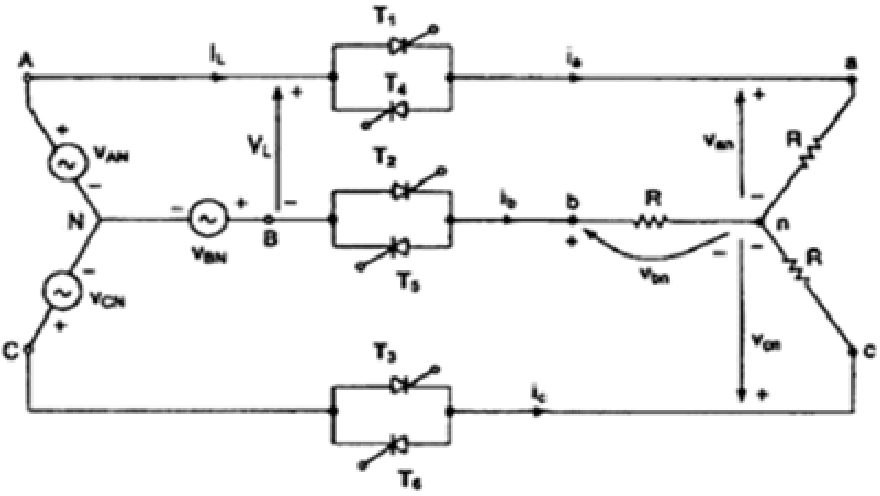
# 12. Three-phase AC Controllers

## Fully controlled Three- phase AC controller

A 3-phase full –wave fully controlled AC controller is shown in Fig.1. With a star connected resistive load.

The firing sequence of thyristors is T1,T6,T2,T4,T3,T5

Fig.1



- For current to flow it is necessary to trigger at least two thyristors at a time.
- If we define the instantaneous input phase voltages as:

  $v_{an} = V_m \sin \omega t$

  $v_{bn} = V_m \sin (\omega t - 2\pi / 3)$

  $v_{cn} = V_m \sin (\omega t - 4\pi / 3)$

- The instantaneous input line voltages are

  $v_{ab} = \sqrt{3}\, v_{an} = \sqrt{3}\, v_m \sin (\omega t + \pi/6)$

  $v_{bc} = \sqrt{3}\, v_{bn} = \sqrt{3}\, v_m \sin (\omega t - \pi/2)$

  $v_{ca} = \sqrt{3}\, v_{cn} = \sqrt{3}\, v_m \sin (\omega t - 7\pi/6)$

The waveforms the input voltages, conduction angles of thyristors and output phase voltages are shown in Fig.2 for $\alpha = 30^\circ$

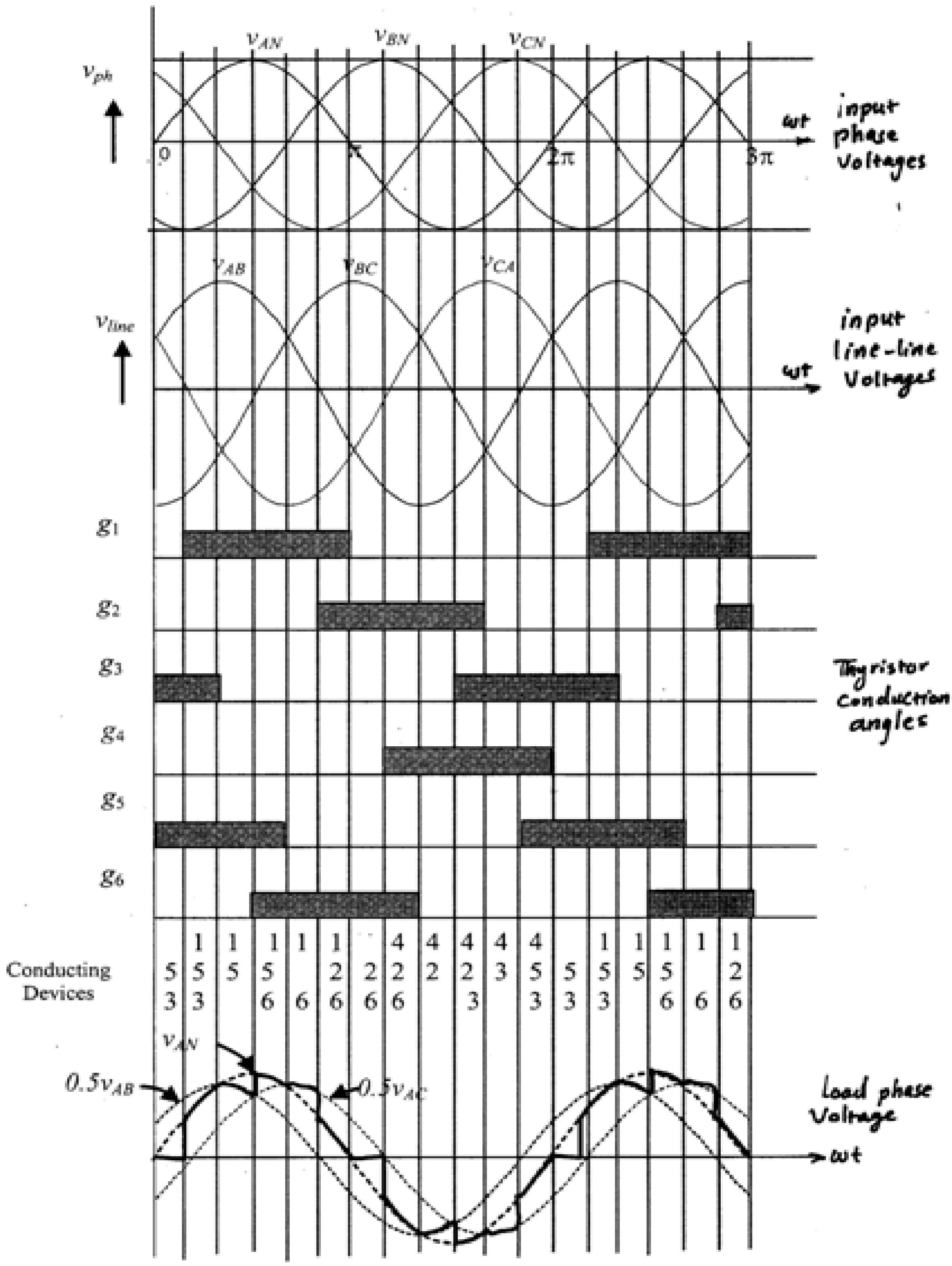



Fig.2 Waveforms

For complete control of the thyristors using the triggering pattern shown each thyristor must be triggered by two separated by 60 degree in time.

Hence we have generally three distinct ranges of firing angle:

| | |
|---|---|
| 1- Range (1) | $0^\circ \le \alpha < 60^\circ$ |
| 2- Range (2) | $60^\circ \le \alpha < 90^\circ$ |
| 3- Range (3) | $90^\circ \le \alpha \le 150^\circ$ |

Similar to half wave controllers the expression for the R.M.S output phase voltage depends on the range of firing angles.

The R.M.S output voltage for a Y– connection loads are found to be:

1- For $0^\circ \le \alpha < 60^\circ$

$$V_o = \sqrt{3}\, V_m \sqrt{\frac{1}{\pi}\left(\frac{\pi}{6} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{8}\right)}$$

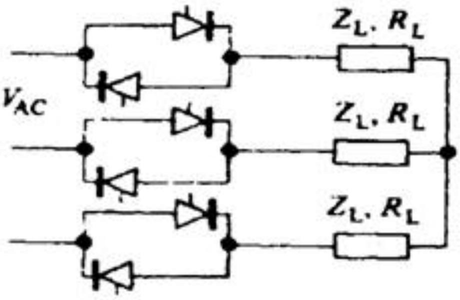
2- For $60^\circ \le \alpha < 90^\circ$

$$V_o = \sqrt{3}\, V_m \sqrt{\frac{1}{\pi}\left(\frac{\pi}{12} - \frac{3\sin 2\alpha}{6} + \frac{\sqrt{3}\cos 2\alpha}{16}\right)}$$

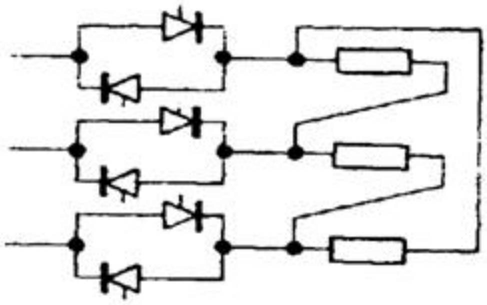
3- For $90^\circ \le \alpha \le 150^\circ$

$$V_o = \sqrt{3}\, V_m \sqrt{\frac{1}{\pi}\left(\frac{5\pi}{24} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{16} + \frac{\sqrt{3}\cos 2\alpha}{16}\right)}$$

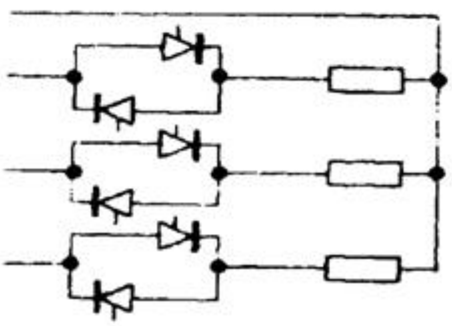
Other types of 3-Phase AC controllers



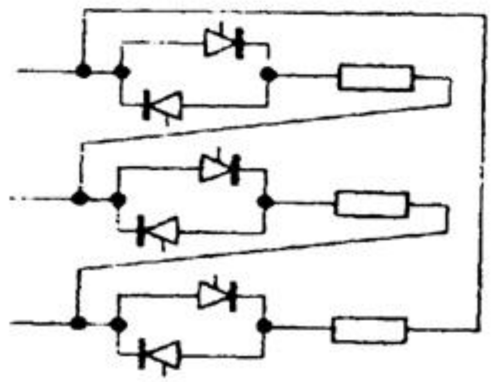

A 3-wire star load



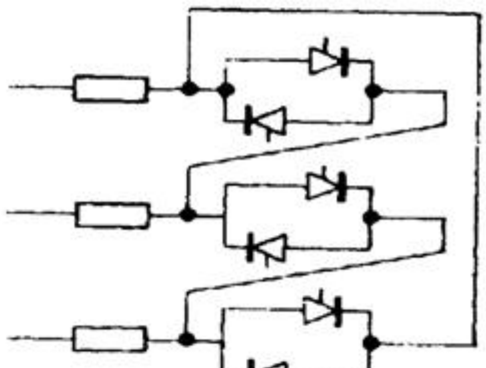
B 3-wire delta load



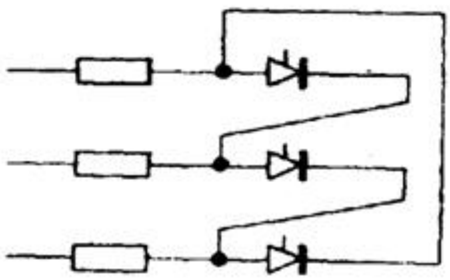
C 4-wire star load



D 3-wire delta controller



E Control in delta



F Half-wave delta control

## Applications:

- Phase controlled systems are used for controlling the speed of induction motor is shown in Fig.4:

Fig.4 (a) Open loop Speed control of induction Motor using 3-phase AC voltage controller

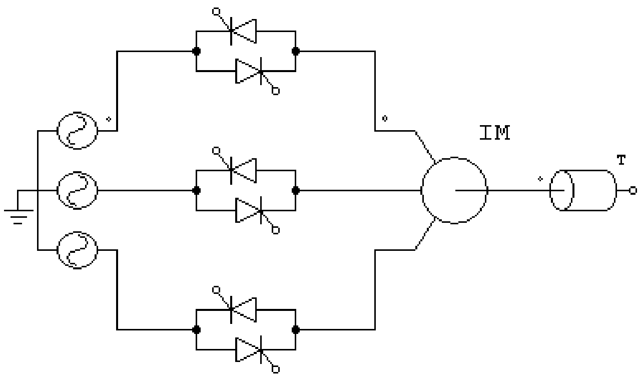
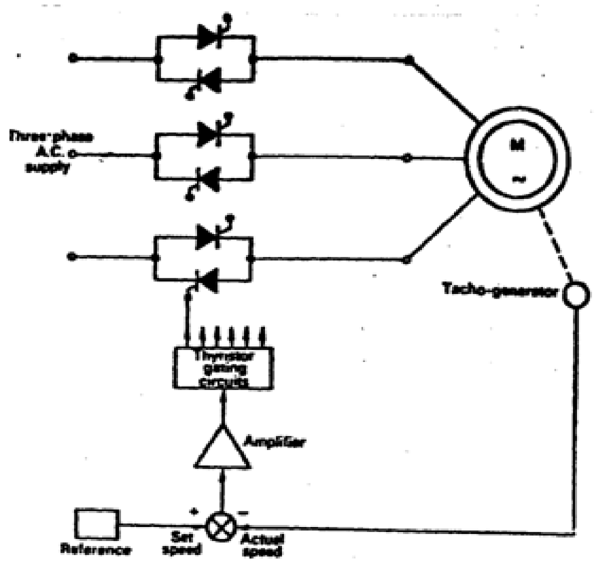
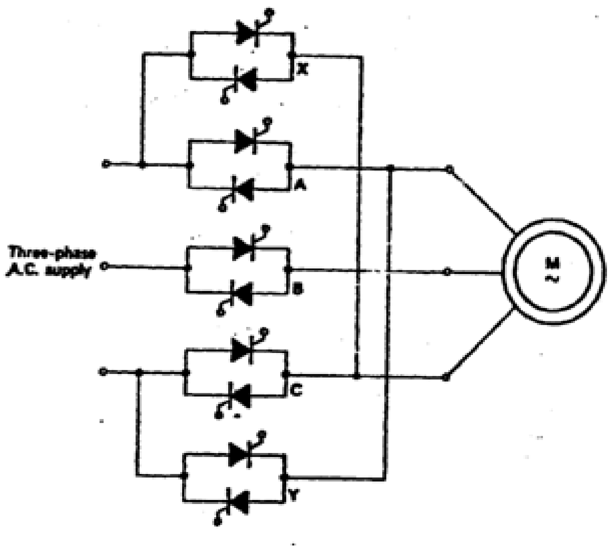



Fig.4(b) Closed loop system for inductive motor speed control using 3-phase AC voltage controller




- If a reversible speed control system is used the line must be change cross connected system Fig.5:

Fig.5 Thyristor configuration of a reversible speed induction drive.



**Example:**

The three phase bidirectional controller in Fig.6 supplies a Y- connected resistive load of R = 10 Ω and line to line voltage is 208V RMS and *f* =60 Hz. For the delay α=π/6 determine

(a)The output power

(b)The input power factor PF

(c) Give one application of such a converter

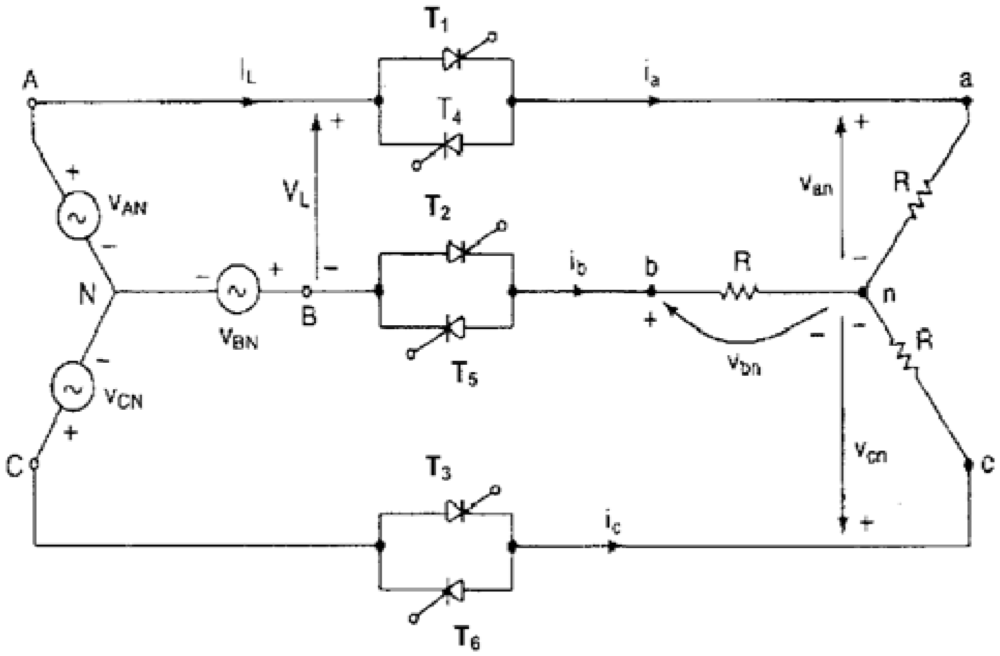



Fig.6

>>> NOT THAT

For $0^\circ \leq \alpha < 60^\circ$

$$V_o = \sqrt{3}\, V_m \sqrt{\frac{1}{\pi}\left(\frac{\pi}{6} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{8}\right)}$$

For $60^\circ \leq \alpha < 90^\circ$

$$V_o = \sqrt{3}\, V_m \sqrt{\frac{1}{\pi}\left(\frac{\pi}{12} - \frac{3\sin 2\alpha}{6} + \frac{\sqrt{3}\cos 2\alpha}{16}\right)}$$

For $90^\circ \leq \alpha \leq 150^\circ$

$$Vo = \sqrt{3}\, V_m \sqrt{\frac{1}{\pi}\left(\frac{5\pi}{24} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{16} + \frac{\sqrt{3}\cos 2\alpha}{16}\right)}$$

**Solution:**

**(a)** For $0^\circ \leq \alpha <, 60^\circ$

$$V_o = \sqrt{3}\, V_m \sqrt{\frac{1}{\pi}\left(\frac{\pi}{6} - \frac{\alpha}{4} + \frac{\sin 2\alpha}{8}\right)} = 117.38V$$

$$I_o = \frac{Vo}{R} = \frac{117.38}{10} = 11.74A$$

$$P_o = 3{I_o}^2 R = 3*(11.74)^2*10 = 4134W$$

**(b)** Since the load is Y-connection the phase current. Thus the input volt-ampere power is

$$S = 3V_s I_o = 3*120*11.74 = 4226VA$$

$$PF = \frac{P_o}{s} = \frac{4134}{4226} = 0.978 lagging$$

**(c)** One application of three-phase AC regulator is in electric oven control or induction motor speed control.