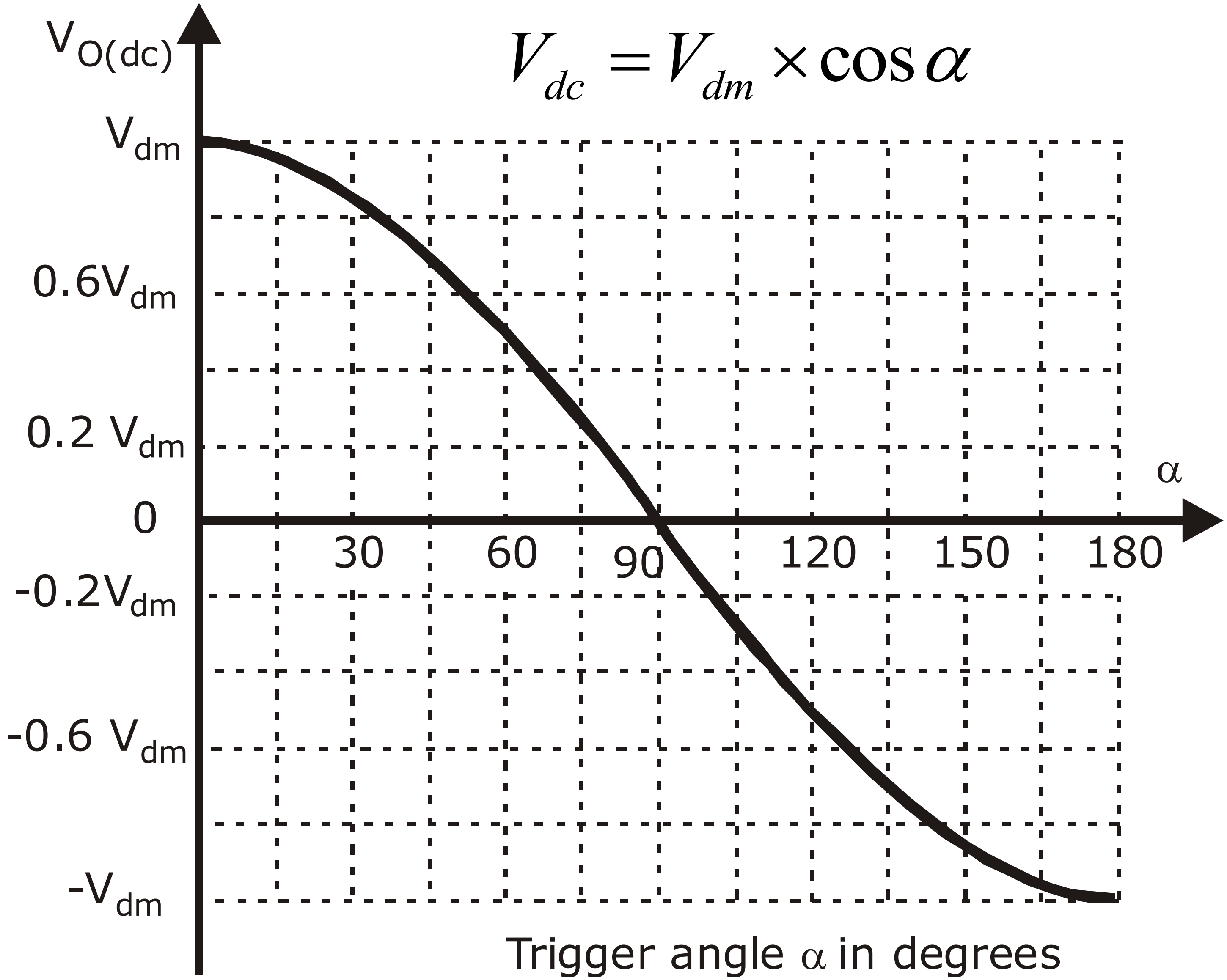


$V_{O(dc)}$
$V_{dc} = V_{dm} \times \cos\alpha$
V_{dm}
$0.6V_{dm}$
$0.2\ V_{dm}$
0
$-0.2V_{dm}$
$-0.6\ V_{dm}$
$-V_{dm}$
30
60
90
120
150
180
α
Trigger angle α in degrees

- During the period from $\omega t = \alpha$ to π the input voltage v_S and the input current i_S are both positive and the power flows from the supply to the load.
- The converter is said to be operated in the rectification mode

Controlled Rectifier Operation

for $0 < \alpha < 90^0$

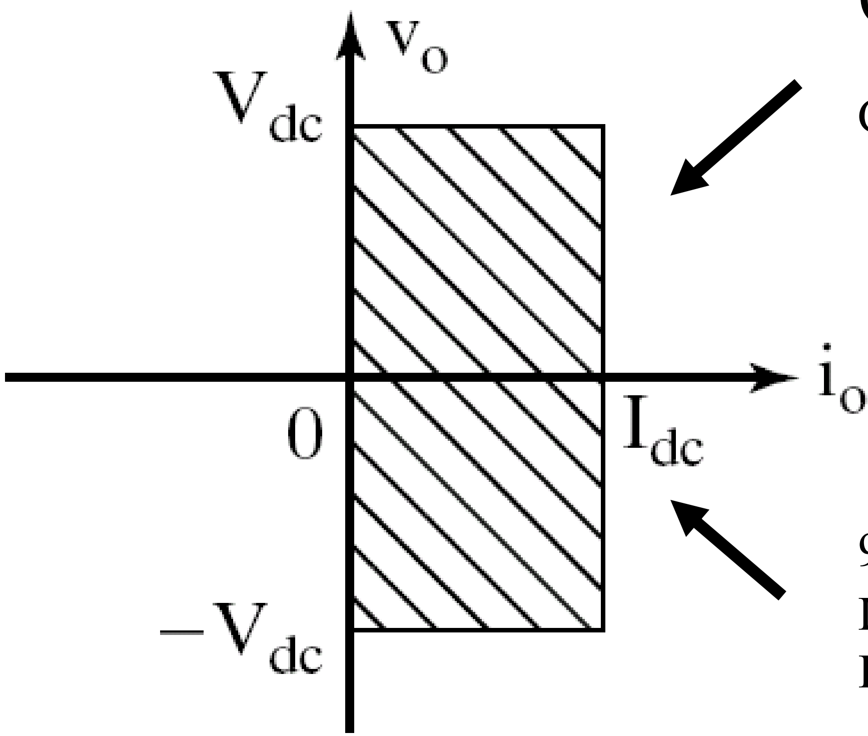
During the period from $\omega t = \pi$ to $(\pi+\alpha)$, the input voltage v_S is negative and the input current i_S is positive and the output power becomes negative and there will be reverse power flow from the load circuit to the supply.

The converter is said to be operated in the inversion mode.

Line Commutated Inverter Operation

for $90^0 < \alpha < 180^0$

Two Quadrant Operation of a Single Phase Full Converter



$0 < \alpha < 90^0$

Controlled Rectifier Operation

$90^0 < \alpha < 180^0$

Line Commutated Inverter Operation

To Derive An Expression For The RMS Value Of The Output Voltage

The rms value of the output voltage is calculated as

$$V_{O(RMS)} = \sqrt{\frac{1}{2\pi}\left[\int_{0}^{2\pi} v_O^2 . d(\omega t)\right]}$$

The single phase full converter gives two output voltage pulses during the input supply time period and hence the single phase full converter is referred to as a two pulse converter. The rms output voltage can be calculated as

$$V_{O(RMS)} = \sqrt{\frac{2}{2\pi}\left[\int_{\alpha}^{\pi+\alpha} v_O^2 .d(\omega t)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{1}{\pi}\left[\int_{\alpha}^{\pi+\alpha} V_m^2 \sin^2 \omega t.d\left(\omega t\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^2}{\pi}\left[\int_{\alpha}^{\pi+\alpha} \sin^2 \omega t.d\left(\omega t\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^2}{\pi}\left[\int_{\alpha}^{\pi+\alpha} \frac{\left(1-\cos 2\omega t\right)}{2}.d\left(\omega t\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^2}{2\pi}\left[\int_{\alpha}^{\pi+\alpha} d\left(\omega t\right) - \int_{\alpha}^{\pi+\alpha} \cos 2\omega t.d\left(\omega t\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^2}{2\pi}\left[\left(\omega t\right)\Big/_{\alpha}^{\pi+\alpha} - \left(\frac{\sin 2\omega t}{2}\right)\Big/_{\alpha}^{\pi+\alpha}\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^2}{2\pi}\left[\left(\pi+\alpha-\alpha\right) - \left(\frac{\sin 2\left(\pi+\alpha\right) - \sin 2\alpha}{2}\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^2}{2\pi}\left[\left(\pi\right) - \left(\frac{\sin\left(2\pi+2\alpha\right) - \sin 2\alpha}{2}\right)\right]};$$

$$\sin\left(2\pi+2\alpha\right) = \sin 2\alpha$$

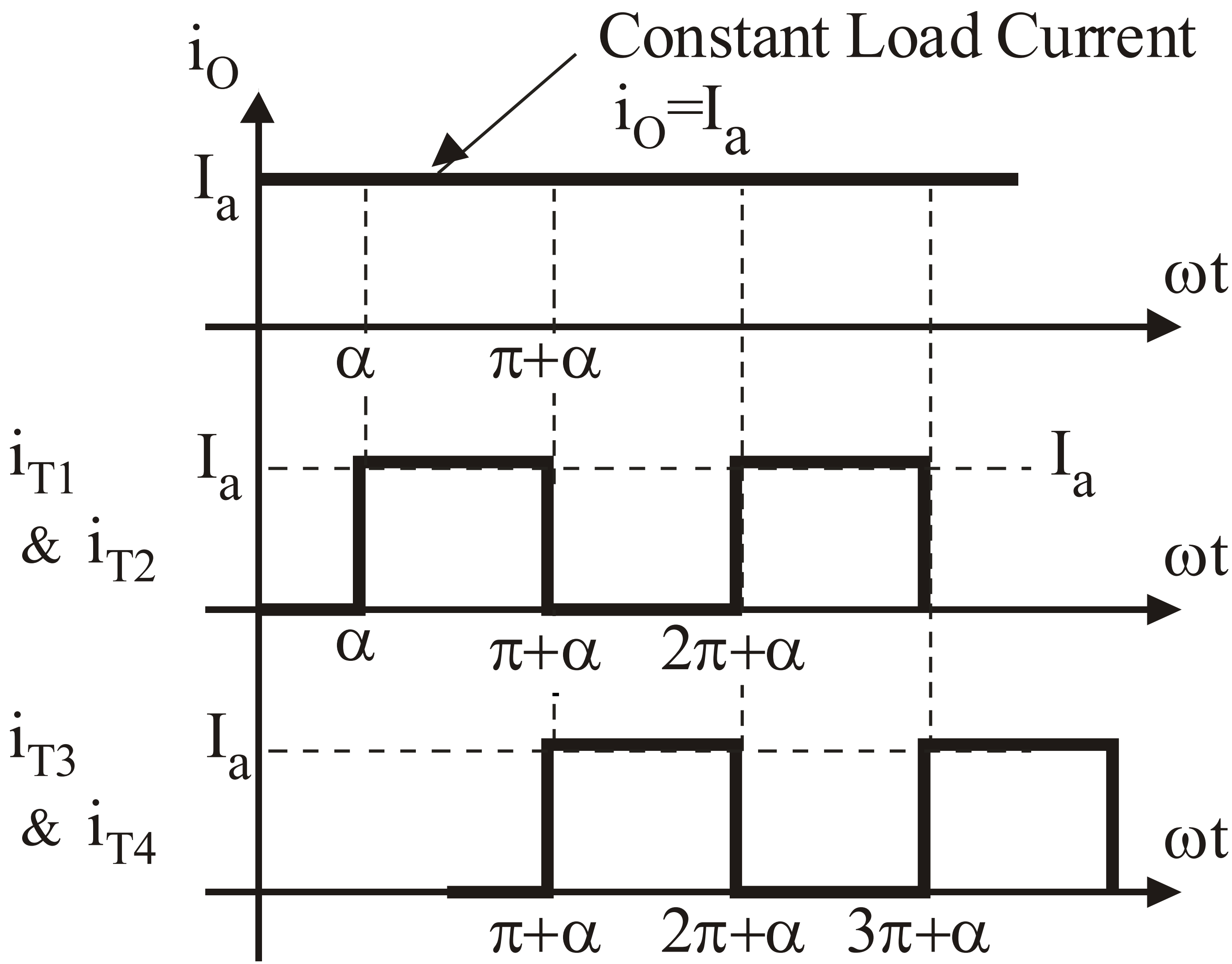
$$V_{O(RMS)} = \sqrt{\frac{V_m^2}{2\pi}\left[(\pi) - \left(\frac{\sin 2\alpha - \sin 2\alpha}{2}\right)\right]}$$

$$V_{O(RMS)} = \sqrt{\frac{V_m^2}{2\pi}(\pi) - 0} = \sqrt{\frac{V_m^2}{2}} = \frac{V_m}{\sqrt{2}}$$

$$\therefore V_{O(RMS)} = \frac{V_m}{\sqrt{2}} = V_S$$

Hence the rms output voltage is same as the rms input supply voltage

Thyristor Current Waveforms



Constant Load Current
$i_O = I_a$
i_O
I_a
ωt
α
$\pi+\alpha$
i_{T1} & i_{T2}
I_a
I_a
ωt
α
$\pi+\alpha$
$2\pi+\alpha$
i_{T3} & i_{T4}
I_a
ωt
$\pi+\alpha$
$2\pi+\alpha$
$3\pi+\alpha$

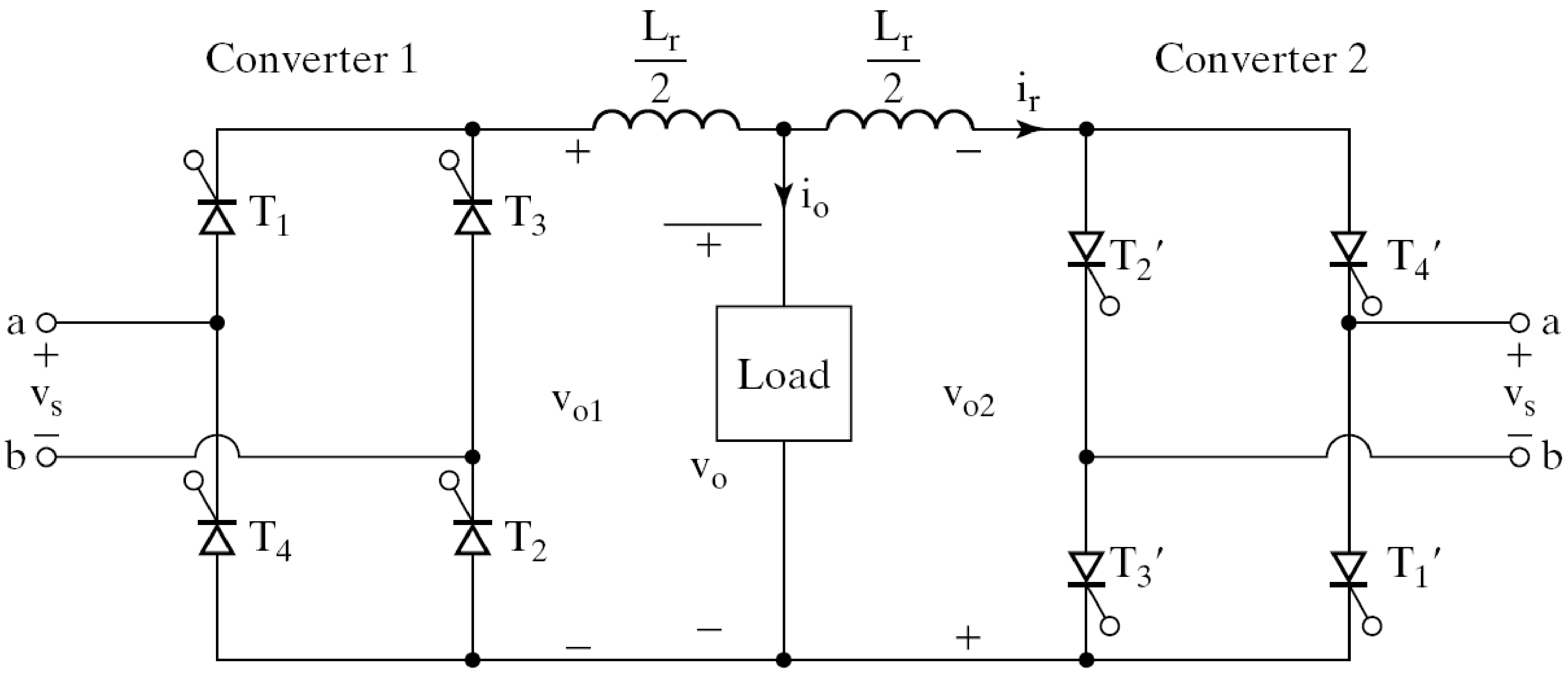
The rms thyristor current can be calculated as

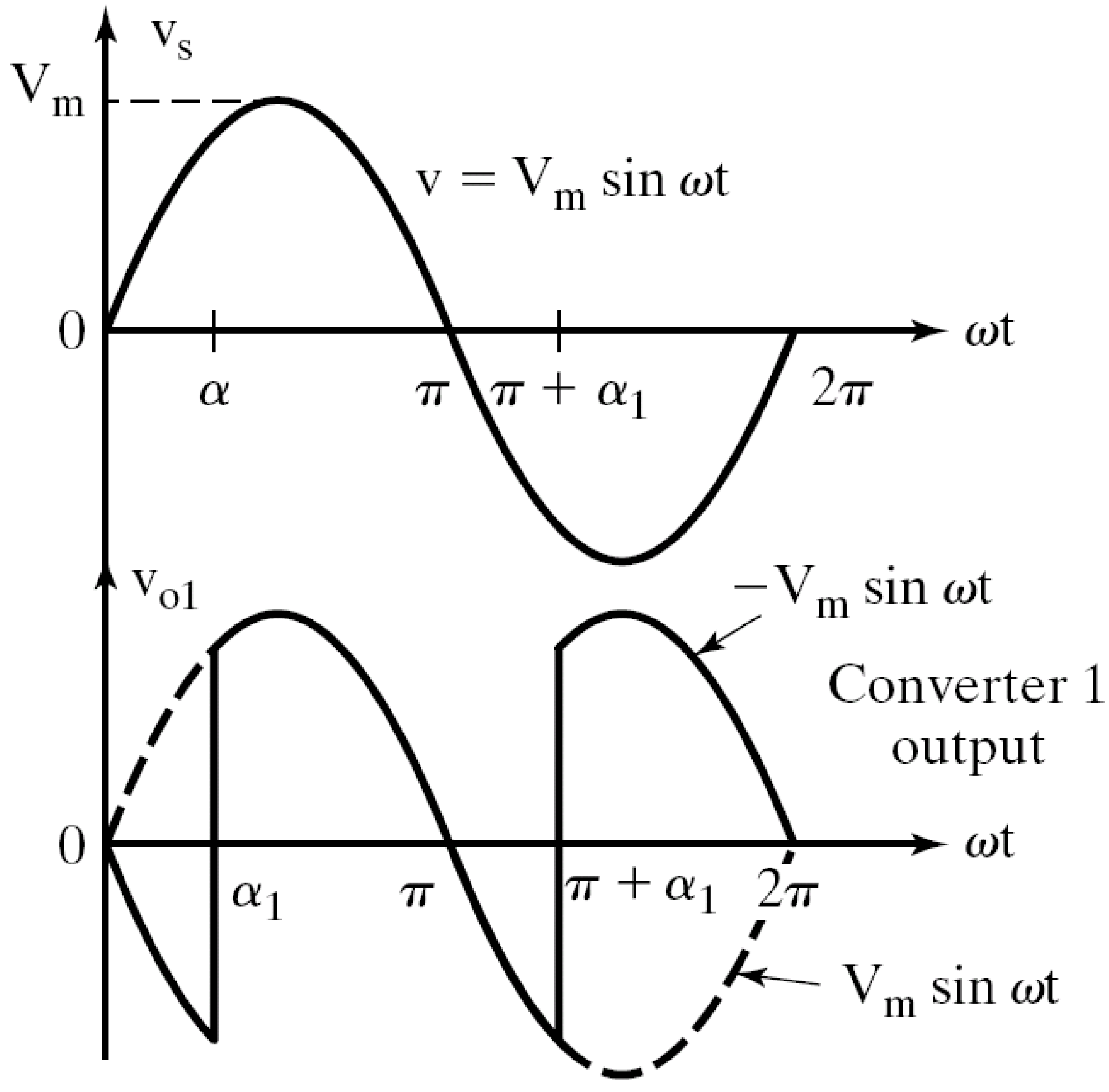
$$I_{T(RMS)} = \frac{I_{O(RMS)}}{\sqrt{2}}$$

The average thyristor current can be calculated as

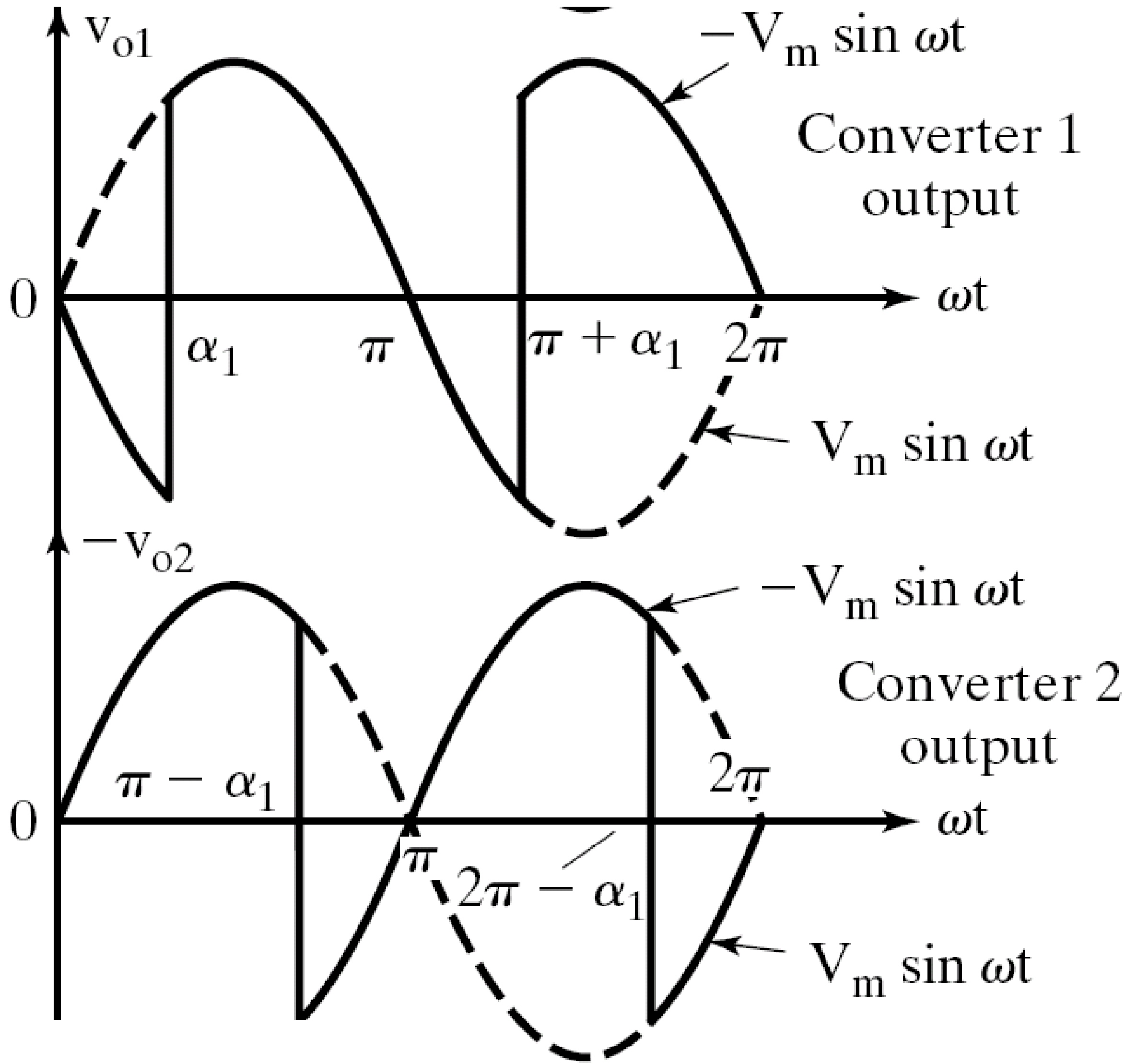
$$I_{T(Avg)} = \frac{I_{O(dc)}}{2}$$

Single Phase Dual Converter

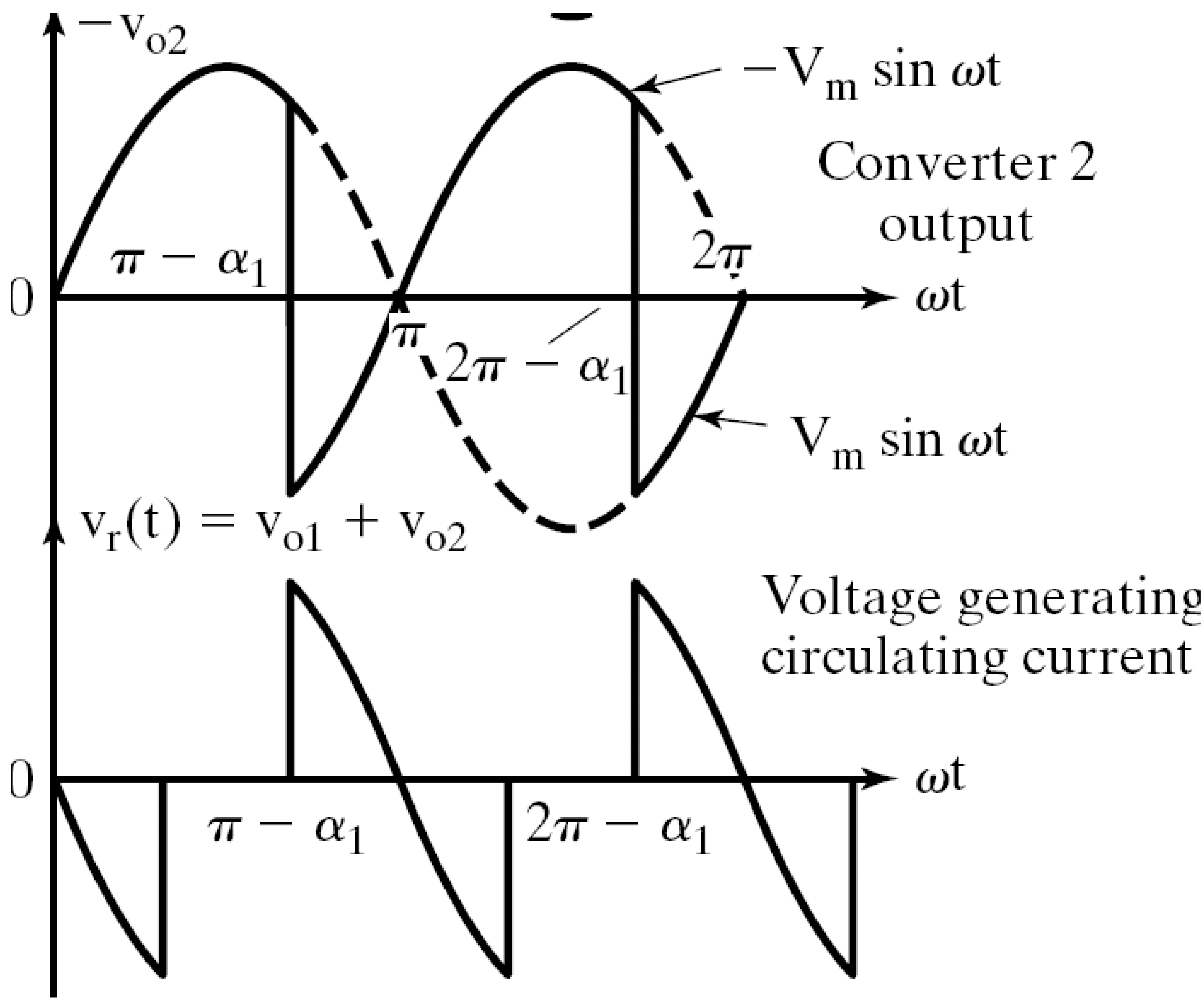




v_s
V_m
$v = V_m \sin \omega t$
0
ωt
α
π
$\pi + \alpha_1$
2π
v_{o1}
$-V_m \sin \omega t$
Converter 1 output
0
ωt
α_1
π
$\pi + \alpha_1$
2π
$V_m \sin \omega t$



v_{o1}
$-V_m \sin \omega t$
Converter 1 output
0
ωt
α_1
π
$\pi + \alpha_1$
2π
$V_m \sin \omega t$
$-v_{o2}$
$-V_m \sin \omega t$
Converter 2 output
$\pi - \alpha_1$
2π
0
ωt
π
$2\pi - \alpha_1$
$V_m \sin \omega t$



$-v_{o2}$
$-V_m \sin \omega t$
Converter 2
output
$\pi - \alpha_1$
2π
0
ωt
π
$2\pi - \alpha_1$
$V_m \sin \omega t$
$v_r(t) = v_{o1} + v_{o2}$
Voltage generating
circulating current
0
ωt
$\pi - \alpha_1$
$2\pi - \alpha_1$

The average dc output voltage of converter 1 is

$$V_{dc1} = \frac{2V_m}{\pi} \cos \alpha_1$$

The average dc output voltage of converter 2 is

$$V_{dc2} = \frac{2V_m}{\pi} \cos \alpha_2$$

In the dual converter operation one converter is operated as a controlled rectifier with $\alpha < 90^0$ & the second converter is operated as a line commutated inverter in the inversion mode with $\alpha > 90^0$

$$\therefore \qquad V_{dc1} = -V_{dc2}$$

$$\frac{2V_m}{\pi}\cos\alpha_1 = \frac{-2V_m}{\pi}\cos\alpha_2 = \frac{2V_m}{\pi}\left(-\cos\alpha_2\right)$$

$\therefore$ $$\cos\alpha_1 = -\cos\alpha_2$$

or

$$\cos\alpha_2 = -\cos\alpha_1 = \cos\left(\pi - \alpha_1\right)$$

$\therefore$ $$\alpha_2 = \left(\pi - \alpha_1\right) \text{ or}$$

$$\left(\alpha_1 + \alpha_2\right) = \pi \text{ radians}$$

Which gives

$$\alpha_2 = \left(\pi - \alpha_1\right)$$