AC → AC CONVERTERS

A power electronic ac-ac converter, in generic form, accepts electric power from one system and converts it for delivery to another ac system with waveforms of different amplitude, frequency and phase

Ac-ac converters employed to vary the rms voltage across the load at constant frequency are known as ac voltage controllers, ac regulators or ac choppers.

The voltage control is accomplished either by a) phase control under natural commutation using pairs of thyristor or triac b) on-off control IGBT or MOSfet.

The usage areas of that converter type

- Heat control
- Light control

* Soft starting
* Speed control of pump and fan drives
* High power low speed large ac motor drives for application in rolling mills and cement kilns
* Ship propellers

Generally phase control circuits produce two signals with adjustable α angle by sensing zero points, positive and negative intervals.

The Ac chopper are used as an ac switch when the switching angle α is equal to zero.

For Resistive loads

$$U_o^2 = \frac{1}{\pi} \int U_{phm}^2 \cdot \sin^2(\omega t)\, d\omega t$$

$$= \frac{1}{\pi} \frac{1}{2} \cdot U_{ph}^2 \cdot \int_{\alpha}^{\pi} (1 - \cos 2(\omega t)) \cdot d(\omega t)$$

$$= \frac{1}{\pi} \frac{1}{2} \cdot U_{phm}^2 \left[\pi - \alpha + \frac{1}{2} \sin 2\alpha \right]$$

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

$$U_o = U_{ph} \cdot \sqrt{\frac{1}{\pi} \left(\pi - \alpha + \frac{1}{2} \sin 2\alpha \right)}$$

$$I_o = \frac{U_o}{R} \qquad P_o = U_o \cdot I_o = \frac{U_o^2}{R}$$

For inductive Load

$$U_o^2 = \frac{1}{\pi} \int_{\alpha}^{\pi+\gamma} U_{phm}^2 \cdot \sin^2(\omega t) \cdot d(\omega t)$$

$$= \frac{1}{\pi} \cdot \frac{1}{2} \cdot U_{fm}^2 \left[\pi + \gamma - \alpha - \frac{1}{2} \left(\sin 2(\pi + \gamma) - \sin 2\alpha \right) \right]$$

$$U_o = U_{ph} \sqrt{\frac{1}{\pi} \left[\pi + \gamma - \alpha + \frac{1}{2} (\sin 2\alpha - \sin 2\gamma) \right]}$$

Power Balance

If we omit the circuit losses, the ac power values can be assumed as equal.

$$P_o = P_i \qquad q \cdot U_{ph} \cdot I_{ph_1} \cdot \cos \varphi_1 = q \cdot \frac{U_o^2}{R}$$

For a triac, waveform is fullwave.

$$I_{TAV} = \frac{1}{\pi} \int_{\alpha}^{\pi} I_{phm} \cdot \sin(\omega t) \cdot d\omega t = \frac{1}{\pi} \cdot \sqrt{2} \cdot I_{ph} (1 + \cos\alpha)$$

$$\text{or} = \frac{1}{\pi} I_{phm} (1 + \cos\alpha)$$

$$I_{Trms}^2 = \frac{1}{\pi} \int_0^{\pi} I_{phm}^2 \cdot \sin^2(\omega t)\, d(\omega t)$$

$$I_{Trms}^2 = \frac{I_{phm}^2}{2} \cdot \left[\frac{1}{\pi} \left(\pi - \alpha + \frac{1}{2} \sin 2\alpha \right) \right]$$

$$I_{Trms} = \frac{I_{phm}}{\sqrt{2}} \cdot \sqrt{\frac{1}{\pi} \left(\pi - \alpha + \frac{1}{2} \sin 2\alpha \right)}$$

if $\alpha = 0$ $\quad I_{Trms} = I_{ph}$ //

For a thyristor

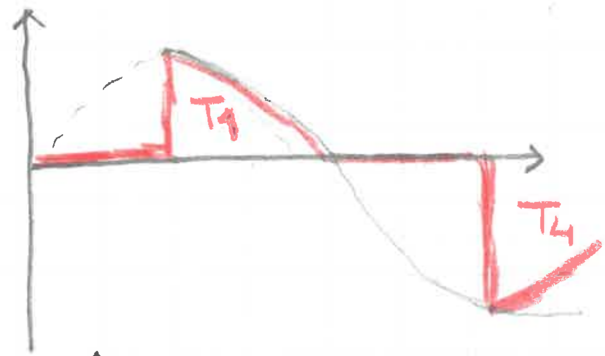
$$I_{TAV} = \frac{1}{2\pi} \sqrt{2} \cdot I_{ph} \quad (1 + \cos\alpha)$$

$$I_{Trms} = \frac{1}{2} \cdot I_{phm} \sqrt{\frac{1}{\pi} \left(\pi - \alpha + \frac{1}{2} \sin 2\alpha \right)} = \sqrt{\frac{1}{2\pi} \int_{\alpha}^{\pi} I_{phm}^2 \cdot \sin^2 \omega t \cdot d\omega t}$$

If $\alpha = 0$

$$I_{TAV} = \frac{1}{\pi} \sqrt{2} \cdot I_{ph}$$

$$I_{Trms} = \frac{\sqrt{2}}{2} \cdot I_{ph}$$



U_{BD_p} or $U_{BD_n} > \sqrt{2} \cdot U_{ph}$. for single phase

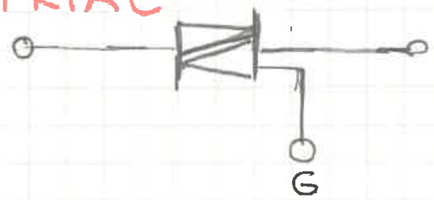
Positive and negative breakdown voltages

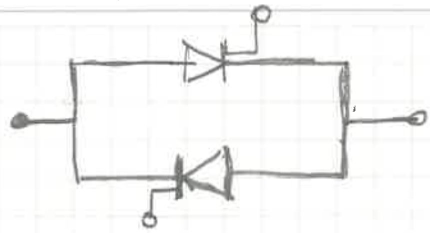
GENERAL SPECIFICATION

* For inductive loads, the signal of triggering is longer than the one with omic load.
* Depending on α angle, phase difference and harmonics occur.

AC-AC Drivers (AC CHOPPERS)

TRIAC





Triac is a power switched that corresponds to two reverse-parallel connected tyristor. The current-voltage characteristics of triac is similar to thyristors curve.

It is a bi-directional controlled device since it has ability to conduct current in forward biased and reverse biased.

Triac was designed to be used in AC/AC converters. It makes converter simple and reduces the cost since it requires just one gate signal and sink.

Due to complex structure, Triacs can not reach higher power levels compared to thyristors.

A heater with 220V and 2.2 kW is supplied via a single phase ac/ac converter with 220V phase voltage. By omitting circuit losses;

a) Find out the heater resistance

b) For $\alpha = 90°$, Find out the voltage and power of heater.

a) Power for the heater $P = \frac{V_{ph}^2}{R} = 2.2 \cdot 10^3 = \frac{220^2}{R}$

$R = 22\ \Omega$.

b) $V = V_{ph} \cdot \sqrt{\frac{1}{\pi} \cdot \left(\pi - \alpha + \frac{1}{2} \cdot \sin 2\alpha\right)}$

$= 220 \cdot \sqrt{\frac{1}{\pi}\left(\pi - \frac{\pi}{2} + \frac{1}{2} \sin 2 \cdot 90°\right)}$

$= 155.56\ V.$

$P = \frac{155.56^2}{22} = 1.1\ kW.$

A single phase ac/ac converter with triac and 220 phase voltage supplies to the heater with 4.4 kW, single phase. By neglecting the circuit losses;

a) Find out the drawn current from network

b) Find out the avarage and rms currents of the triac

c) Calculate the exposed max voltage of the triac

a) $P = V_{ph} \cdot I_{ph} \cdot \cos\phi$

$4.4 \cdot 10^3 = 220 \cdot I_{ph} \cdot 1 \Rightarrow I_{ph} = 20A$.

b) $I_{TAV} = \frac{2}{\pi} \cdot \sqrt{2} \cdot I_{ph} = 18A$.

$I_{rms} = I_{ph} = 20A$.

c) $V_{T_{max}} = \sqrt{2} \cdot V_{ph} = \sqrt{2} \cdot 220V = 311V$.

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