AC TO AC CONVERTER

1. ***AC-to ac converters transfer power from one ac system to another with waveforms of different amplitude, frequency, or phase.***
2. ***These converters are designed for one-quadrant to four quadrant operation..***
3. ***Typical applications are listed below :***

- **Variable speed drives for appliances and tools**
- **Four-quadrant PWM drives for traction**
- **Steel mill roll drives**
- **Industrial heating**
- **On-load transformer tap changing**

1. Direct conversion

- *The ac input waveforms are directly converted into the desired output waveforms.*
- *Converters that do not involve change of frequency are call the ac controllers.*
- *The converters with the change of frequency are called cycloconverters.*

2. Indirect conversion

- *Indirect ac-ac conversion involves an intermediate dc stage, called the dc-link or dc bus and the converters are called the dc-link converters.*

1. AC voltage controllers

(1) Single-phase controller

(a) unidirectional or half-wave control
(b) bidirectional or full-wave control

(2) Three-phase controller

(a) unidirectional or half-wave control
(b) bidirectional or full-wave control

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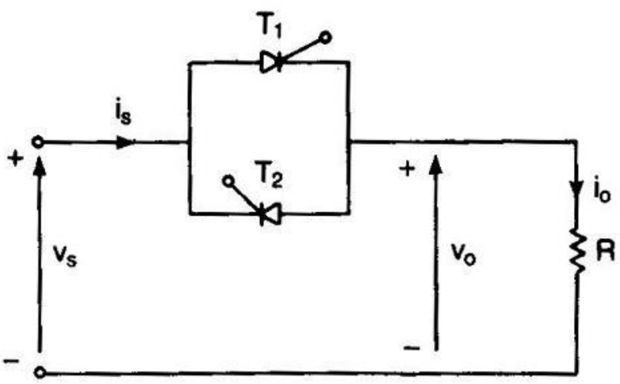
2. Cycloconverters

(1) Single-phase cyclocontroller

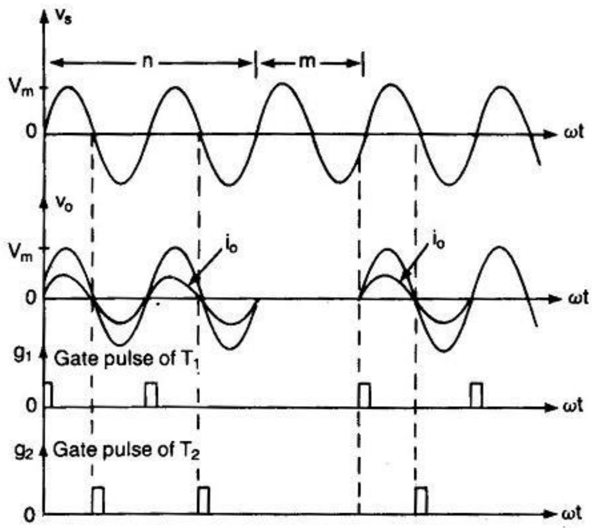
(2) Three-phase cyclocontroller

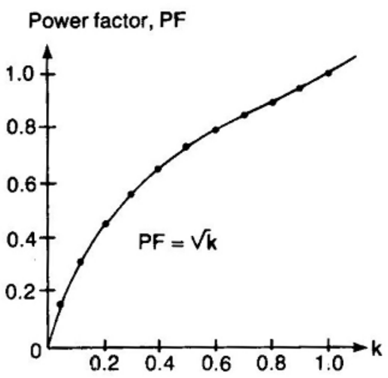
For power transfer, two types of control are normally used **:**

(1) On-off control
(2) Phase-angle control



On-off control





If the input voltage is connected to load for n cycles and is disconnected for m cycles, the rms output (or load) voltage can be found from

$$V_o = \left[\frac{n}{2\pi(n+m)} \int_0^{2\pi} 2V_s^2 \sin^2 \omega t \; d(\omega t) \right]^{1/2}$$

$$= V_s \sqrt{\frac{n}{m+n}} = V_s \sqrt{k}$$

$k = n/(m+n)$: *duty cycle*

V_s : *rms phase voltage*

For a sinusoidal input voltage,

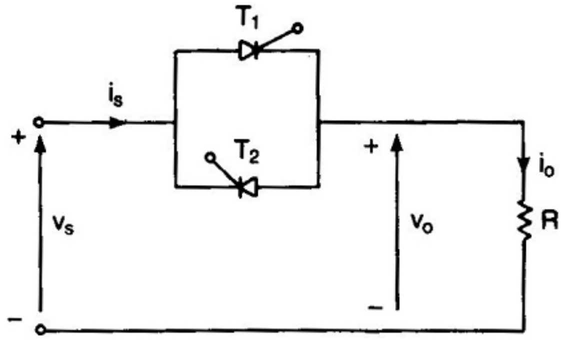
$$v_s = V_m \sin \omega t$$

$$= \sqrt{2}\, V_s \sin \omega t$$

EXAMPLE 1:-

An ac voltage controller in figure has a resistive load of R=10Ω and the *rms* input voltage is V_s=120V, 60Hz.
The thyristors switch is on for n=25cycles and is off for m=75 cycles. Determine,

(a) The *rms* output voltage V_o
(b) The input power factor *PF*
(c) The average and *rms* current of thyristors



$$R = 10\Omega,\ V_s = 120\,\text{V},\ V_m = \sqrt{2}\times 120 = 169.7\,\text{V},\ k = \frac{n}{n+m} = 0.25$$

$$(a)\ V_o = \left[\frac{n}{2\pi(n+m)}\int_0^{2\pi} 2V_s^2 \sin^2\omega t\ d(\omega t)\right]^{1/2}$$

$$= V_s\sqrt{k} = V_s\sqrt{\frac{n}{m+n}} = 120\sqrt{\frac{25}{100}} = 25\ \text{V}$$

$$(b)\ I_o = V_o / R = 60/10 = 6.0\,\text{A}$$

$$\textit{the load power},\quad P_o = I_o^2 R = 6^2\times 10 = 360\,\text{W}$$

Since the input current is the same as the load current, the input volt – amperes is

$$VA = V_s I_s = V_s I_o = 120\times 6 = 720\,\text{W}$$

Thus, input power factor,

$$PF = \frac{P_o}{VA} = \sqrt{\frac{n}{m+n}} = \sqrt{k} = \sqrt{0.25} = \frac{360}{720} = 0.5\ (lagging)$$

(c) *The peak thyristor current is* $I_m = V_m / R = 169.7/10 = 16.97\ \text{A}$

The average current of thyristors is

$$I_A = \frac{n}{2\pi(m+n)} \int_0^{\pi} I_m \sin\omega t \ d(\omega t) = \frac{I_m n}{\pi(m+n)} = \frac{kI_m}{\pi}$$

$$= \frac{16.97}{\pi} \times 0.25 = 1.33\ \text{A}$$

The rms current of thyristors is

$$I_R = \left[\frac{n}{2\pi(m+n)} \int_0^{\pi} I_m^2 \sin^2\omega t \ d(\omega t)\right]^{1/2}$$

$$= \frac{I_m}{2}\sqrt{\frac{n}{m+n}} = \frac{I_m\sqrt{k}}{2}$$

$$= \frac{16.97}{2} \times \sqrt{0.25} = 4.24\ \text{A}$$

Example 2:- A single-phase voltage controller has input voltage of 230 V, 50 Hz and a load of R=15 ohm. For 6 cycles on and 4 cycles off, determine

(a) rms output voltage.

(b) input pf .

(c) average and rms thyristor currents.

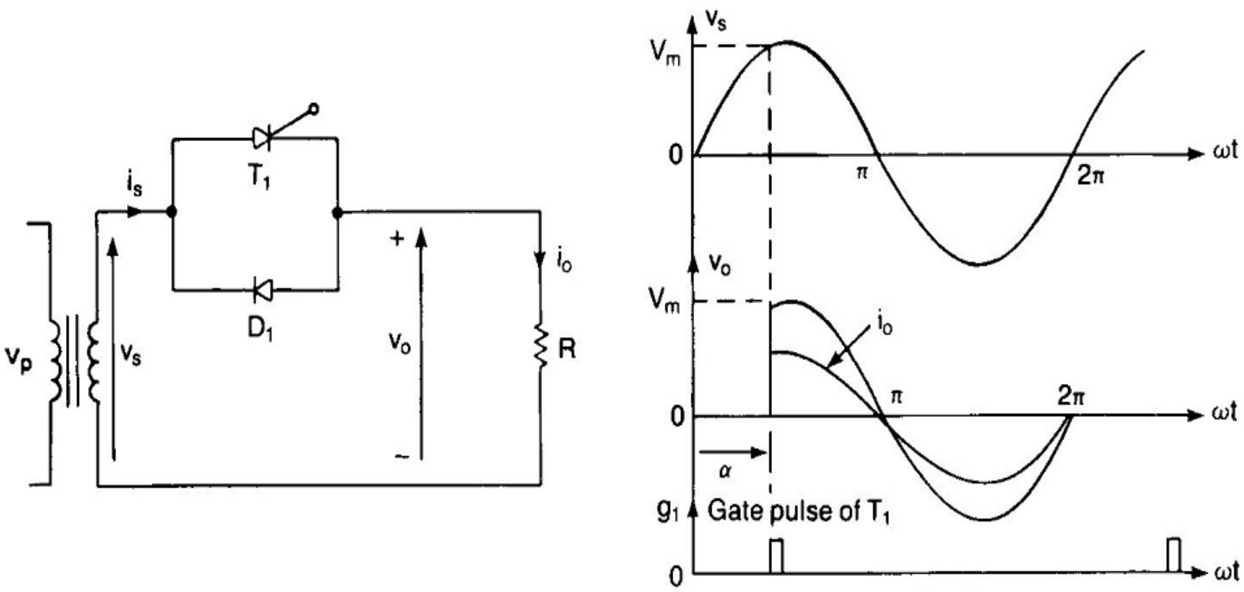
Ans:-

a) Vo=178.157 V

b) Pf= 0.7746

c) Ia= 4.1407A , Irms=8.397A

Unidirectional Controller



Single-phase angle control

$$\textit{if input voltage, } v_s = V_m \sin\omega t = \sqrt{2}\,V_s \sin\omega t$$

$$\textit{delay angle of thyristor } T_1,\ \omega t = \alpha$$

the rms output voltage,

$$V_o = \left\{ \frac{1}{2\pi}\left[\int_{\alpha}^{\pi} 2V_s^2 \sin^2\omega t \; d(\omega t) + \int_{\pi}^{2\pi} 2V_s^2 \sin^2\omega t \; d(\omega t) \right] \right\}^{1/2}$$

$$= \left\{ \frac{2V_s^2}{4\pi}\left[\int_{\alpha}^{\pi} (1-\cos 2\omega t)\; d(\omega t) + \int_{\pi}^{2\pi} (1-\cos 2\omega t)\; d(\omega t) \right] \right\}^{1/2}$$

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

the average value of output voltage,

$$V_{dc} = \frac{1}{2\pi}\left[\int_{\alpha}^{\pi} \sqrt{2}\, V_s \sin\omega t\ d(\omega t) + \int_{\pi}^{2\pi} \sqrt{2}\, V_s \sin\omega t\ d(\omega t)\right]$$

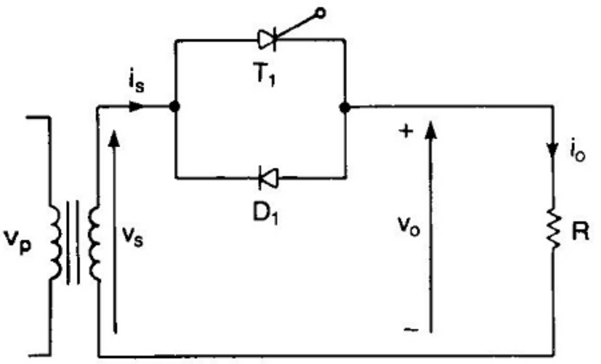
$$= \frac{\sqrt{2}\, V_s}{2\pi}(\cos\alpha - 1)$$

$$If,\ \alpha = 0 \rightarrow \pi\ :\ V_o = V_s \rightarrow \frac{V_s}{\sqrt{2}},\ \ V_{dc} = 0 \rightarrow \frac{-\sqrt{2}V_s}{\pi}$$

EXAMPLE 2:-

A single-phase ac voltage controller in figure has a resistive load of R=10Ω and the input voltage is V_s=120V, 60Hz. The delay angle of thyristor T_1 is $\alpha=\pi/2$. Determine,

(a) The *rms* value of output voltage V_o
(b) The input power factor *PF*
(c) The average input current



$$R = 10\Omega,\ V_s = 120\,\text{V},\ V_m = \sqrt{2}\times 120 = 169.7\,\text{V},\ \alpha = \frac{\pi}{2}$$

(a) the rms value of output voltage,

$$V_o = V_s\left[\frac{1}{2\pi}\left(2\pi - \alpha + \frac{\sin 2\alpha}{2}\right)\right]^{1/2} = 120\sqrt{\frac{3}{4}} = 103.92\,\text{V}$$

(b) *the rms load current,*

$$I_o = \frac{V_o}{R} = \frac{103.92}{10} = 10.392\,\text{A}$$

the load power, $P_o = I_o^2 R = 10.392^2 \times 10 = 1079.94\,\text{W}$

$$VA = V_s I_s = V_s I_o = 120 \times 10.392 = 1247.04\ \text{VA}$$

the input power factor,

$$PF = \frac{P_o}{VA} = \frac{V_o}{V_s} = \left[\frac{1}{2\pi}\left(2\pi - \alpha + \frac{\sin 2\alpha}{2}\right)\right]^{1/2} = \sqrt{\frac{3}{4}} = \frac{1079.94}{1247.04}$$

$$= 0.866\ \ (lagging)$$

(c) *the average output voltage,*

$$V_{dc} = \frac{\sqrt{2}\,V_s}{2\pi}(\cos\alpha - 1) = -120 \times \frac{\sqrt{2}}{2\pi} = -27\ \text{V}$$

the average input current

$$I_D = \frac{V_{dc}}{R} = -\frac{27}{10} = -2.7\ \text{A}$$