Power Electronics Lab

three phase
controlled rectifier

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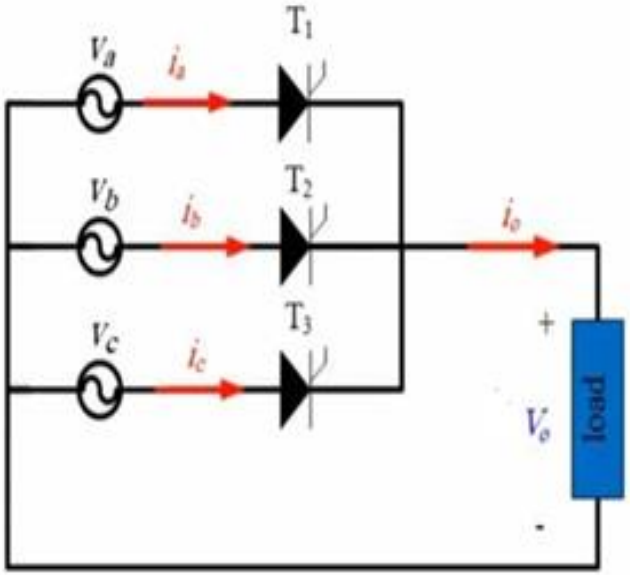
Three Phase controlled Rectifier

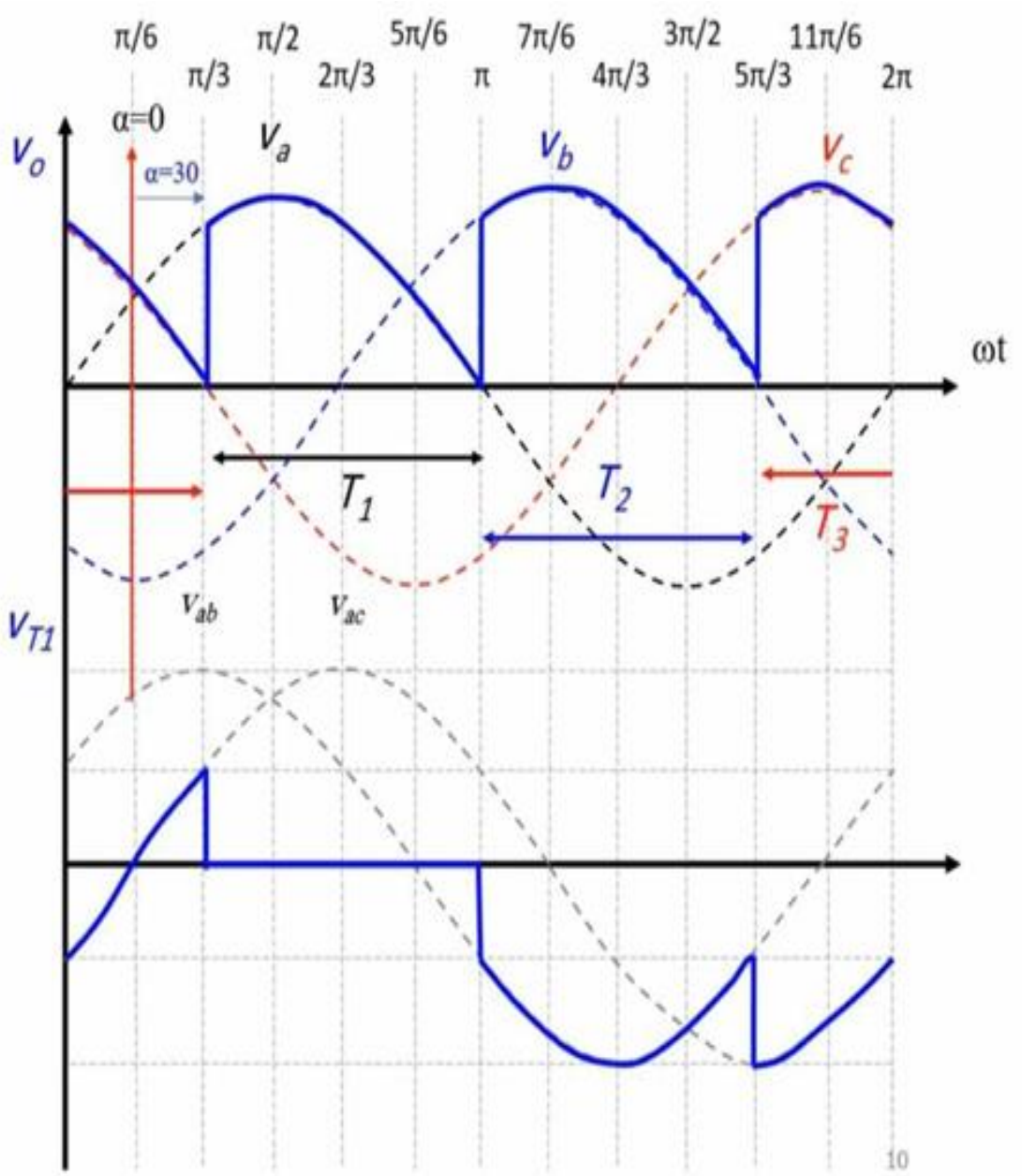
1- the controlled three - pulse Mid – point circuit M3C

2- the controlled six - pulse Bridge Circuit B6C

Three-phase Half-wave Controlled Rectifier

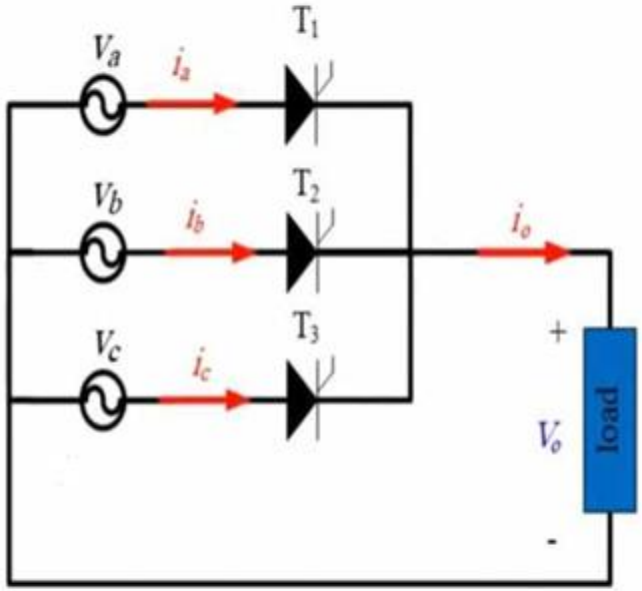
RL load

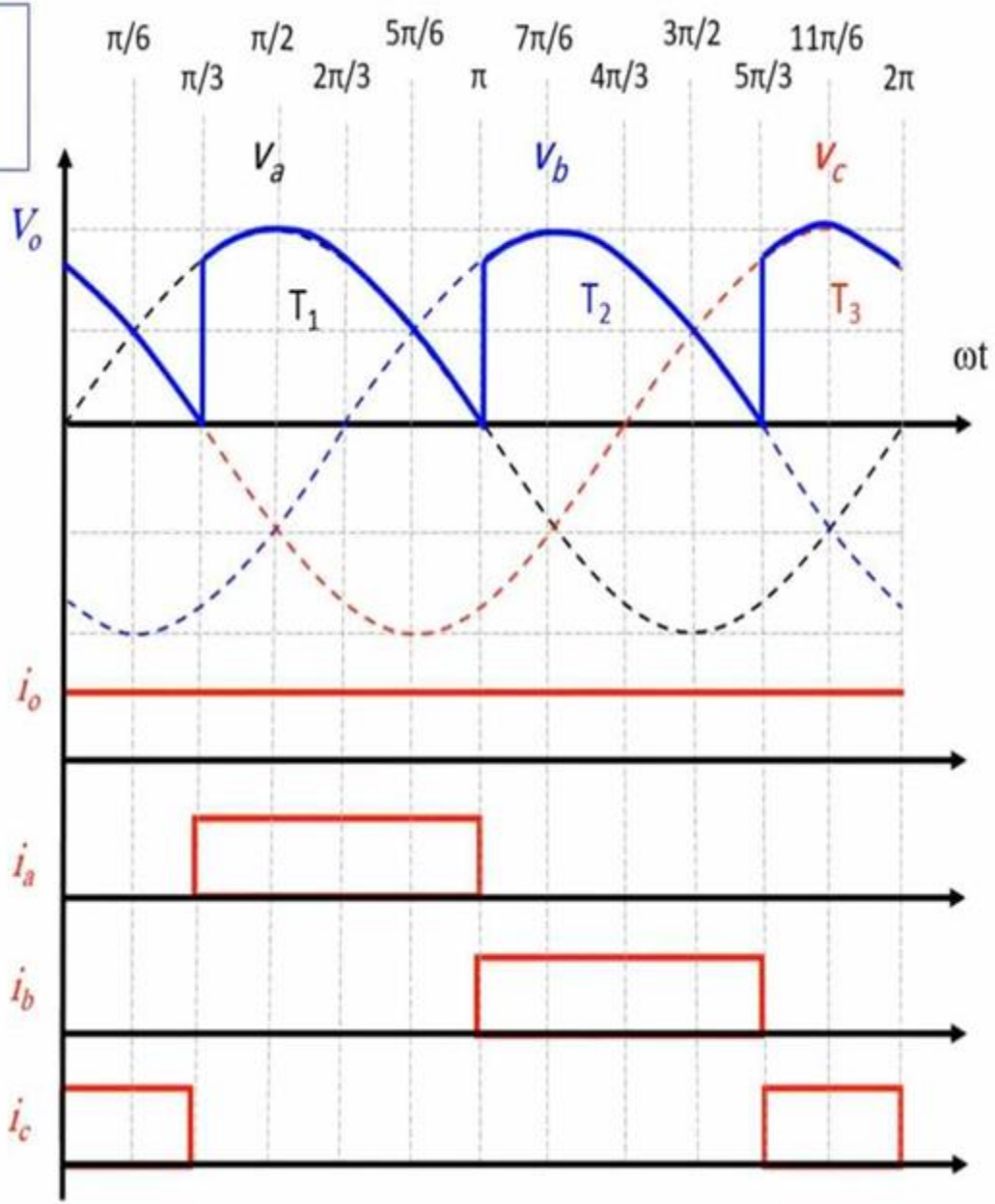




Three-phase Half-wave Controlled Rectifier

RL load

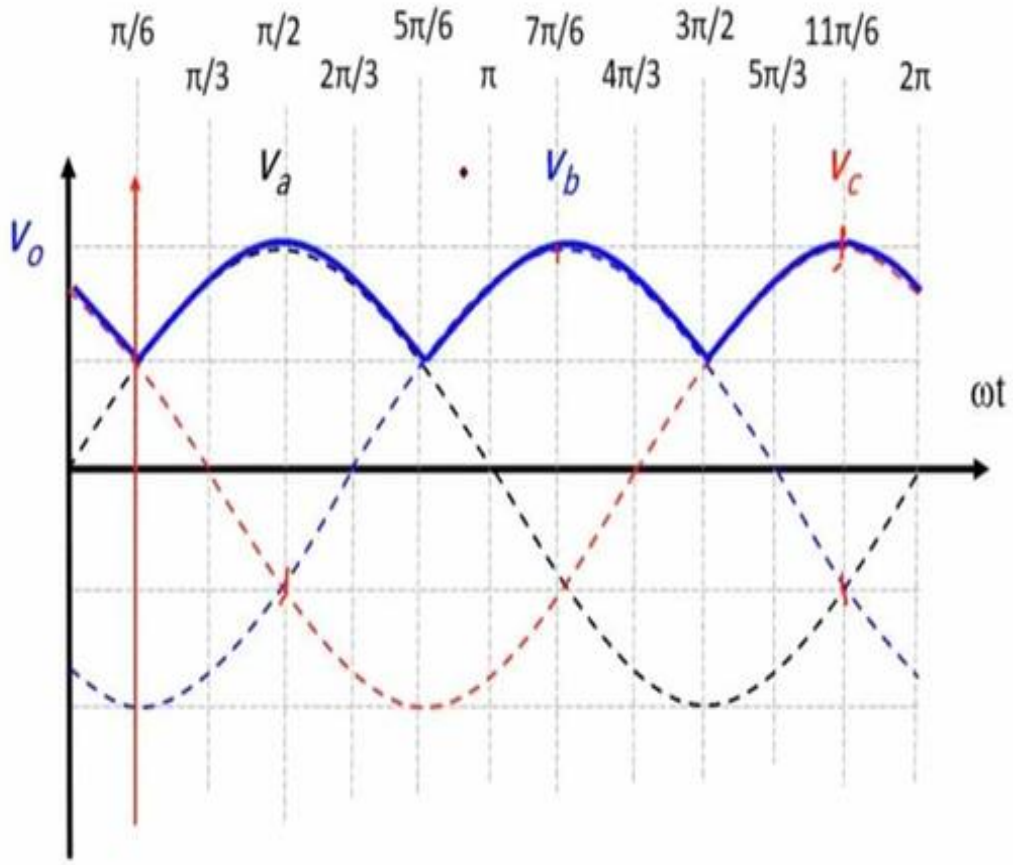




Output Voltage

α=0

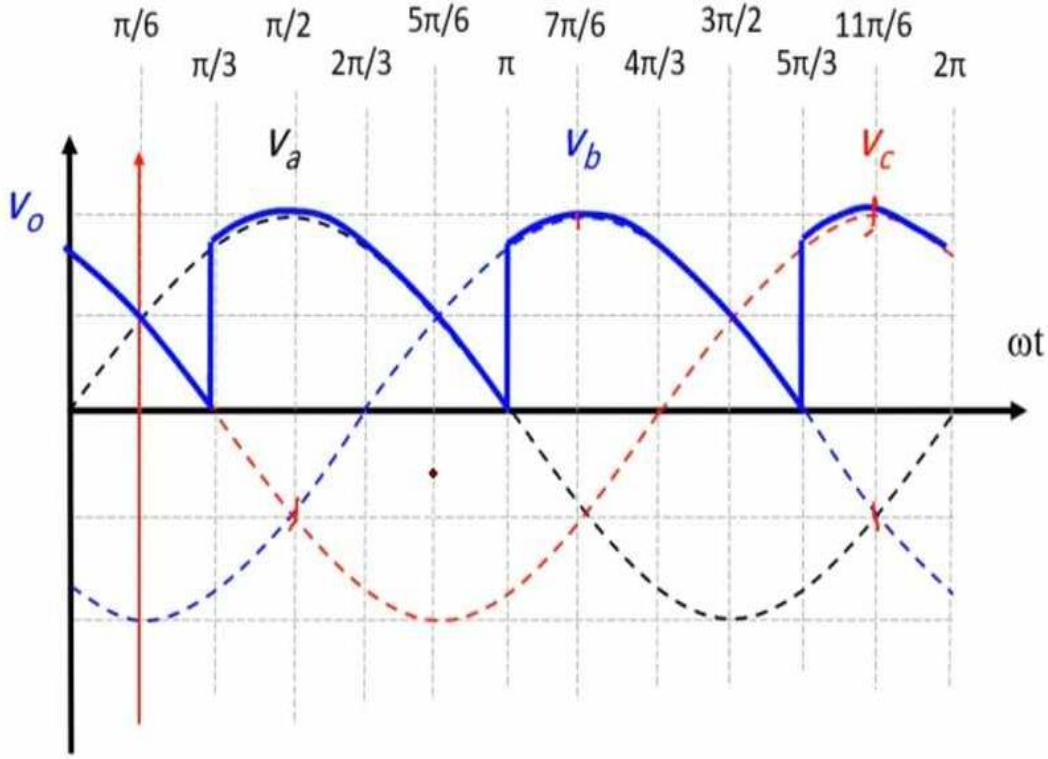
RL load



Output Voltage

α=30

RL load

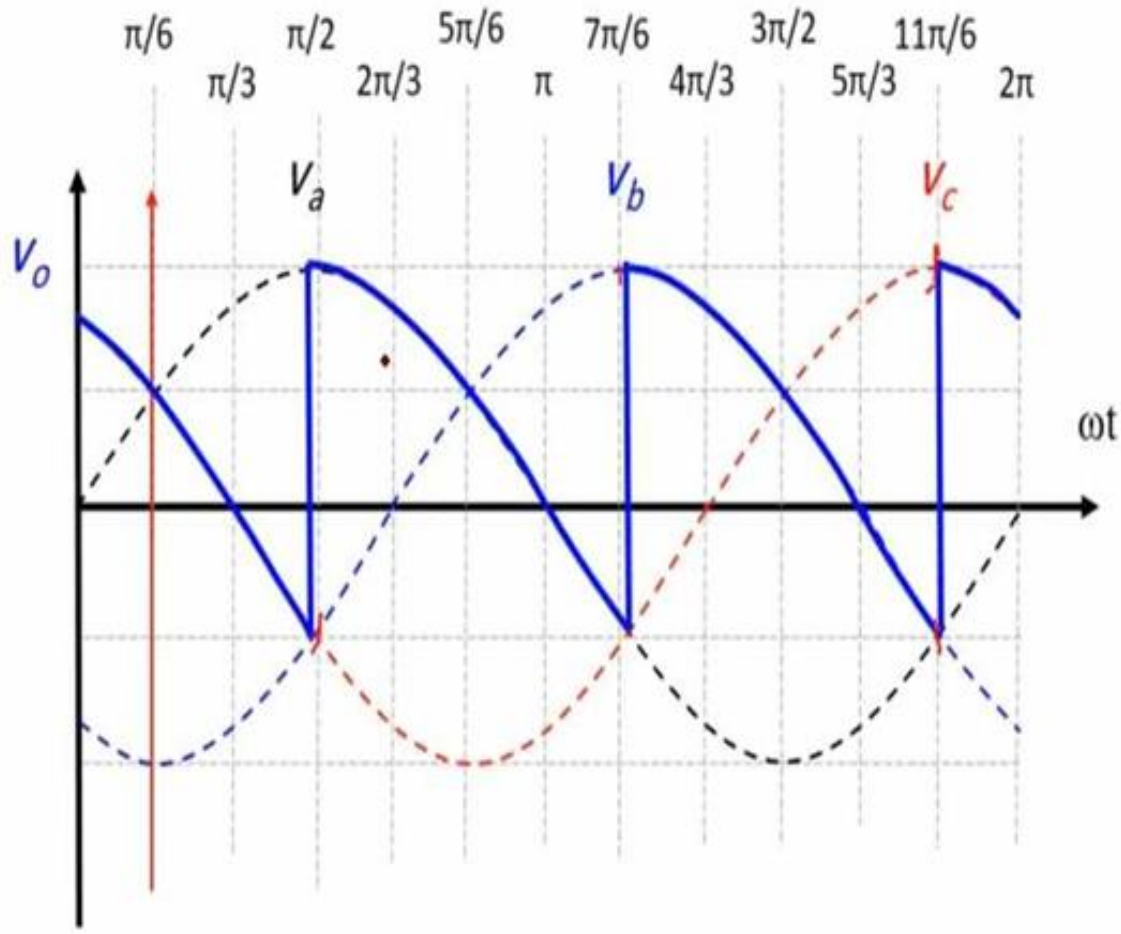


Output Voltage

α=60

RL load

$v_{o,avg} = +ve \quad \alpha < 90$



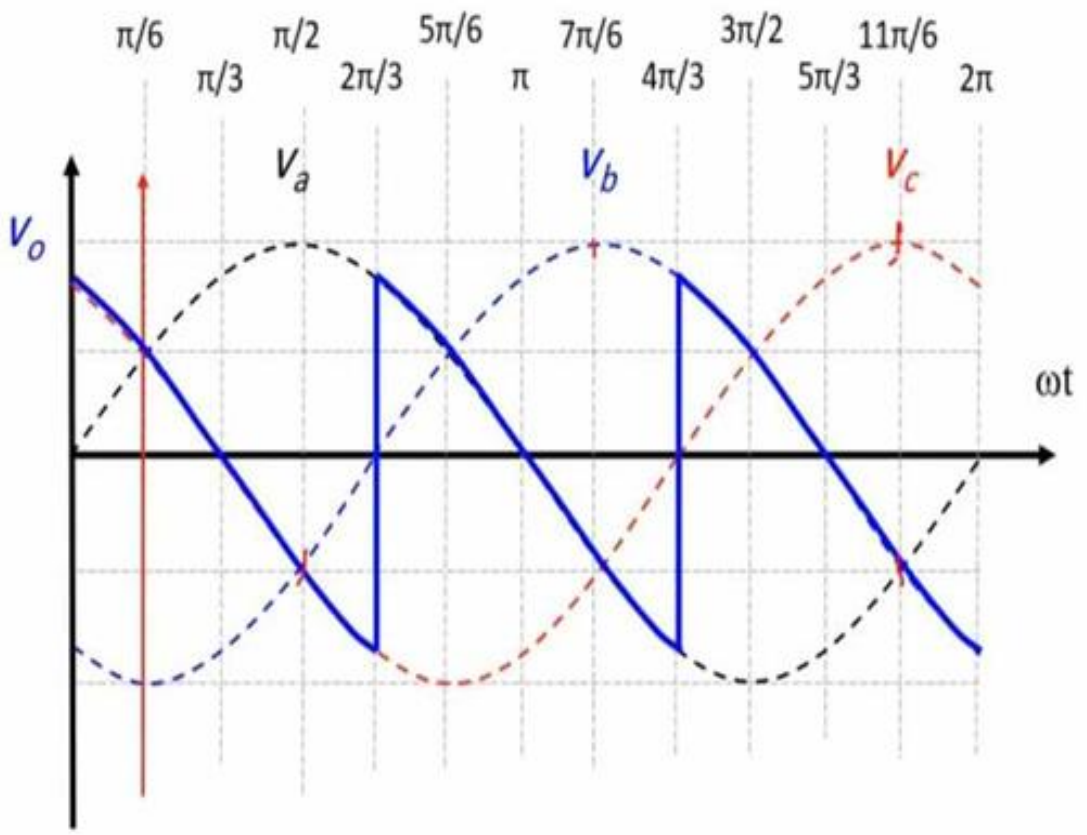
Output Voltage

α=90

RL load

$v_{o,avg} = +ve \quad \alpha < 90$

$v_{o,avg} = zero \quad \alpha = 90$



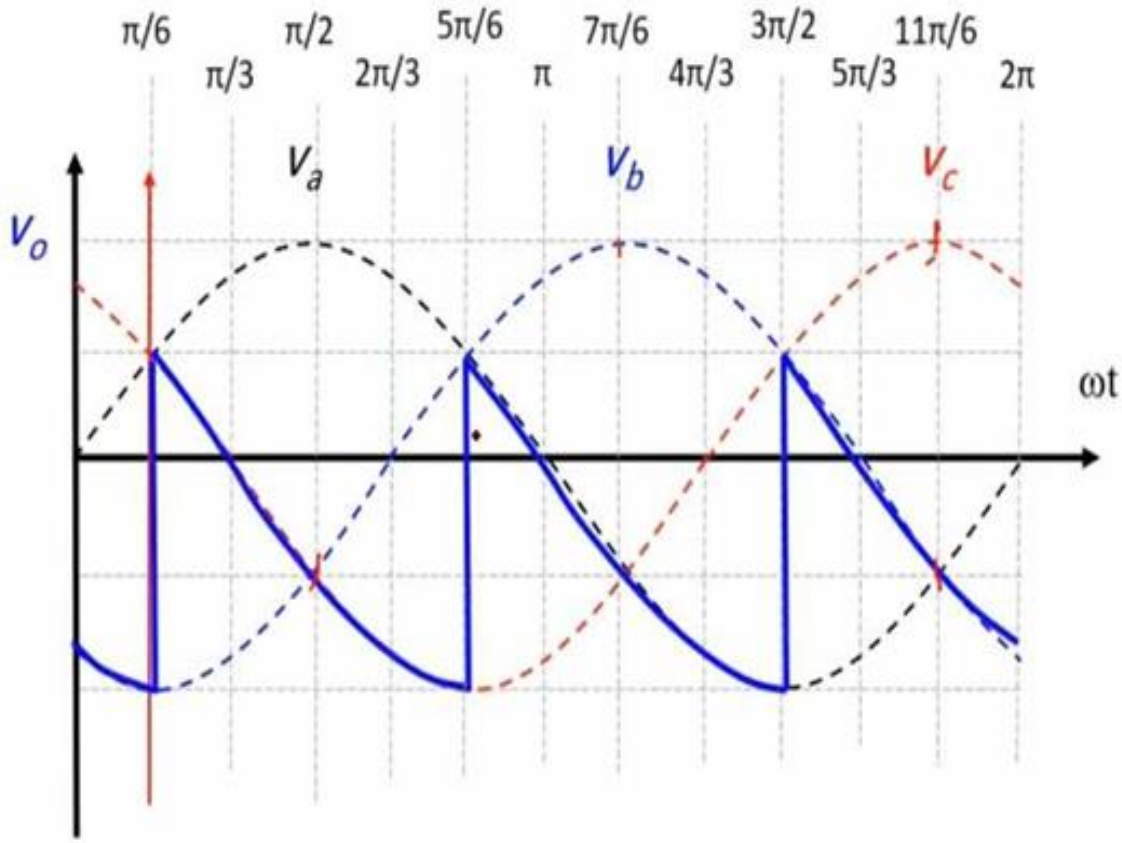
Output Voltage

α=120

RL load

$v_{o,avg} = +ve \quad \alpha < 90$

$v_{o,avg} = zero \quad \alpha = 90$



Output Voltage

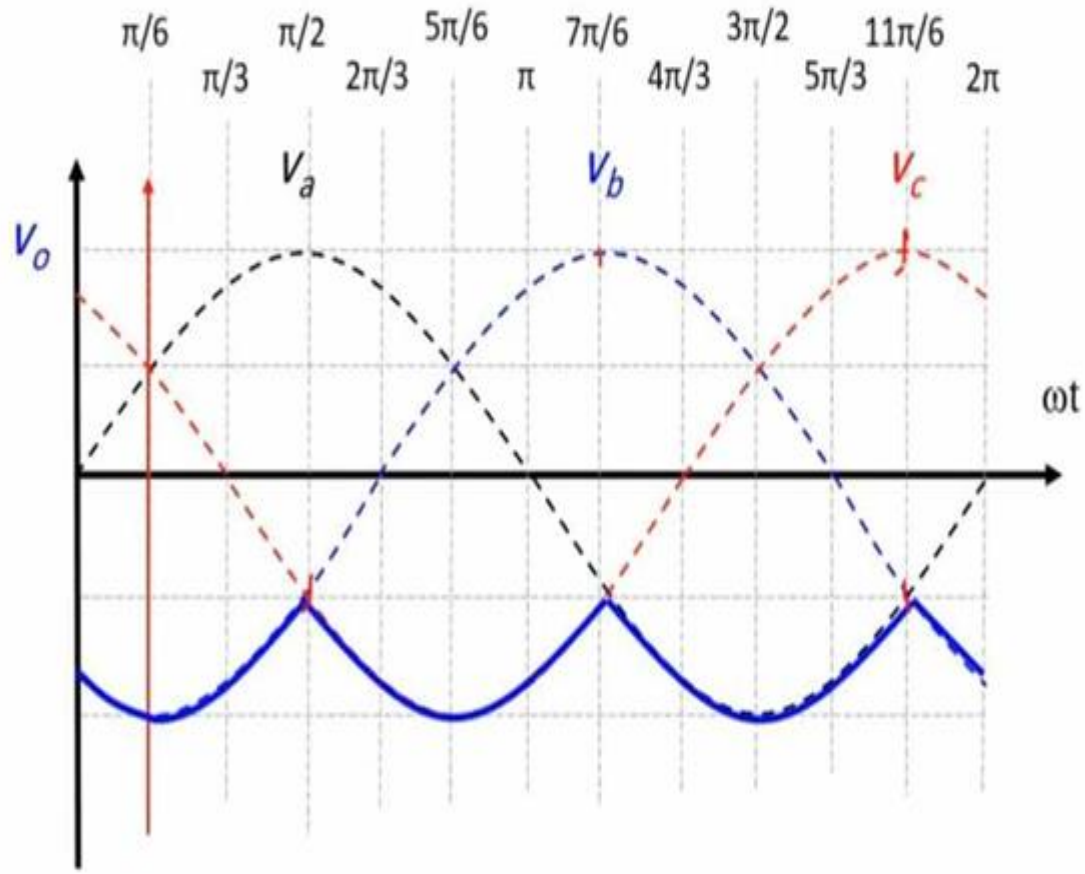
α=180

RL load

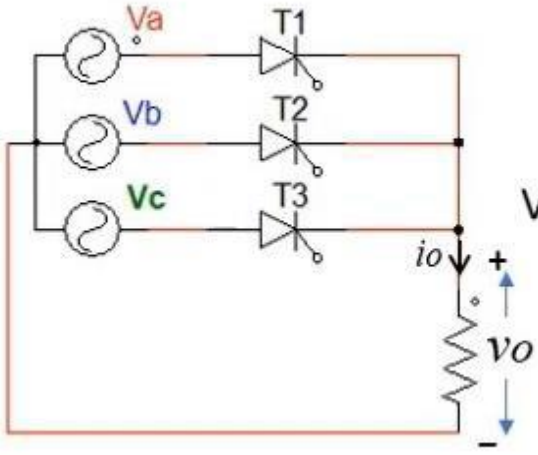
$v_{o,avg} = +ve \quad \alpha < 90$

$v_{o,avg} = zero \quad \alpha = 90$

$v_{o,avg} = -ve \quad \alpha > 90$



1. 3Φ half wave controlled rectifier, with R load $\alpha=30^\circ$

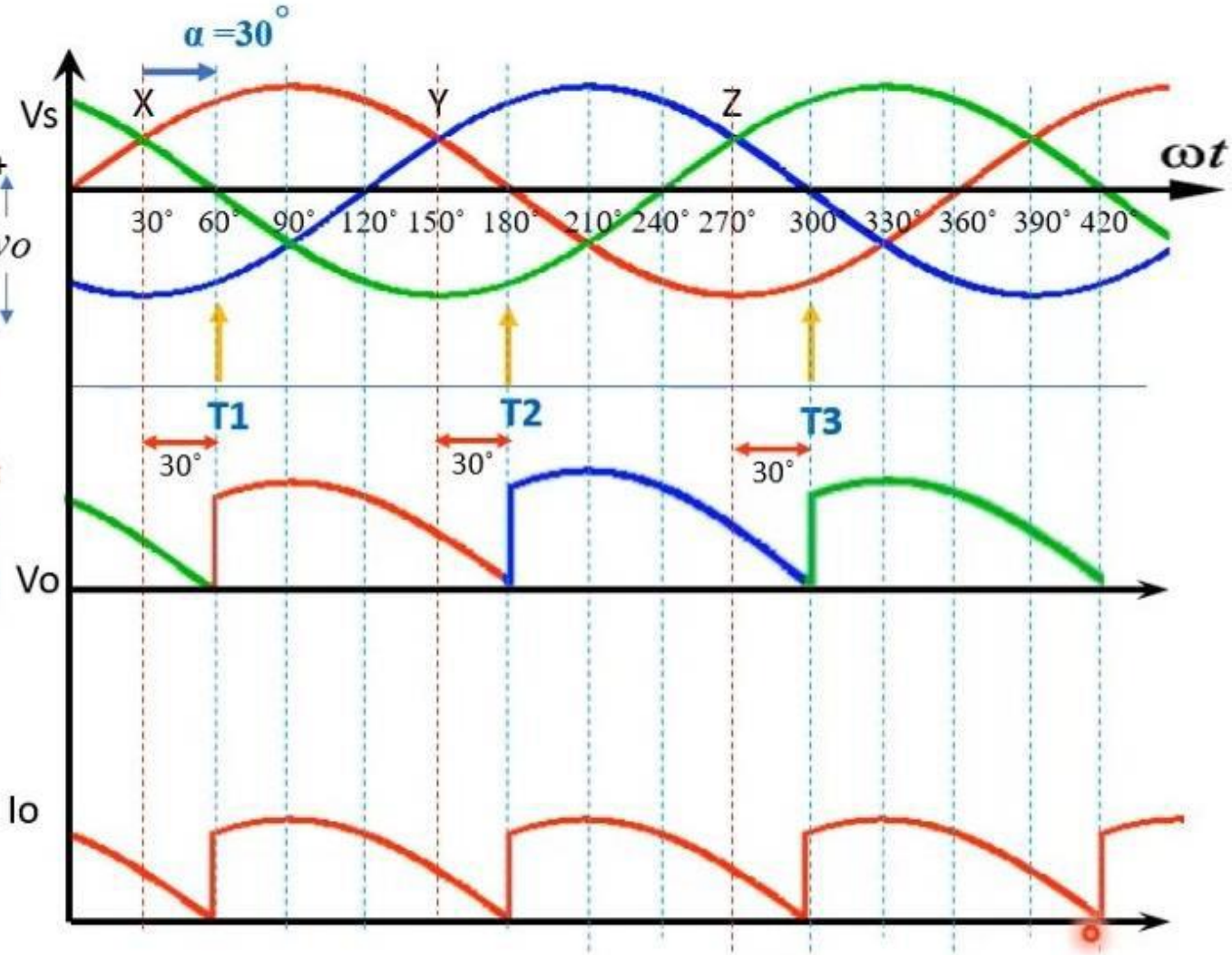


Triggering angle, α=30°

$\omega t = 60^\circ$ *to* 180° , T1 conduct

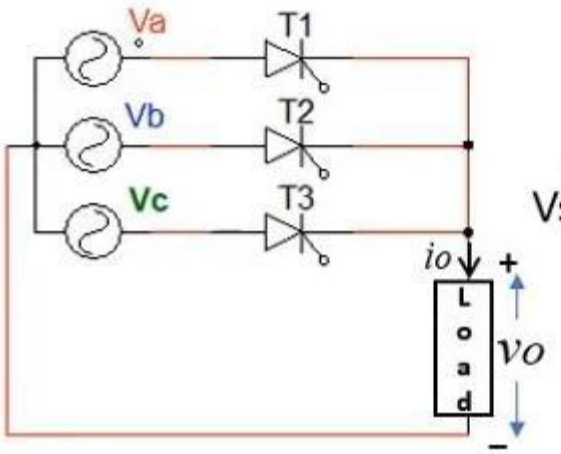
$\omega t = 180^\circ$ *to* 300° , T2 conduct

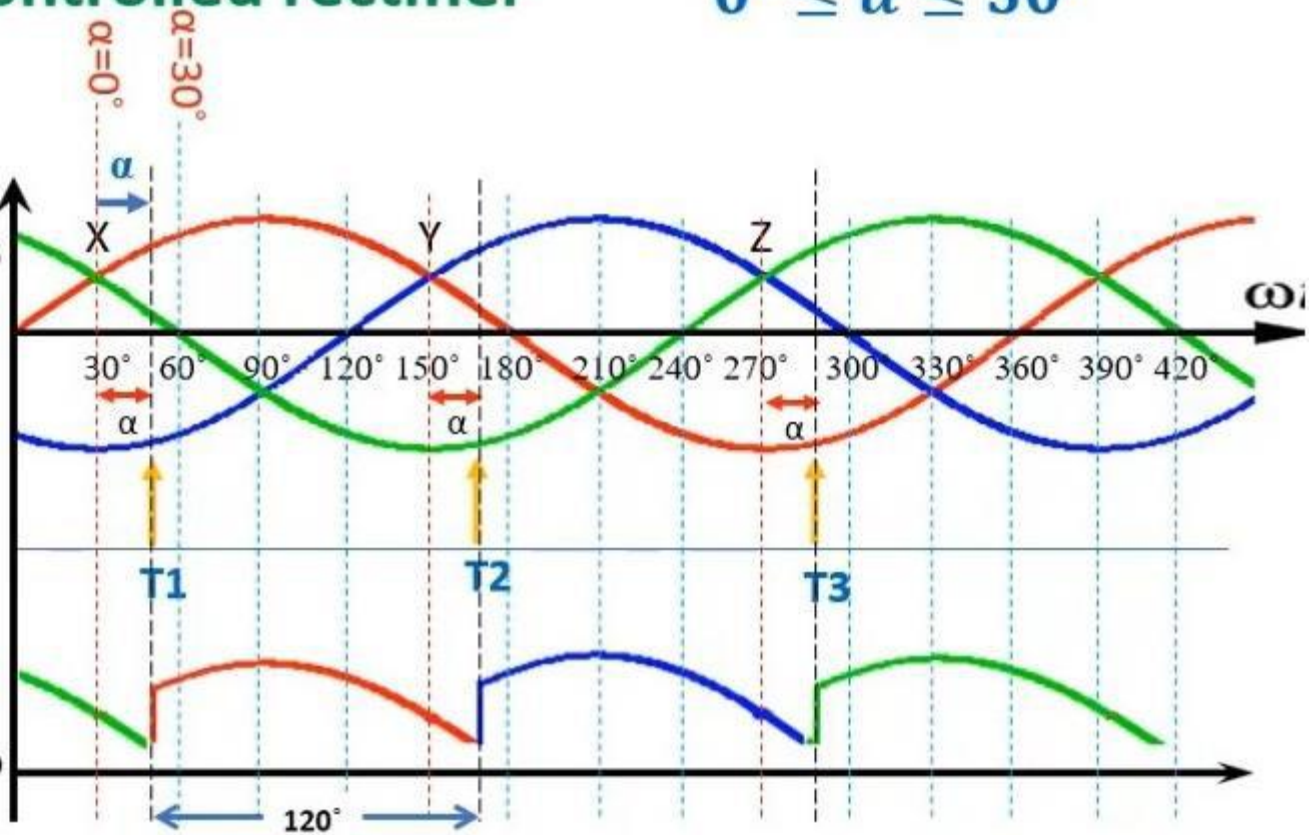
$\omega t = 300^\circ$ *to* 420° , T3 conduct



1. 3Φ half wave controlled rectifier

$0° \le \alpha \le 30°$





Triggering angle, $0 \le \alpha \le 30$

$\omega t = 30° + \alpha$ *to* $150° + \alpha$, T1 conduct

$\omega t = 150° + \alpha$ *to* $270° + \alpha$, T2 conduct

$\omega t = 270° + \alpha$ *to* $390° + \alpha$, T3 conduct

Average output voltage,

$$V_0 = \frac{1}{2\pi/3}\int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} V_m \sin\omega t \, d(\omega t) = \frac{3\sqrt{3}}{2\pi} V_m \cos\alpha,$$ where, $Vm \rightarrow$ maximum phase voltage

$$= \frac{3\sqrt{2}}{2\pi} V \cos\alpha,$$ where, $V \rightarrow$ rms line voltage

RMS o/p voltage, $V_{or} = \left[\frac{1}{2\pi/3}\int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} {V_m}^2 \sin^2\omega t \, d(\omega t)\right]^{1/2} = V_m\left[\frac{3}{2\pi}\left(\frac{\pi}{3} + \frac{\sqrt{3}}{3}\cos 2\alpha\right)\right]^{1/2}$

Output voltage and output current

RL load

The average output voltage

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin(\omega t)\, d\omega t = \frac{3\sqrt{3}V_m}{2\pi}\cos(\alpha)$$

The average output current

$$I_{o,avg} = \frac{V_{o,avg}}{R} = \frac{3\sqrt{3}V_m}{2\pi R}\cos(\alpha) = I_{o,rms}$$

The rms output voltage

$$v_{o,rms} = \sqrt{\frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} \left(V_m \sin(\omega t)\right)^2 d\omega t} = \sqrt{3}V_m\sqrt{\frac{1}{6}+\frac{\sqrt{3}}{8\pi}\cos(2\alpha)}$$

Supply and Thyristor Current

RL load

The average supply/Thyristor current

$$I_{s,avg} = I_{T,avg} = \frac{I_{o,avg}}{3}$$

The rms supply/ Thyristor current

$$I_{s,rms} = I_{T,rms} = \frac{I_{o,rms}}{\sqrt{3}}$$

Output power and Power factor

The output power

$$P_o = I_{o,rms}^2 R$$

The apparent power

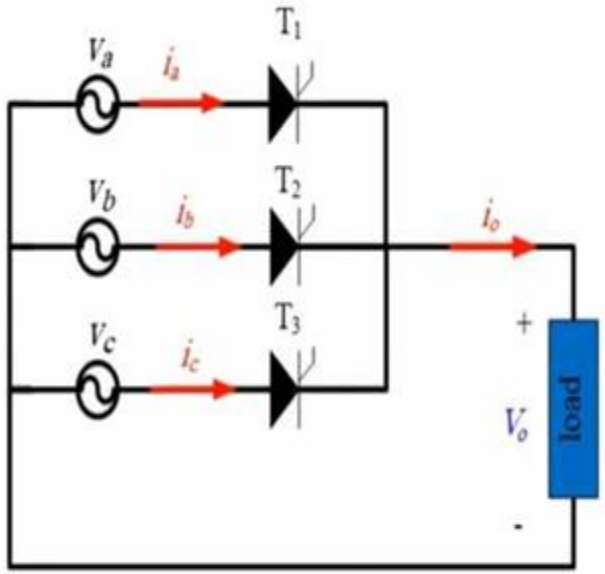
$$S = 3V_{s,rms(phase)} I_{s,rms}$$

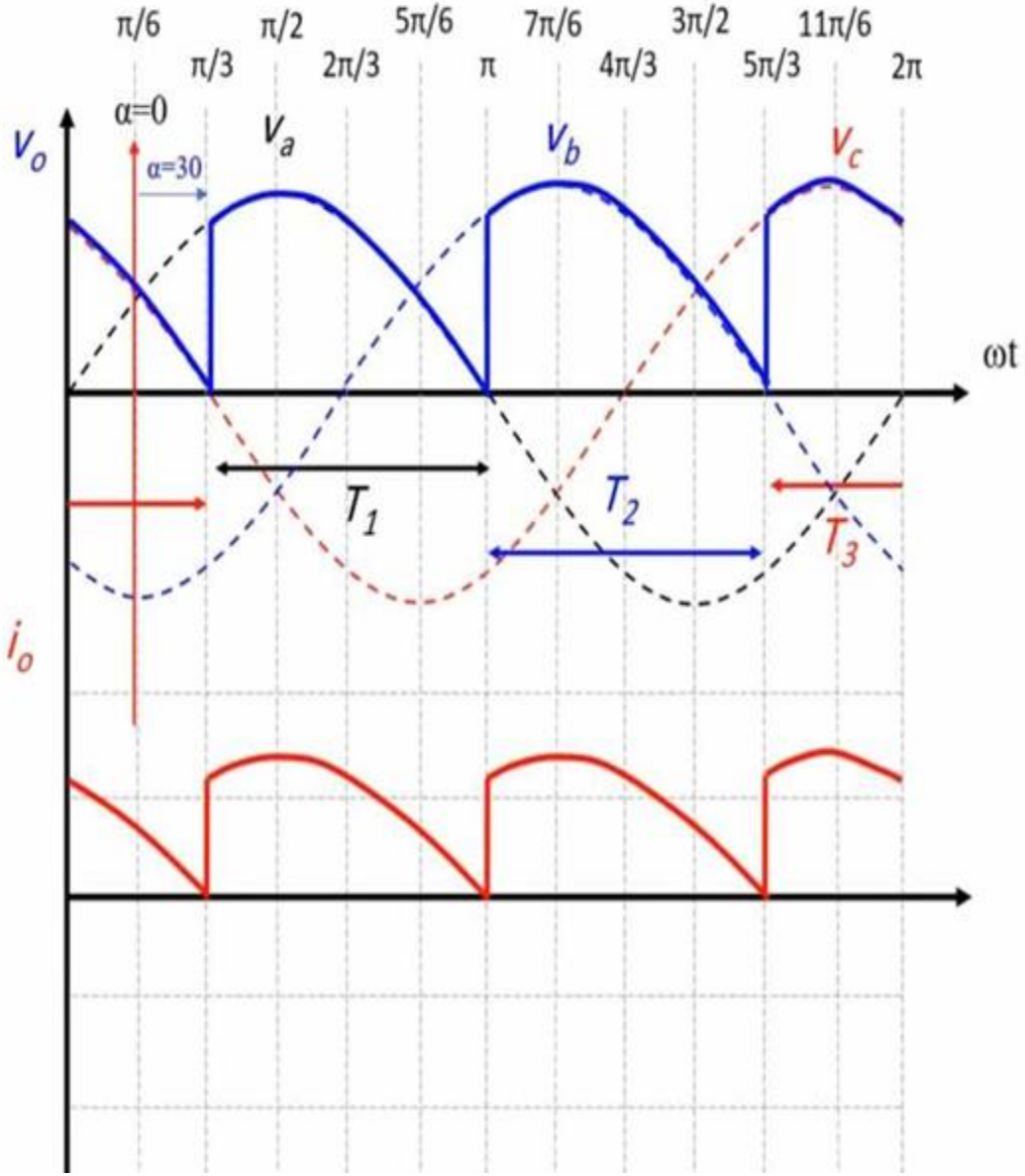
The supply power factor

$$pf = \frac{P_o}{S}$$

Three-phase Half-wave Controlled Rectifier

R load





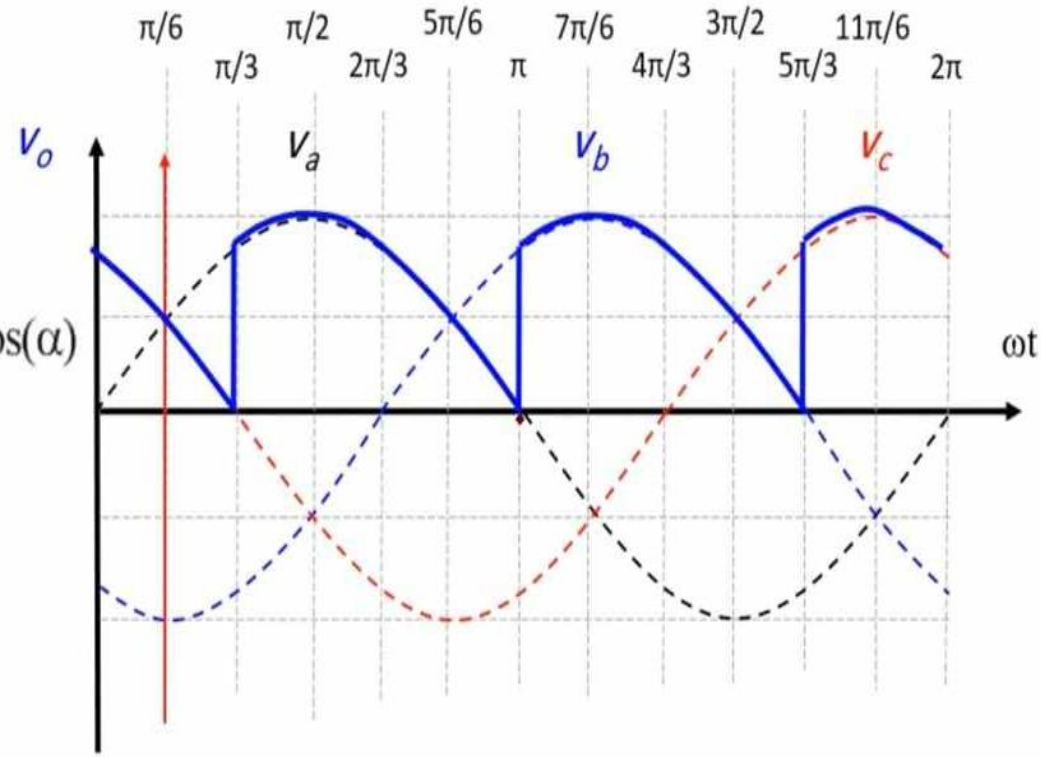
Output Voltage

α=30

R load

$$\alpha \le 30$$

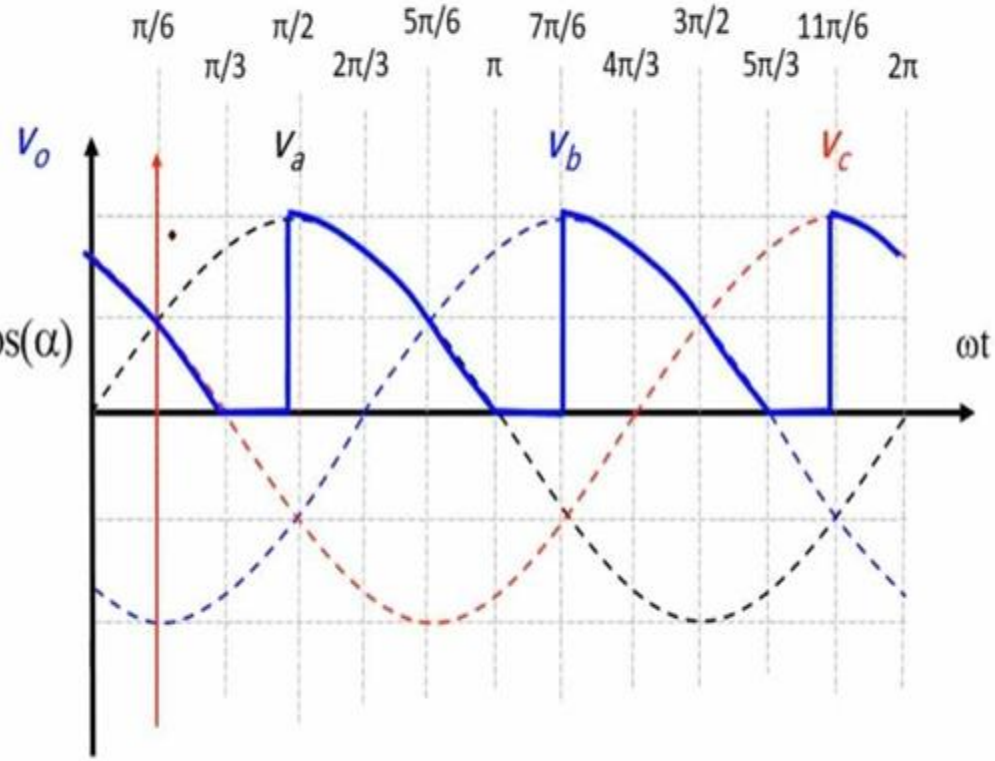
$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin(\omega t)\, d\omega t = \frac{3\sqrt{3}V_m}{2\pi}\cos(\alpha)$$



Output Voltage

α=60

R load



$\alpha \leq 30$

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin(\omega t)\, d\omega t = \frac{3\sqrt{3}V_m}{2\pi}\cos(\alpha)$$

$\alpha > 30$

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m \sin(\omega t)\, d\omega t = \frac{3V_m}{2\pi}\left[1+\cos(\alpha+30)\right]$$

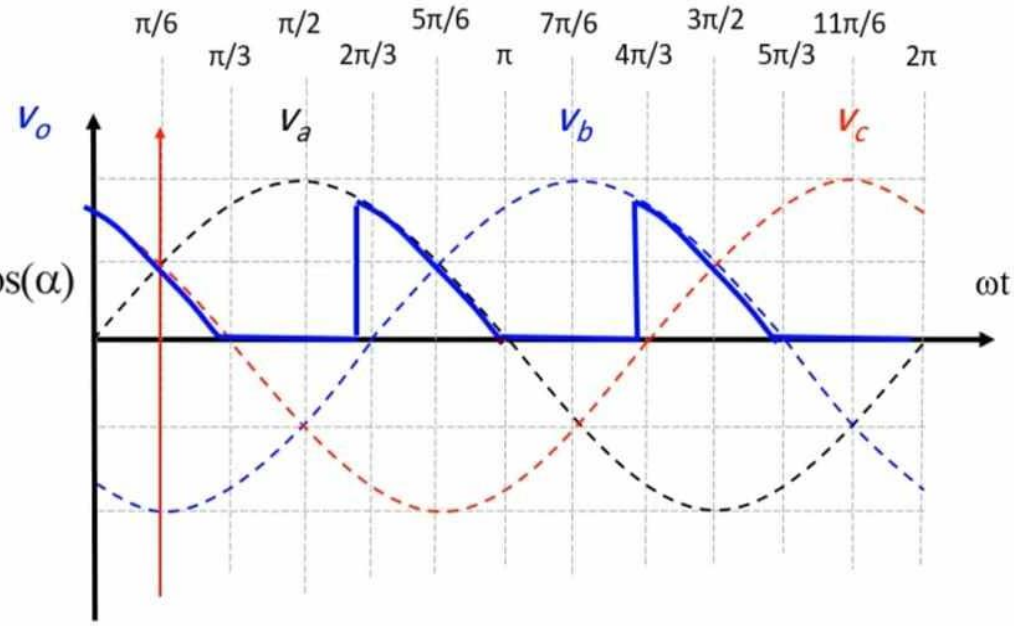
Output Voltage

α=90

R load

$\alpha \le 30$

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin(\omega t)\, d\omega t = \frac{3\sqrt{3}V_m}{2\pi}\cos(\alpha)$$



$\alpha > 30$

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m \sin(\omega t)\, d\omega t = \frac{3V_m}{2\pi}\left[1+\cos(\alpha+30)\right]$$

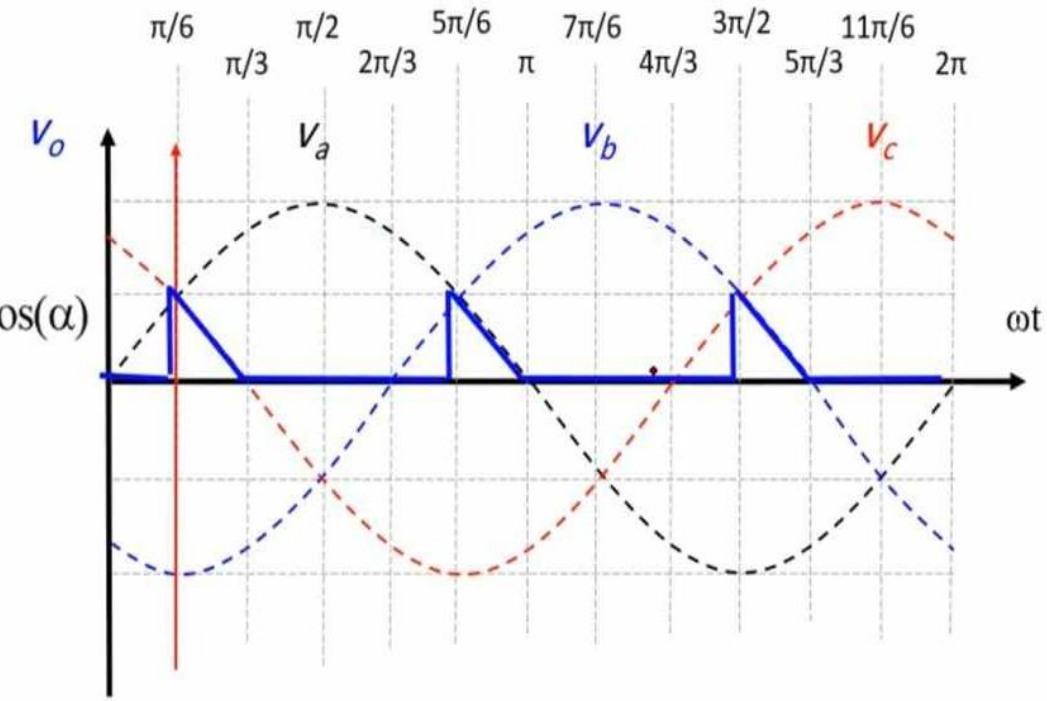
Output Voltage

α=120

R load

$\alpha \le 30$

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin(\omega t)\, d\omega t = \frac{3\sqrt{3}V_m}{2\pi}\cos(\alpha)$$



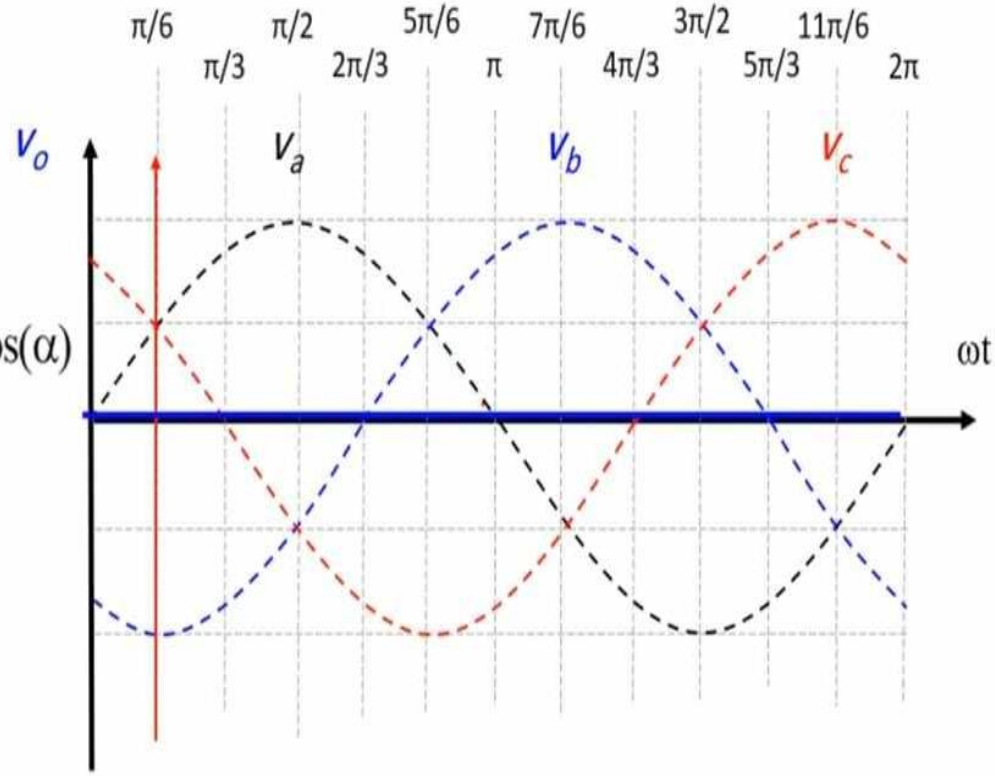
$\alpha > 30$

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m \sin(\omega t)\, d\omega t = \frac{3V_m}{2\pi}\left[1+\cos(\alpha+30)\right]$$

Output Voltage

α=150

R load



$\alpha \le 30$

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha} V_m \sin(\omega t)\, d\omega t = \frac{3\sqrt{3}V_m}{2\pi}\cos(\alpha)$$

$\alpha > 30$

$$v_{o,avg} = \frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi} V_m \sin(\omega t)\, d\omega t = \frac{3V_m}{2\pi}\left[1+\cos(\alpha+30)\right]$$

$0 \le \alpha \le 150$

Output voltage and output current

R load

The average output current

$$I_{o,avg} = \frac{V_{o,avg}}{R}$$

The rms output current

$$I_{o,rms} = \frac{V_{o,rms}}{R}$$

The rms output voltage

$$v_{o,rms} = \sqrt{\frac{3}{2\pi}\int_{\pi/6+\alpha}^{5\pi/6+\alpha}\left(V_m \sin(\omega t)\right)^2 d\omega t} = \sqrt{3}V_m\sqrt{\frac{1}{6}+\frac{\sqrt{3}}{8\pi}\cos(2\alpha)} \quad \alpha \le 30$$

$$v_{o,rms} = \sqrt{\frac{3}{2\pi}\int_{\pi/6+\alpha}^{\pi}\left(V_m \sin(\omega t)\right)^2 d\omega t} \quad \alpha > 30$$

Supply and Thyristor Current

R load

The average supply/ Thyristor current

$$I_{s,avg} = I_{T,avg} = \frac{I_{o,avg}}{3}$$

The rms supply/ Thyristor current

$$I_{s,rms} = I_{T,rms} = \frac{I_{o,rms}}{\sqrt{3}}$$

Output power and Power factor

The output power

$$P_o = I_{o,rms}{}^2 R$$

The apparent power

$$S = 3V_{s,rms(phase)} I_{s,rms}$$

The supply power factor

$$pf = \frac{P_o}{S}$$