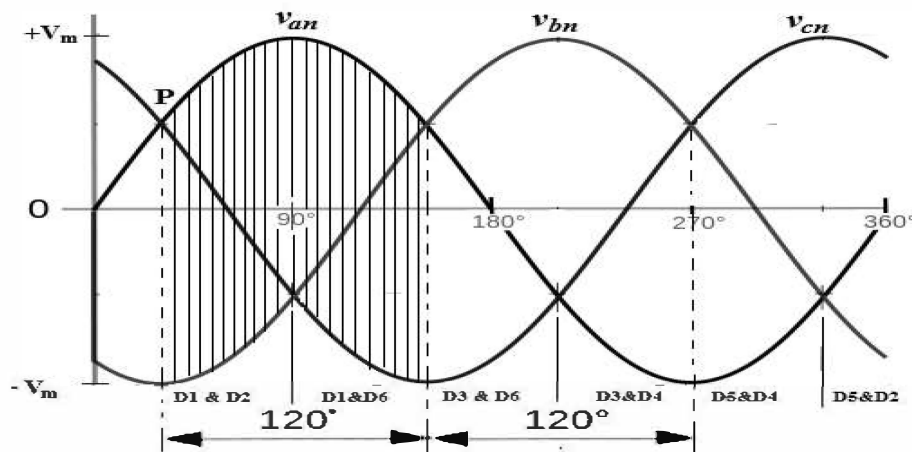


Fig.5.5 Each diode conducts for 120° .

The output voltage is the instantaneous difference between two appropriate phases at each instant as depicted in Fig.5.6, and the resultant dc output voltage wave is shown in Fig.5.7.

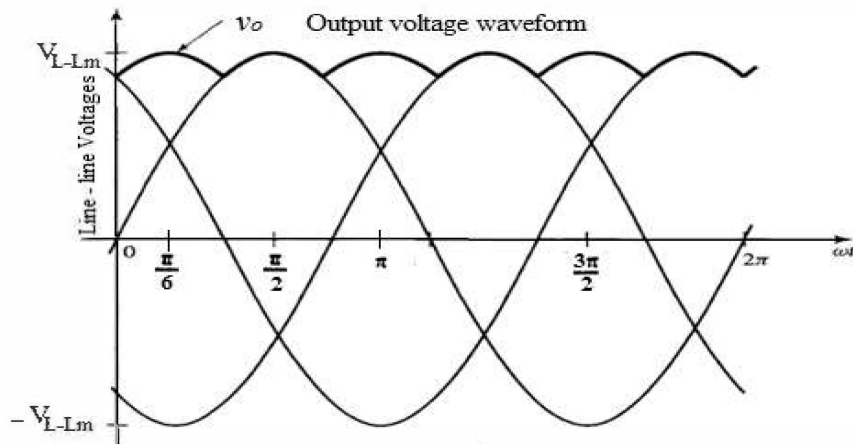


Fig.5.6 The line to line supply voltage and the output voltage waveforms.

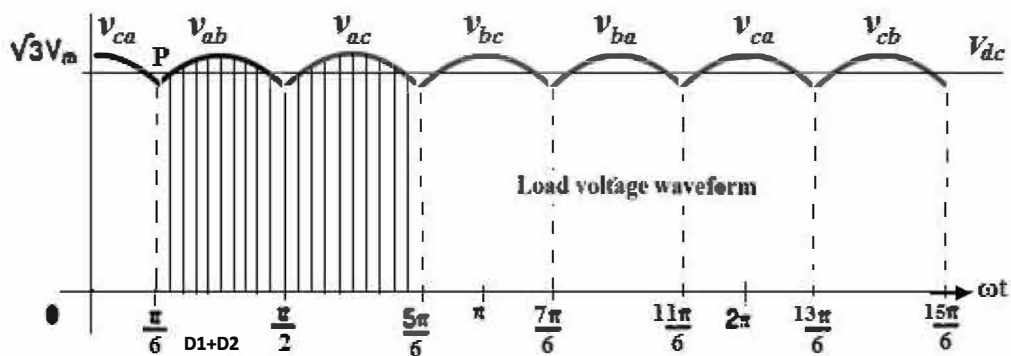


Fig.5.7 The dc output voltage waveform.

The average output voltage:

To find the average voltage V_{dc} on the load, assume that the line –to – line voltages are represented by the following equations,

$$v_{ab} = v_{an} - v_{bn} = V_m \sin(\omega t) - V_m \sin(\omega t - 2\pi/3),$$

hence

$$v_{ab}(\omega t) = \sqrt{3} V_m \sin\left(\omega t + \frac{\pi}{6}\right)$$

Similarly,

$$v_{bc}(\omega t) = \sqrt{3} V_m \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$v_{ca}(\omega t) = \sqrt{3} V_m \sin\left(\omega t + \frac{7\pi}{6}\right)$$

Hence: by integrating over 1/6 of a cycle,

$$\begin{aligned} V_{dc} &= \frac{3}{\pi} \int_{\pi/6}^{\pi/2} v_{ab}(\omega t) d\omega t \\ &= \frac{3}{\pi} \int_{\pi/6}^{\pi/2} \sqrt{3} V_m \sin\left(\omega t + \frac{\pi}{6}\right) d\omega t \\ &= \frac{3}{\pi} \int_{\pi/6}^{\pi/2} \sqrt{3} V_m \left(\sin \omega t \cos \frac{\pi}{6} + \cos \omega t \sin \frac{\pi}{6}\right) d\omega t \\ &= \frac{3}{\pi} \int_{\pi/6}^{\pi/2} \sqrt{3} V_m \left(\sin \omega t \frac{\sqrt{3}}{2} + \cos \omega t \frac{1}{2}\right) d\omega t \\ &= \frac{3\sqrt{3} V_m}{\pi} \left[-\cos(\pi/2) + \cos(\pi/6)\right] x \frac{\sqrt{3}}{2} + \left[\sin(\pi/2) - \sin(\pi/6)\right] x \frac{1}{2} \\ &= \frac{3\sqrt{3} V_m}{\pi} \left[0 + \frac{\sqrt{3}}{2}\right] x \frac{\sqrt{3}}{2} + \left[1 - \frac{1}{2}\right] x \frac{1}{2} \\ &= \frac{3\sqrt{3} V_m}{\pi} \left[\frac{3}{4} + \frac{1}{4}\right] = \frac{3\sqrt{3} V_m}{\pi} \end{aligned}$$

The load current I_{dc} is:

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

The average power is:

$$P_{dc} = V_{dc} I_{dc} = \frac{3\sqrt{3} V_m}{\pi} x \frac{3\sqrt{3} V_m}{\pi R} = \frac{27 V_m^2}{\pi R}$$

3. Six –phase (hexa-phase) uncontrolled rectifier

To get more smooth output voltage waveform, a six –phase supply is obtained from a three-phase system using transformer with centre tapped secondary winding as shown in the Fig.5.8 below:

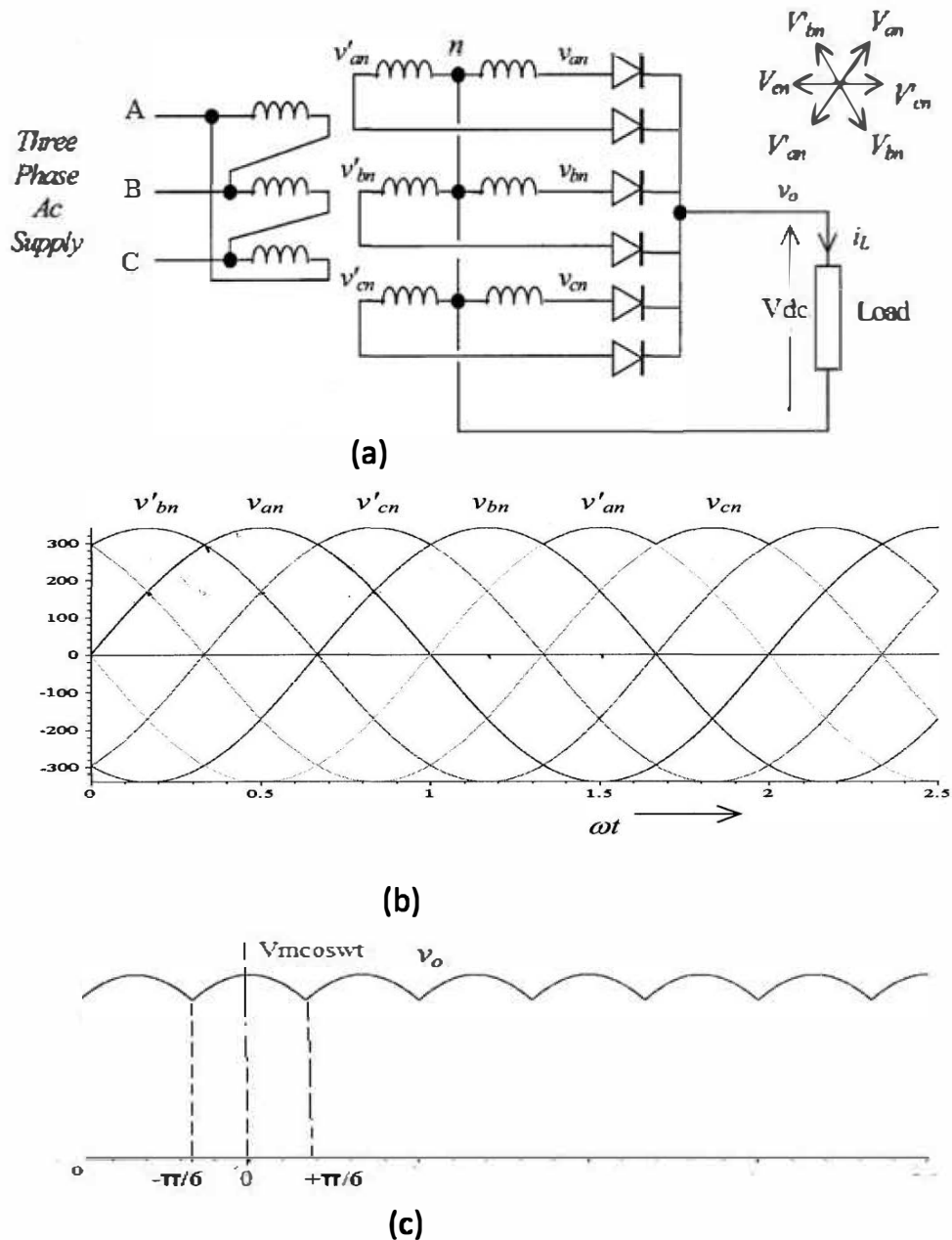


Fig.5.8 Six – phase rectifier (a) Circuit, (b) Input voltages, (c) output voltage

The average output voltage is: $V_{dc} = \frac{3}{\pi} \int_{-\pi/6}^{\pi/6} V_m \cos \omega t d\omega t = \frac{3V_m}{\pi}$