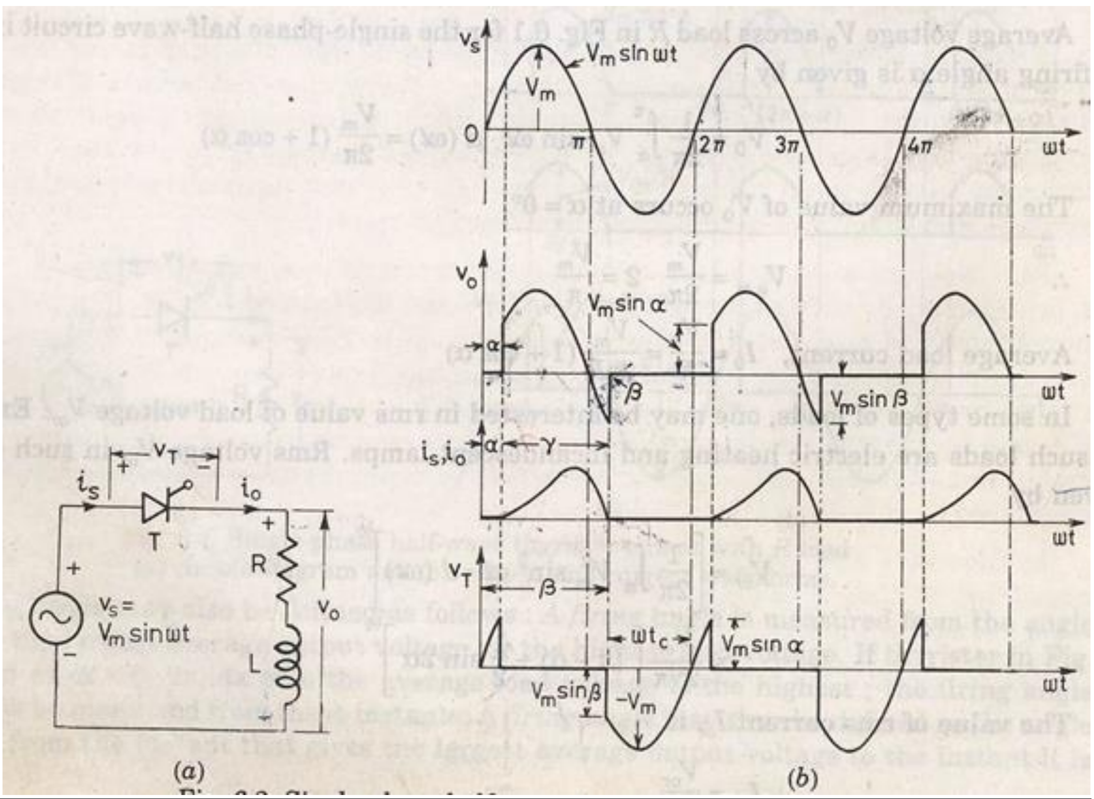
RECTIFIER

Rectifier are used to convert A.C to D.C supply.

Rectifiers can be classified as single phase rectifier and three phase rectifier. Single phase rectifier are classified as 1-Φ half wave and 1-Φ full wave rectifier. Three phase rectifier are classified as 3-Φ half wave rectifier and 3-Φ full wave rectifier. 1-Φ Full wave rectifier are classified as1-Φ mid point type and 1-Φ bridge type rectifier. 1-Φ bridge type rectifier are classified as 1-Φ half controlled and 1-Φ full controlled rectifier. 3-Φ full wave rectifier are again classified as 3-Φ mid point type and 3-Φ bridge type rectifier. 3-Φ bridge type rectifier are again divided as 3-Φ half controlled rectifier and 3-Φ full controlled rectifier.

Single phase half wave circuit with R-L load



Output current i_o rises gradually. After some time i_o reaches a maximum value and then begins to decrease.

At π, v_o=0 but i_o is not zero because of the load inductance L. After π interval SCR is reverse biased but load current is not less then the holding current.

At β>π, i_o reduces to zero and SCR is turned off.

At 2π+β SCR triggers again

α is the firing angle.

β is the extinction angle.

$$v = \beta - \alpha = conduction\ angle$$

Analysis for V_T.

At $\omega t = \square, V_T = V_m sin\square$

During $= \square\ to\ \square\ , V_T = 0;$

When $= \square\ , V_T = V_m sin\square;$

$$V_m \sin \omega t = Ri_0 + L\frac{di_0}{dt}$$

$$i_s = \frac{V_m}{\sqrt{R^2 + X^2}} \sin(\omega \mathrm{t} - \phi)$$

Where,

$$\phi = \tan^{-1}\frac{X}{R}$$

$$X = \omega L$$

Where $\square$ is the angle by which I_s lags V_s.

The transient component can be obtained as

$$Ri_t + L\frac{di_0}{dt} = 0$$

So $i_t = Ae^{-(Rt/L)}$

$$i_0 = i_s + i_t$$

$$\frac{V_m}{z}\sin(\omega t - \square) + Ae^{-(Rt/L)}$$

Where $z = \sqrt{R^2 + X^2}$

At $\alpha = \omega t, i_o = 0;$

$$0 = \frac{V_m}{z}\sin(\alpha - \square) + Ae^{-(R\alpha/L\omega)};$$

$$A = \frac{-V_m}{z}\sin(\alpha - \square)e^{(R\alpha/L\omega)}$$

$$i_o = \frac{V_m}{z}\sin(\omega t - \square) - \frac{V_m}{z}\sin(\alpha - \square)e^{-R(\omega t - \alpha)/L\omega}$$

Therefore,

$\omega t = \beta, i_0 = 0;$

So $\sin(\beta - \alpha) = \sin(\alpha - \square)e^{-(\beta-\alpha)/(\omega L)}$

β can obtained from the above equation.

The average load voltage can be given by

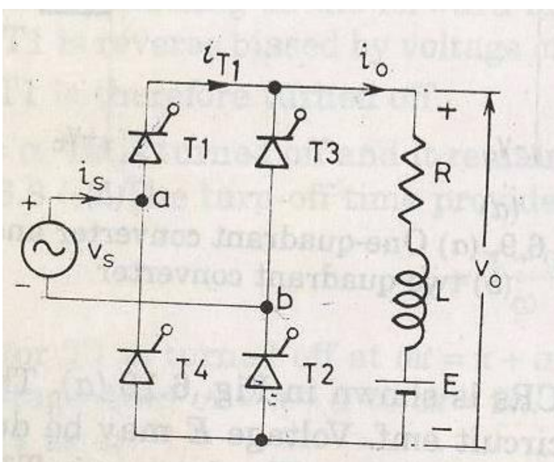
$$V_0 = \frac{1}{2\pi}\int_{\alpha}^{\beta} V_m \sin \omega t d(\omega t)$$

$$\frac{V_m}{2\pi}(\cos(\alpha) - \cos(\beta))$$

Average load current

$$I_0 = \frac{V_m}{2\pi R}(\cos\alpha - \cos\beta)$$

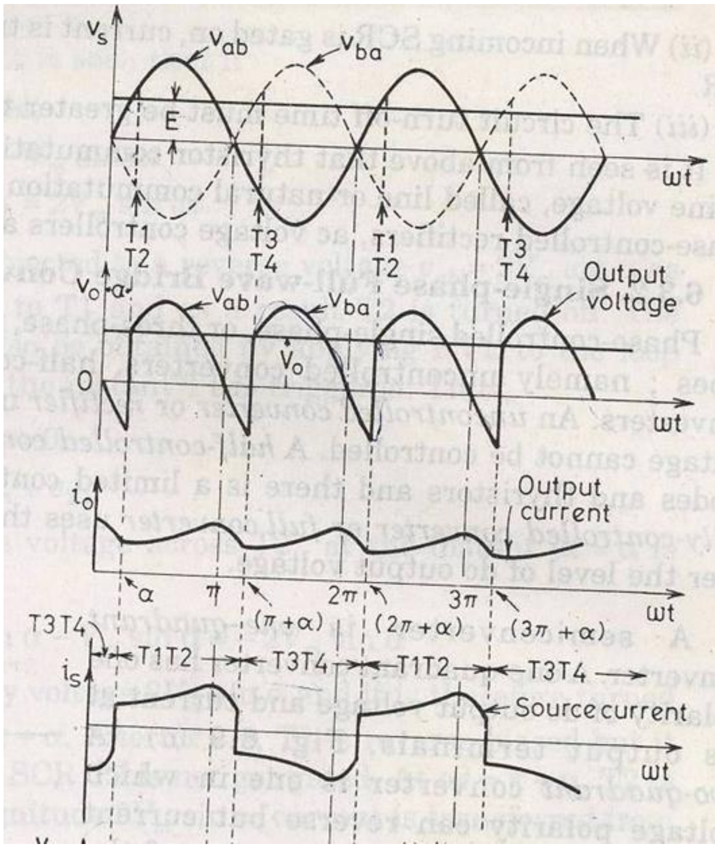
<u>Single phase full converter</u>



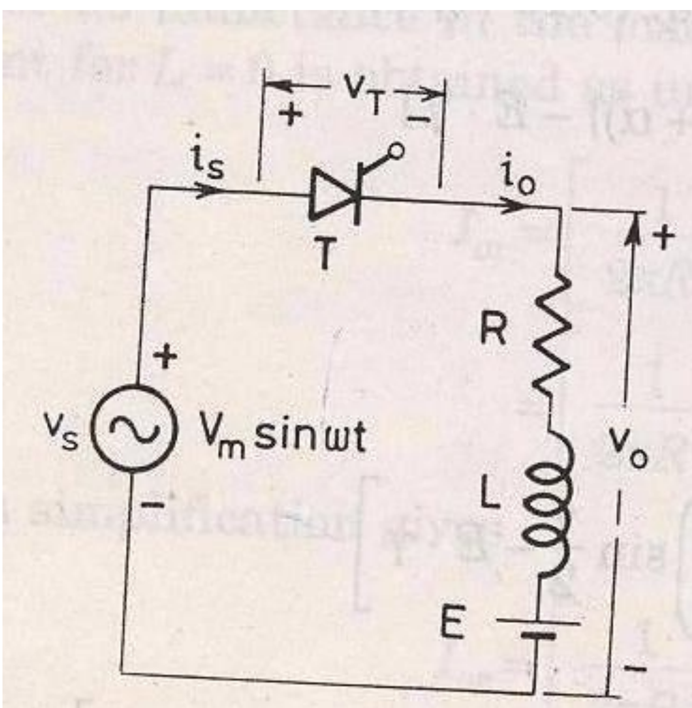
$$V_0 = \frac{1}{\pi}\int_{\alpha}^{\pi+\beta} V_m \sin(\omega t) d(\omega t)$$

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

T_1,T_2 triggered at α and π radian latter T_3, T_4 are triggered.



Single phase half wave circuit with RLE load



The minimum value of firing angle is

$$V_m \sin(\omega t) = E$$

So,

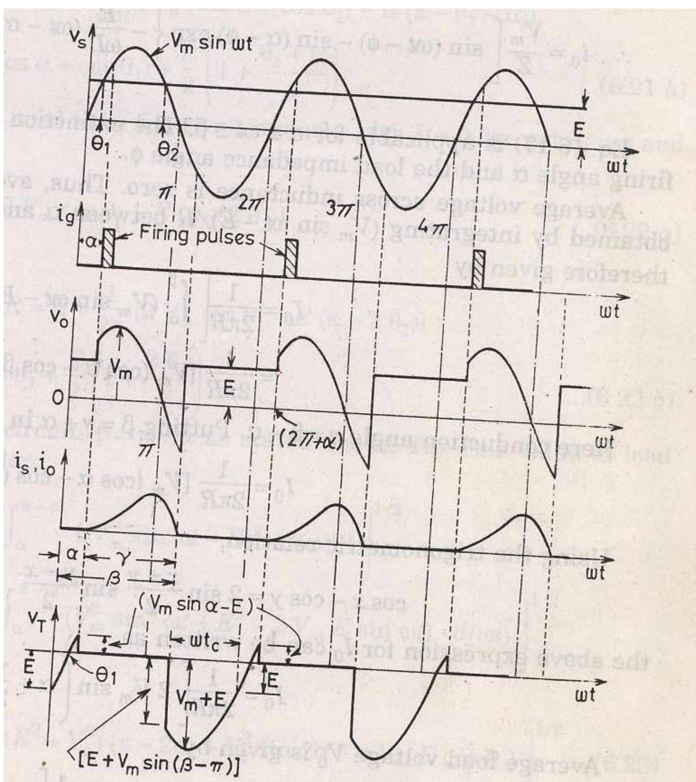
$$\theta_1 = \sin^{-1}\frac{E}{V_m}$$

Maximum value of firing angle

$$\theta_2 = \pi - \theta_2$$

The voltage differential equation is

$$V_m \sin(\omega t) = Ri_0 + L\frac{di_0}{dt} + E$$



$$i_s = i_{s1} + i_{s2}$$

Due to source volt

$$i_{s1} = \frac{V_m}{Z}\sin(\omega t - \phi)$$

Due to DC counter emf

$i_{s2} = -(E/R)$

$i_t = Ae^{-(R/L)t}$

Thus the total current is given by

$i_{s1} + i_{s2} + i_t$

$= \frac{V_m}{Z}\sin(\omega t - \phi) - \frac{E}{R} + Ae^{-(R/L)t}$

$i_{s0} = \frac{V_m}{Z}\sin(\omega t - \phi) - \frac{E}{R} + Ae^{-(R/L)t}$

$At\, \omega t = \alpha, i_0 = 0$

$$A = [\frac{E}{R} - \frac{V_m}{Z}\sin(\alpha - \phi)]e^{-R\alpha/L\omega}$$

So

$$i_0 = \frac{V_m}{Z}[\sin(\omega t - \phi) - \sin(\alpha - \phi)e^{\{\frac{-R}{\omega L}(\omega t - \alpha)\}} - \frac{E}{R}[1 - e^{\{\frac{-R}{\omega L}(\omega t - \alpha)\}}]$$

Average voltage across the inductance is zero. Average value of load current is

$\mathrm{I}_0 = \frac{1}{2\pi R}\int_\alpha^\beta (V_m \sin\omega t - E)\,\mathrm{d}(\omega t)$

$= \frac{1}{2\pi R}[V_m(\cos\alpha - \cos\beta) - \mathrm{E}(\beta - \alpha)]$

Conduction angle $\nu = \beta - \alpha$

$\Rightarrow \beta = \alpha + \nu$

$\mathrm{I}_0 = \frac{1}{2\pi R}[V_m(\cos\alpha - \cos(\alpha + \nu)) - \mathrm{E}(\nu)]$

$\cos A - \cos\mathrm{B} = 2\sin\frac{A+B}{2}\sin\frac{A-B}{2}$

So

$\mathrm{I}_0 = \frac{1}{2\pi R}[2V_m \sin(\alpha + \frac{\nu}{2})\sin\frac{\nu}{2} - E.\nu]$

$$v = E + I_0 R$$

$$= \mathrm{E} + \frac{1}{2\pi}[2V_m \sin(\alpha + \frac{v}{2})\sin\frac{v}{2} - E.v]$$

$$= \mathrm{E}(1 - \frac{v}{2\pi}) + [\frac{V_m}{\pi}\sin(\alpha + \frac{v}{2})\sin\frac{v}{2}]$$

If load inductance L is zero then

$$\beta = \theta_2$$

And $v = \beta - \alpha = \theta_2 - \alpha$

But $\theta_2 = \pi - \theta_1$

So $\beta = \theta_2 = \pi - \theta_1$

And $v = \pi - \theta_1 - \alpha$

So average current will be

$$\mathrm{I}_0 = \frac{1}{2\pi R}[V_m(\cos\alpha - \cos(\pi - \theta_1)) - E(\pi - \theta_1 - \alpha)]$$

So $V_0 = E + I_0 R$

$$= \frac{V_m}{2\pi}(\cos\alpha + \cos\theta_1) + \frac{E}{2}(1 + \frac{\theta_1 + \alpha}{\pi})$$

For no inductance rms value of load current

$$\mathrm{I}_0 = [\frac{1}{2\pi R^2}\int_{\alpha}^{\pi-\alpha}(V_m \sin(\omega t) - E)^2 d\left(\omega t\right)]^{1/2}$$

Power delivered to load

$$P = I_{or}^2 R + I_0 E$$

Supply power factor

$$Pf = \frac{I_{or}^2 R + I_0 E}{V_s I_{or}}$$

<u>Single phase full wave converter:</u>