AC VOLTAGE CONTROLLER

INTRODUCTION

AC Voltage controllers are thyristor based devices which convert fixed alternating voltage to variable alternating voltage without a change in frequency

Since AC Voltage controllers are phase controlled devices, thyristors and TRIACs are line commutated.

The main disadvantage of ac voltage controllers is the introduction of objectionable harmonics in the supply current and load voltage waveforms, particularly at reduced output voltage levels.

<u>Applications:</u>

Domestic and Industrial heating, Transformer tap changing, lighting control, speed control of single phase and three phase ac drives, starting of induction motors.

AC Voltage controls are adaptable for closed loop control systems.

CONTROL STRATEGIES

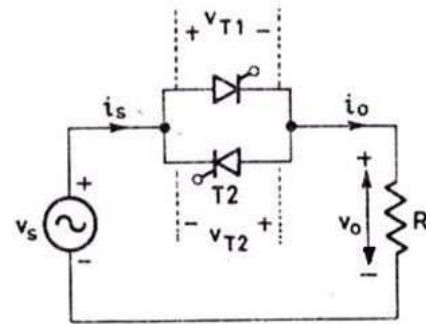Two control strategies are used to control the power flow in ac voltage regulators.

a) Phase Control:

The switching device is so operated that load gets connected to ac source for a part of each cycle of the input voltage.
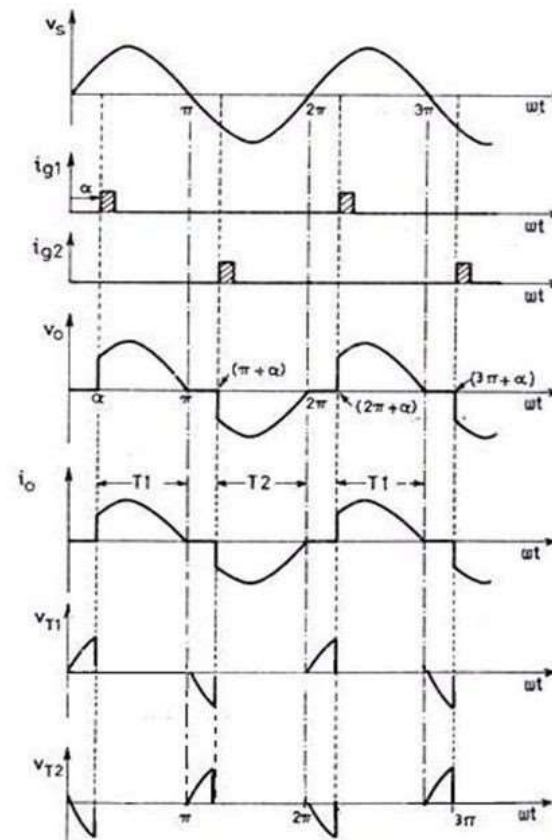
b) Integral cycle control:

Switching on the supply to the load for an integral number of cycles and switching off the supply for a further number of integral cycles.
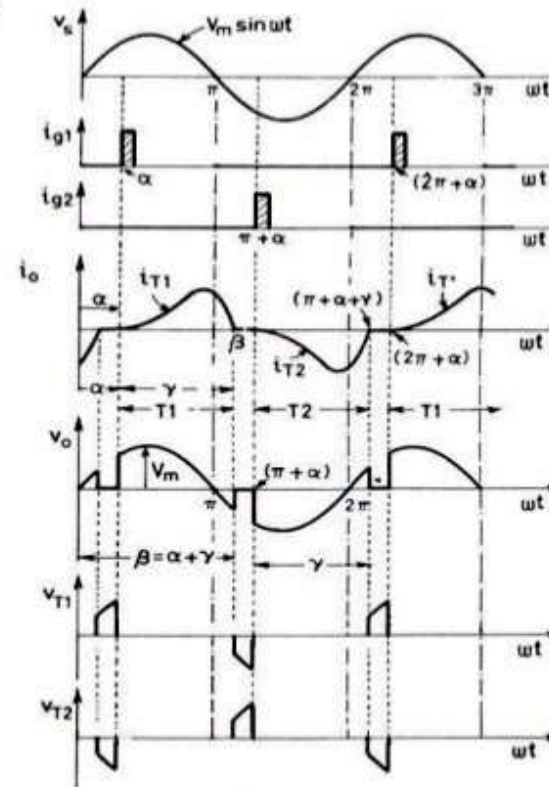
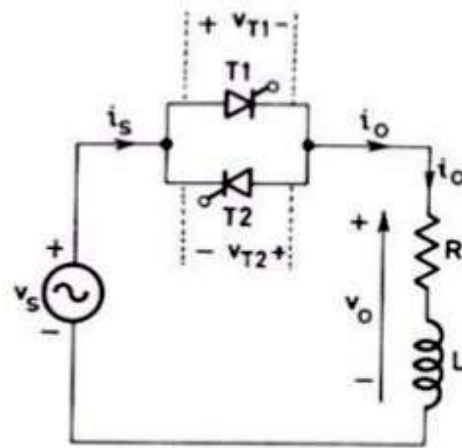# 1 PHASE AC VOLTAGE CONTROLLERS WITH R LOAD

Load power can be varied by changing α over the full range from zero to 180°

1 PHASE AC VOLTAGE CONTROL USING RL LOAD

Circuit & waveforms:
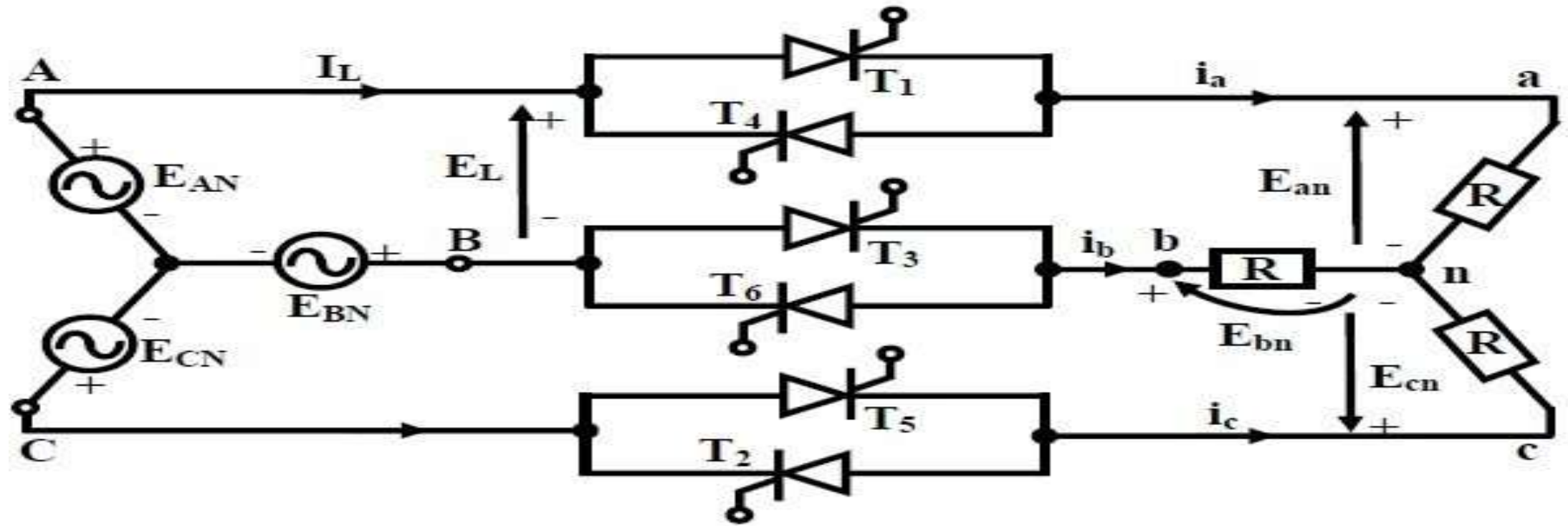
GATING SIGNAL REQUIREMENTS

In a half wave controller, a pulse signal is enough to trigger the thyristor. Whereas in a full wave controller with RL load a pulse signal is not enough.

This is because when thyristor T2 is triggered at $\pi+\alpha$, the current through the thyristor T1 is non-zero which prevent the thyristor from turning off. At $\beta+\alpha$, the current through the thyristor T1 becomes zero. But at this time the pulse signal in T2 for firing would have been zero if it is a pulse signal.

Hence a continuous gating signal is used in case of RL loads.

Three Phase Ac Voltage controllers

Circuit Diagram

Operation

The thyristors are fired in sequence starting from 1 in ascending order, with the angle between the triggering of thyristors 1 & 2 being (one-sixth of the time period ($60°T$) of a complete cycle).

The line frequency is 50 Hz, with $T=1/f=20$ ms.

The thyristors are fired or triggered after a delay of α from the natural commutation point.

The natural commutation point is the starting of a cycle with period, ($60°=T/6$) of output voltage waveform, if six thyristors are replaced by diodes.
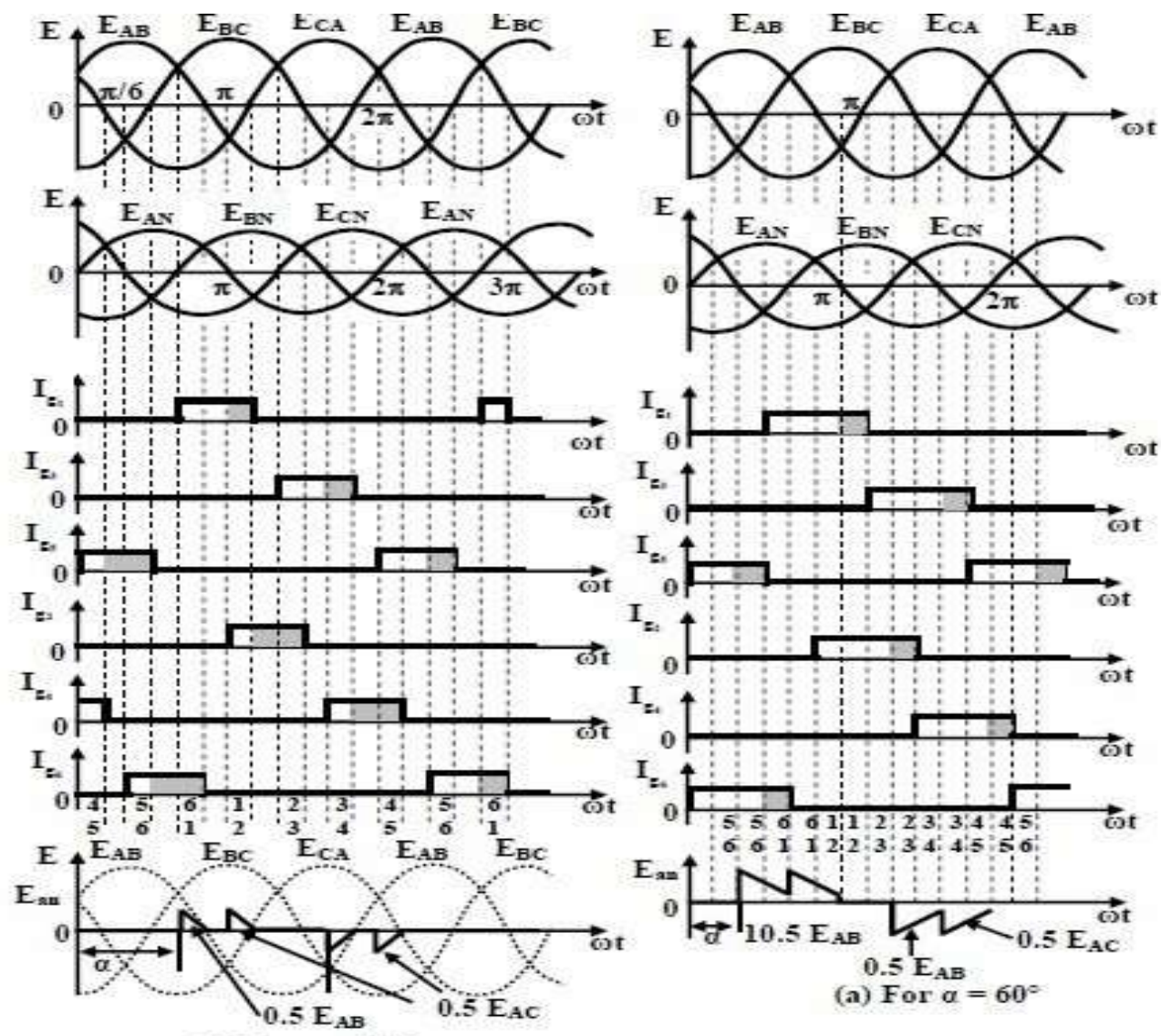
Note that the output voltage is similar to phase-controlled waveform for a converter, with the difference that it is an ac waveform in this case.

The current flow is bidirectional, with the current in one direction in the positive half, and then, in other (opposite) direction in the negative half. So, two thyristors connected back to back are needed in each phase.

The turning off of a thyristor occurs, if its current falls to zero.

To turn the thyristor on, the anode voltage must be higher that the cathode voltage, and also, a triggering signal must be applied at its gate.

Waveforms

(b) For α = 120°

(a) For α = 60°

Expressions

$$e_{AN} = \sqrt{2}\,E_s \sin \omega t, \quad e_{BN} = \sqrt{2}\,E_s \sin(\omega t - 120°) \quad \text{and} \quad e_{CN} = \sqrt{2}\,E_s \sin(\omega t + 120°)$$

Then, the instantaneous input line voltages are,

$$e_{AB} = \sqrt{6}\,E_s \sin(\omega t + 30°), \quad e_{BC} = \sqrt{6}\,E_s \sin(\omega t - 90°) \quad \text{and}$$

$$e_{CA} = \sqrt{6}\,E_s \sin(\omega t + 150°)$$

For $0° \le \alpha \le 60°$:

$$E_0 = \left[\frac{1}{2\pi} \int_0^{2\pi} (e_{AN})^2\, d\theta \right]^{\frac{1}{2}}$$

$$= \sqrt{6}\,E_s \left\{ \frac{2}{2\pi} \left[\int_\alpha^{\pi/3} \frac{\sin^2\theta}{3}\,d\theta + \int_{\pi/2}^{\pi/2+\alpha} \frac{\sin^2\theta}{4}\,d\theta + \int_{\pi/3+\alpha}^{2\pi/3} \frac{\sin^2\theta}{3}\,d\theta + \int_{\pi/2}^{\pi/2+\alpha} \frac{\sin^2\theta}{4}\,d\theta + \int_{2\pi/3+\alpha}^{\pi} \frac{\sin^2\theta}{3}\,d\theta \right] \right\}^{\frac{1}{2}}$$

$$= \sqrt{6}\,E_s \left[\frac{1}{\pi}\left(\frac{\pi}{6} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{8} \right) \right]^{\frac{1}{2}}$$

For $60° \le \alpha \le 90°$:

$$E_0 = \sqrt{6}\,E_s \left\{ \frac{2}{2\pi} \left[\int_{\pi/2-\pi/3+\alpha}^{5\pi/6-\pi/3+\alpha} \frac{\sin^2\theta}{4}\,d\theta + \int_{\pi/2-\pi/3+\alpha}^{5\pi/6-\pi/3+\alpha} \frac{\sin^2\theta}{4}\,d\theta \right] \right\}^{\frac{1}{2}}$$

$$= \sqrt{6}\,E_s \left[\frac{1}{\pi}\left(\frac{\pi}{12} - \frac{3\sin 2\alpha}{16} + \frac{\sqrt{3}\cos 2\alpha}{16} \right) \right]^{\frac{1}{2}} = \sqrt{6}\,E_s \left[\frac{1}{\pi}\left(\frac{\pi}{12} + \frac{\sqrt{3}\sin(2\alpha+30°)}{8} \right) \right]^{\frac{1}{2}}$$

For $90° \le \alpha \le 150°$:

$$E_0 = \sqrt{6}\,E_s \left\{ \frac{2}{2\pi} \left[\int_{\pi/2-\pi/3+\alpha}^{\pi} \frac{\sin^2\theta}{4}\,d\theta + \int_{\pi/2-\pi/3+\alpha}^{\pi} \frac{\sin^2\theta}{4}\,d\theta \right] \right\}^{\frac{1}{2}}$$

$$= \sqrt{6}\,E_s \left[\frac{1}{\pi}\left(\frac{5\pi}{24} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{16} + \frac{\sqrt{3}\cos 2\alpha}{16} \right) \right]^{\frac{1}{2}} = \sqrt{6}\,E_s \left[\frac{1}{\pi}\left(\frac{5\pi}{24} - \frac{\alpha}{4} + \frac{\sin(2\alpha+60°)}{8} \right) \right]^{\frac{1}{2}}$$