Power Electronics

AC VOLTAGE CONTROLLERS

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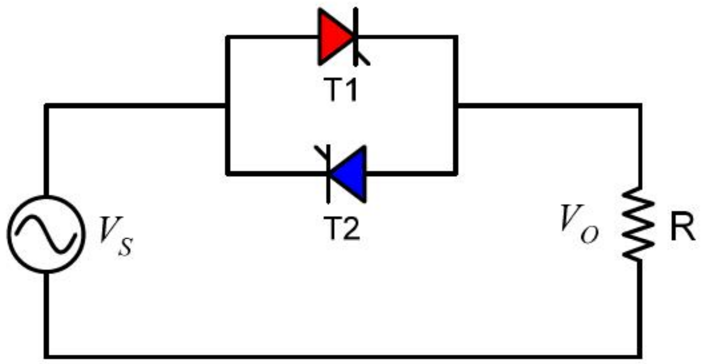
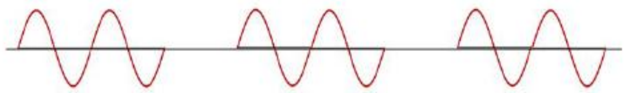
AC Voltage Controllers



- Converts Fixed AC Voltage to Variable AC Voltage
- Thyristor based controller
- Two Types of Control
  - Phase Control
    - Conduction take place in a portion of each half cycle, starting from a specific phase angle (firing angle)

  - Integral Cycle Control
    - Conduction takes place for integral number of full cycles and turn off for further number of cycles.
    - Used in systems with large time constant



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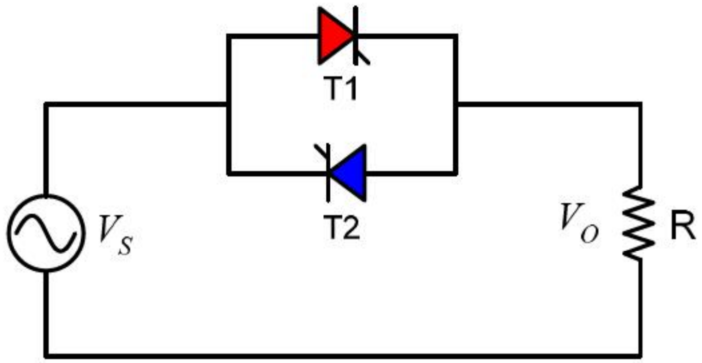
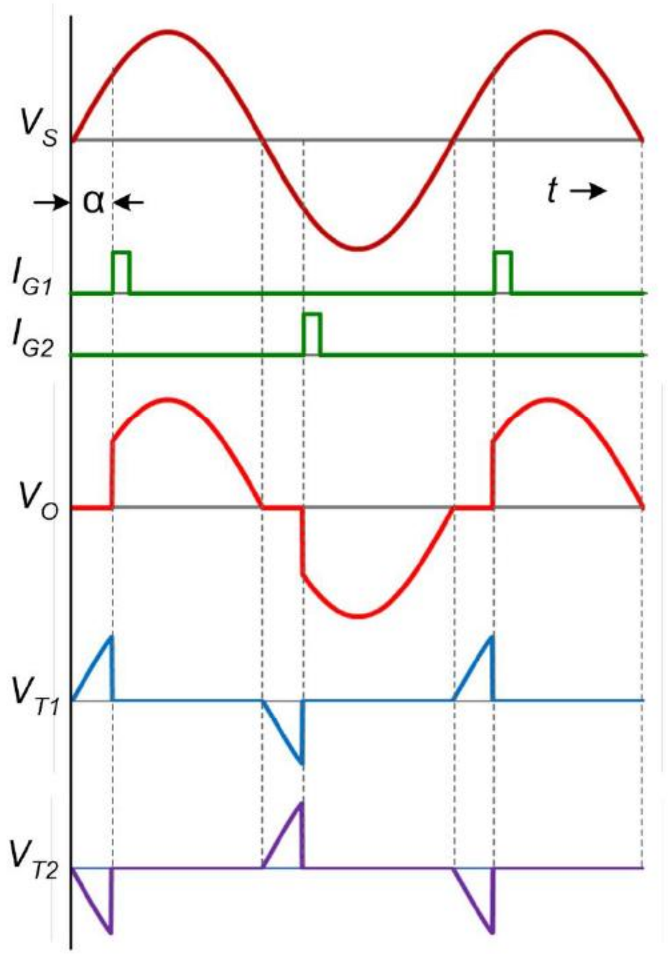
Basic Controller with R Load





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

$$= \frac{V_m}{\sqrt{2}}\left[\frac{1}{\pi}\left((\pi - \alpha) + \frac{\sin 2\alpha}{2}\right)\right]^{\frac{1}{2}}$$

$$I_{O(RMS)} = \frac{V_{O(RMS)}}{R} \qquad Input\ PF = \frac{Output\ Power}{Input\ VA} = \frac{P_O}{V_S \times I_O}$$

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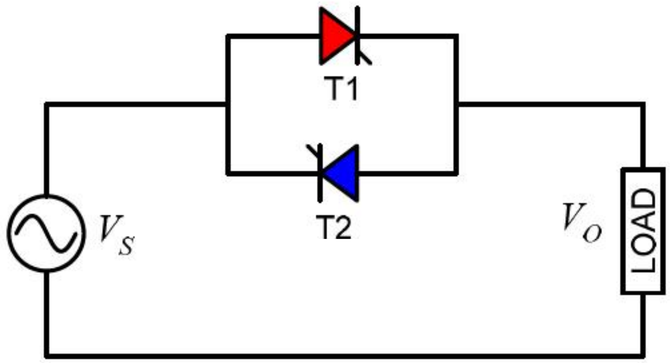
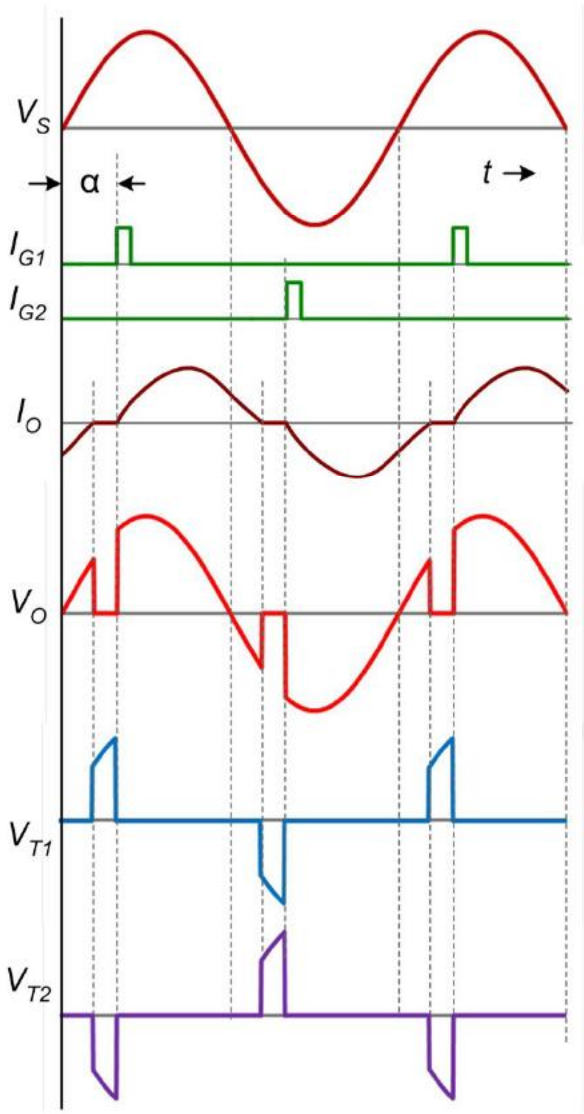
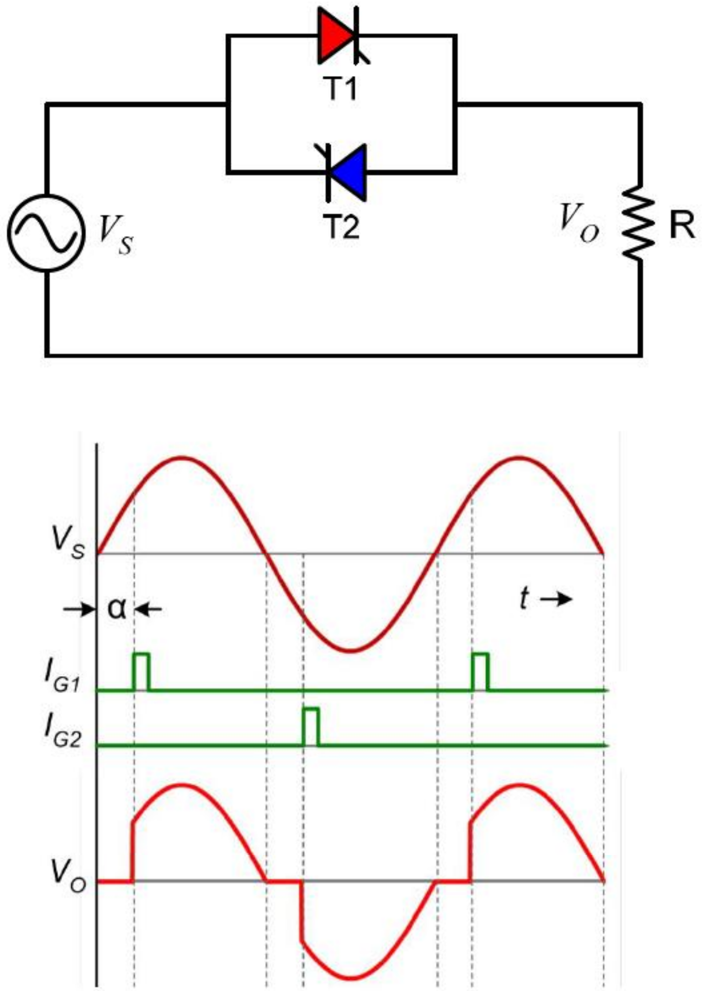
Basic Controller with RL Load

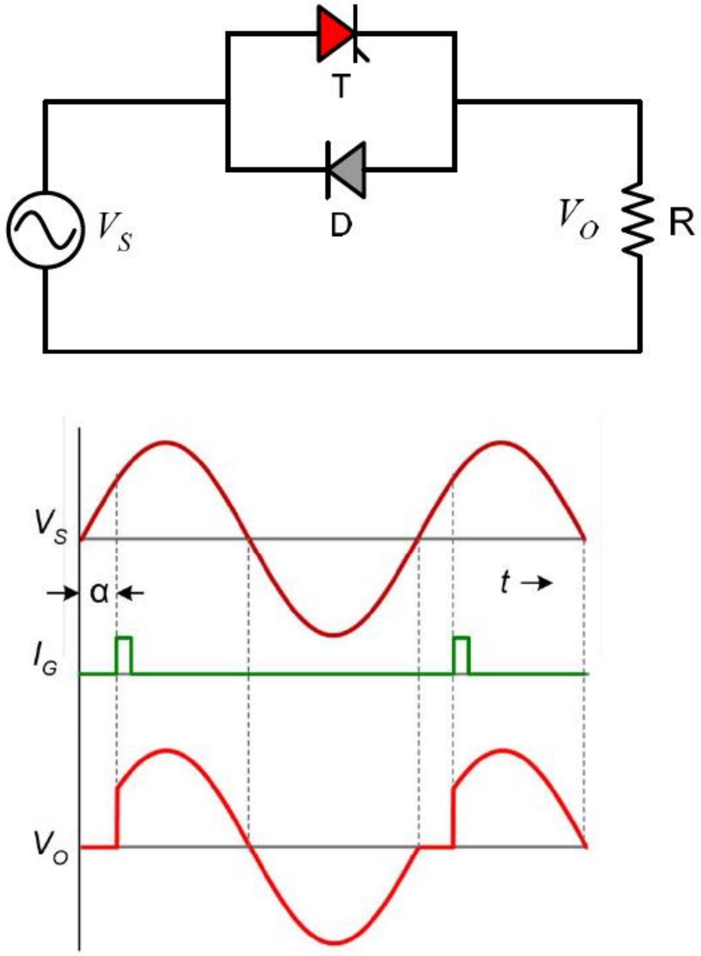




- Output current extends beyond the zero crossing point of input voltage
- Output voltage follows input as long as current is present
- Control may not be possible with highly inductive loads

Full Wave and Half Wave controller



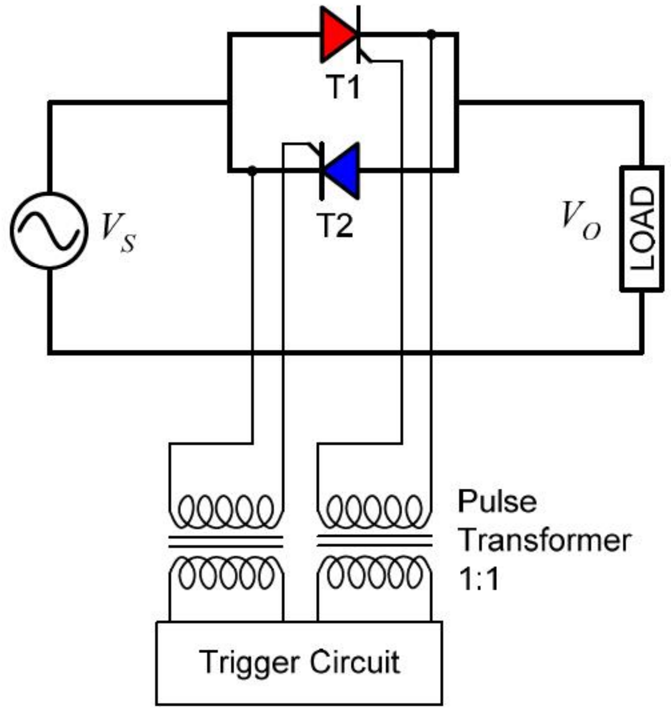


$$V_{O(RMS)} = \frac{V_m}{\sqrt{2}}\left[\frac{1}{\pi}\left(\left(\pi - \alpha\right) + \frac{\sin 2\alpha}{2}\right)\right]^{\frac{1}{2}}$$

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

Controller Types

Anti-parallel connection



- Each SCR conducts for one half cycle
- Cathodes are not connected to a common point; so isolated trigger circuit is needed
- Efficient, since only one SCR conducts during turn on

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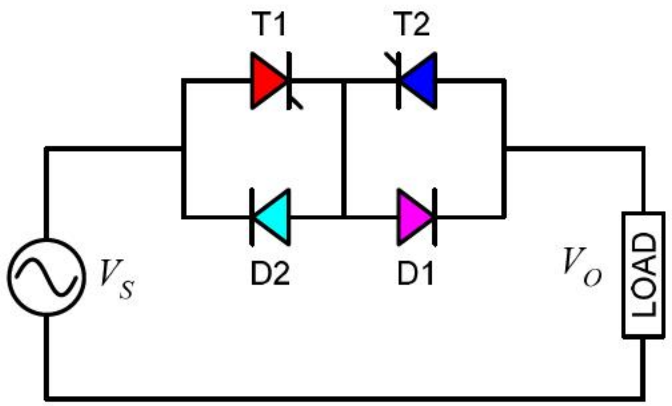
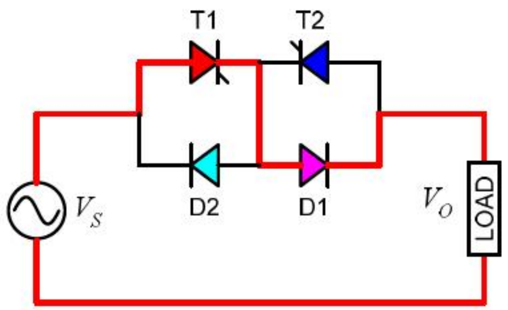
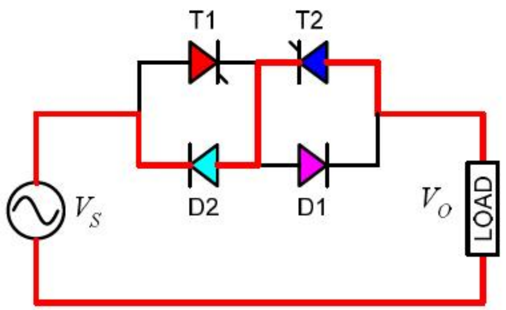
Controller Types

Series connection



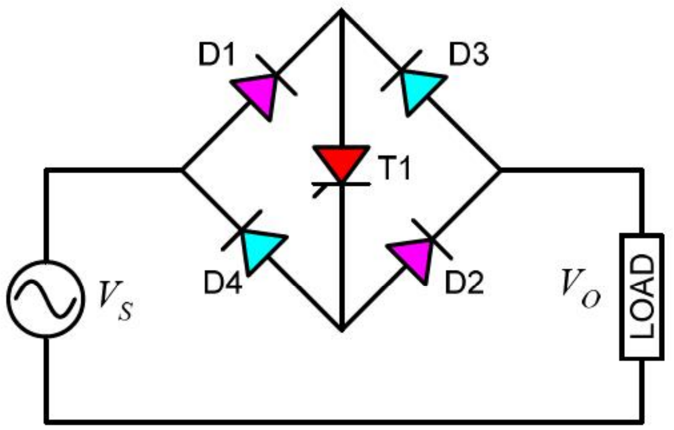
- Cathodes of thyristors connected together; so isolated trigger circuit is not necessary
- Each SCR conducts for one half cycle along with a diode
- Less efficient, since one SCR and one diode conduct during turn on



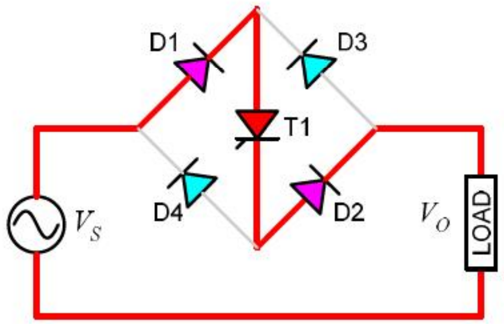


Controller Types

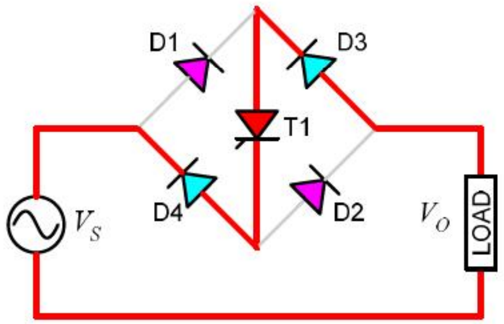
Bridge connection



- Employs four diodes and one thyristor
- Less expensive
- Since there is only one thyristor, isolated trigger circuit is not necessary
- Low efficiency since one SCR and two diodes conduct during turn on



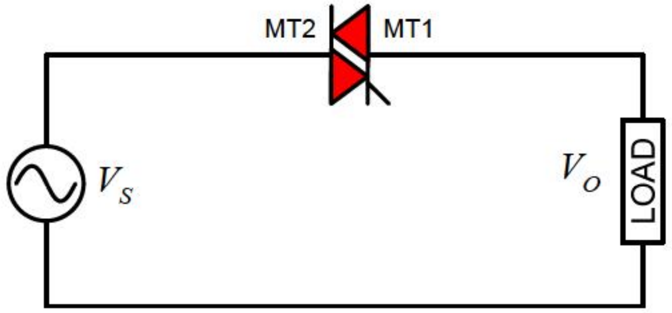
Conduction in Positive Half Cycle



Conduction in Negative Half Cycle

Controller Types

TRIAC connection



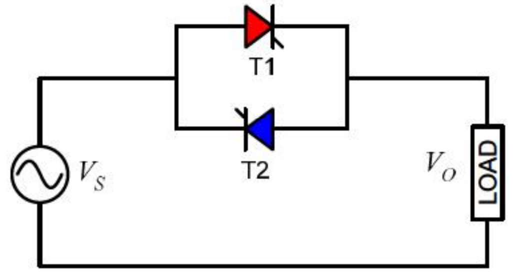
- Employs one triac only
- Suitable for low power applications
- Isolated trigger circuit is not necessary

Example 8.1

An integral cycle control type ac voltage regulator has input voltage of 240 V, 50 Hz and a load resistance of 20 ohms. The thyristors switch on for 20 cycles and remain off for the next 30 cycles. Determine the rms output voltage, average and rms current in each thyristor and input power factor.

Number of cycles on, $n = 20$

Number of cycles off, $m = 30$



$$V_O = V_S\sqrt{\frac{n}{m+n}} = 240\sqrt{\frac{20}{30+20}} = 151.8 \text{ V}$$

$$I_O = \frac{V_O}{R} = \frac{151.8}{20} = 7.59 \text{ A}$$

Peak value of thyristor current, $I_m = \frac{240\sqrt{2}}{20} = \sqrt{2} \times 7.59 = 16.97 \text{ A}$

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$$\text{Average cycle current when thyristor is on} = \frac{I_m}{\pi}$$

$$\text{Average current of one thyristor} = \frac{I_m}{\pi} \times \frac{n}{m+n} = \frac{16.97}{\pi} \times \frac{20}{30+20} = 2.16 \text{ A}$$

$$\text{Cycle rms current when thyristor is on} = \frac{I_m}{2}$$

$$\text{RMS current of one thyristor} = \frac{I_m}{2} \times \sqrt{\frac{n}{m+n}} = \frac{16.97}{2} \times \sqrt{\frac{20}{30+20}} = 5.366 \text{ A}$$

$$\text{Power Factor} = \frac{P_O}{V_S I_S} = \frac{V_O I_O}{V_S I_S} = \frac{V_O}{V_S} = \frac{V_S\sqrt{\frac{n}{m+n}}}{V_S} = \sqrt{\frac{n}{m+n}} = \sqrt{\frac{20}{30+20}} = 0.632$$

$I_S = I_O$ *for this case*

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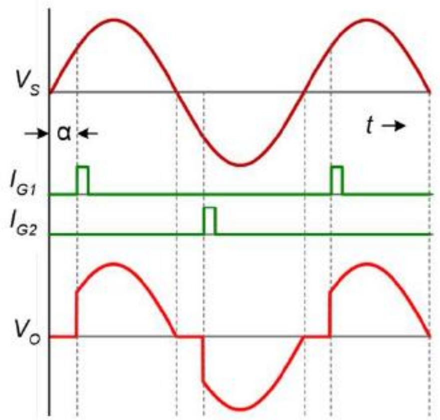
Example 8.2

A single phase full wave ac voltage controller has input voltage of 240 V, 50 Hz and a load resistance of 20 ohms. The delay angle of thyristors is 60 degrees. Determine the rms output voltage, input power factor and average and rms current in each thyristor.

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



$$V_{O(RMS)} = \frac{\sqrt{2}\times 240}{\sqrt{2}}\left[\frac{1}{\pi}\left(\left(\pi-\frac{\pi}{3}\right)+\frac{\sin 2\times\frac{\pi}{3}}{2}\right)\right]^{\frac{1}{2}} = 215.3\ \text{V}$$

$$\text{Power Factor} = \frac{P_O}{V_S I_S} = \frac{V_O I_O}{V_S I_S} = \frac{V_O}{V_S} = \frac{215.3}{240} = 0.897$$

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Average current in one thyristor,

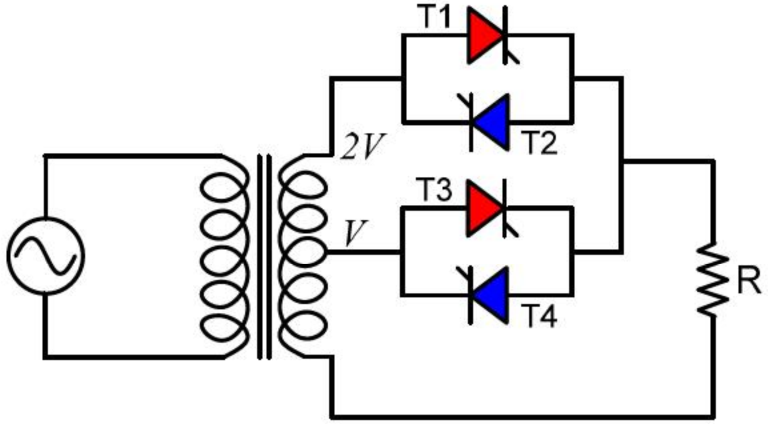
$$I_{T(ave)} = \frac{V_m}{2\pi R}(1+\cos\alpha) = \frac{\sqrt{2}\times 240}{2\pi R}\left(1+\cos\frac{\pi}{3}\right) = 4.05\text{A}$$

RMS current in one thyristor,

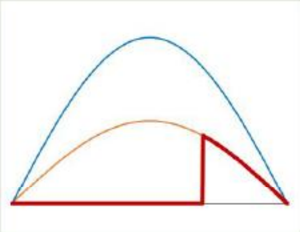
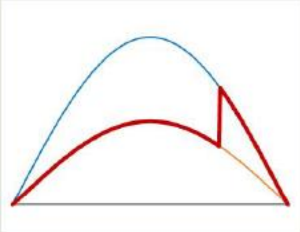
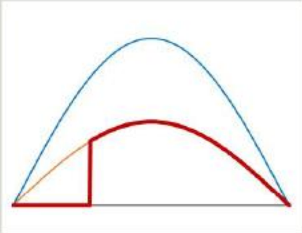
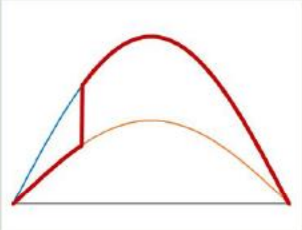
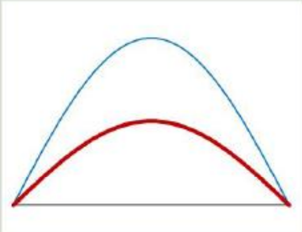
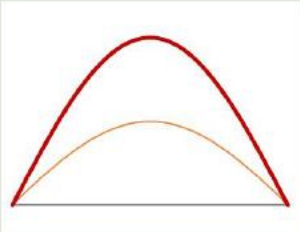
$$I_{T(rms)} = \frac{V_m}{R}\left[\frac{\pi-\alpha}{4\pi}+\frac{\sin 2\alpha}{8\pi}\right]^{\frac{1}{2}}$$

$$= \frac{\sqrt{2}\times 240}{20}\left[\frac{\pi-\frac{\pi}{3}}{4\pi}+\frac{\sin 2\times\frac{\pi}{3}}{8\pi}\right]^{\frac{1}{2}} = 7.61\text{ A}$$

Sequence control of AC Voltage



- May be of two stage or more
- Can work with resistive or inductive load
- Reduces waveform distortion in current for full range of control
- Improves average input power factor

Voltage Variation from 0 to V	Voltage Variation from V to 2V	
T1, T2 **Off** T3, T4 controlled	T3, T4 **On*** T1, T2 controlled	
		*α=150°*
		*α=60°*
		*α=0°*

** T3 and T4 are on at ωt = 0 and turned off at ωt = α.*

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Thank You