POWER ELECTRONICS I

AC-DC Converters

Three-Phase Rectifiers

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Questions Lecture 1

Q_1) what are the rating values of the Diodes in the converter?

Q_2) Draw the waveforms of the diodes voltage and current

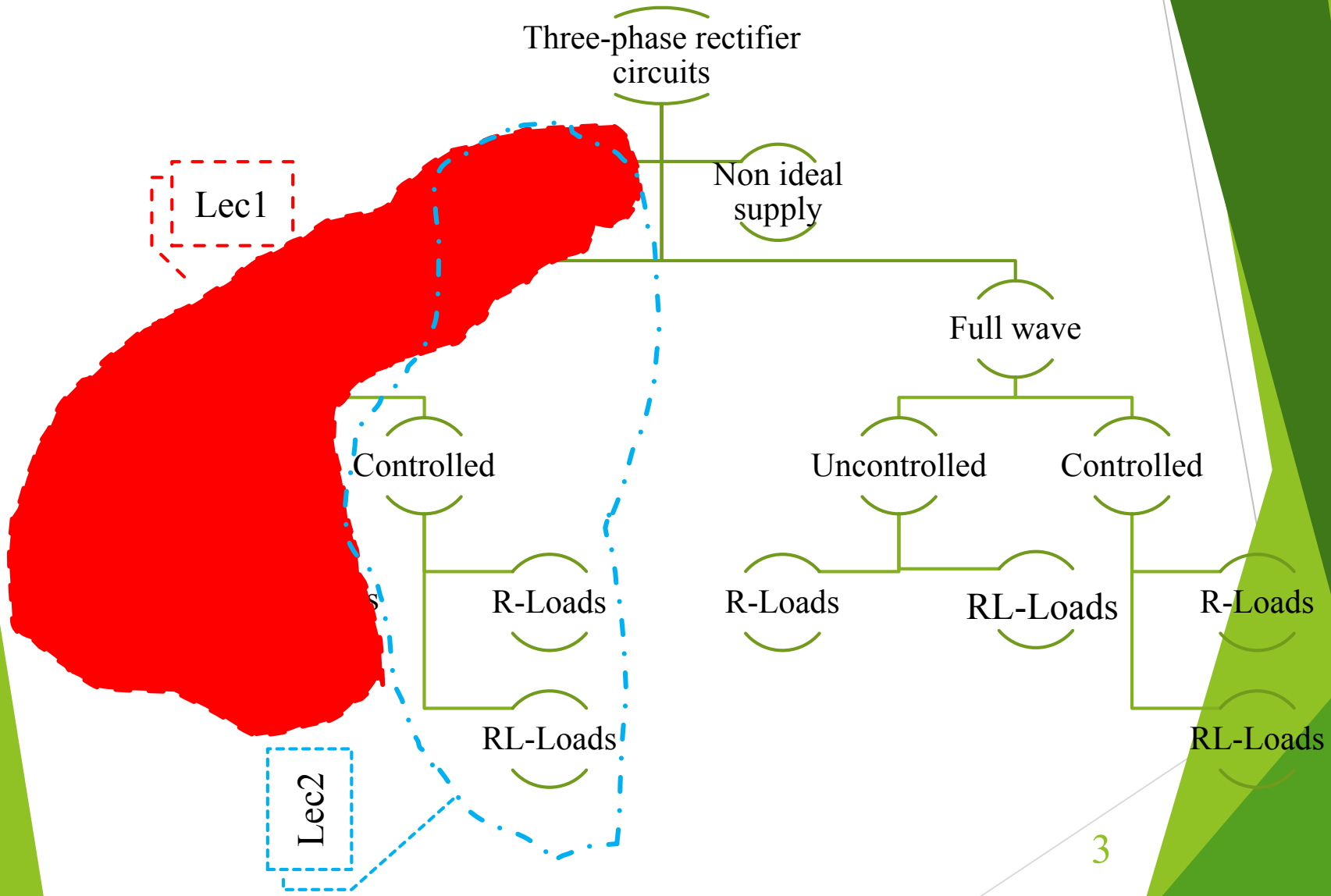
Q_3) Compare between the rms harmonic voltages in single phase and three phase half wave uncontrolled rectifiers

Q_4) what are the disadvantages of the three-phase half –wave rectifiers?

Q_5) Do you need to use a freewheeling diode in the pervious circuit?

Q_6) Write an expression for the instantaneous load current for all pervious case studies

Three-phase rectifier Plan



Lecture two: Three-phase half-wave controlled rectifiers

Construction
- Circuit diagram
- Components

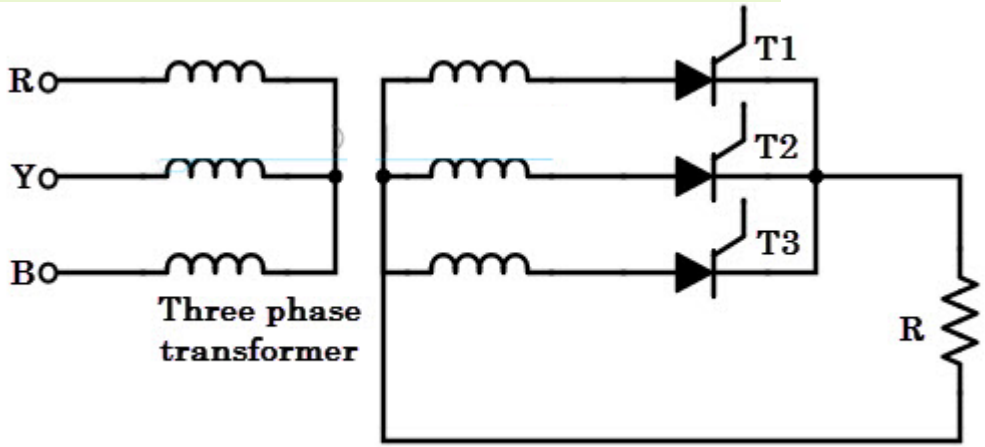
Operation
- Output waveforms at different values of firing angle
- R-load and Highly inductive load

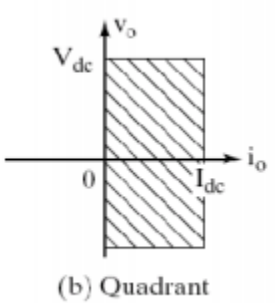
Analysis
- Analysis of the circuit with R-load
- Analysis of the circuit with highly inductive load

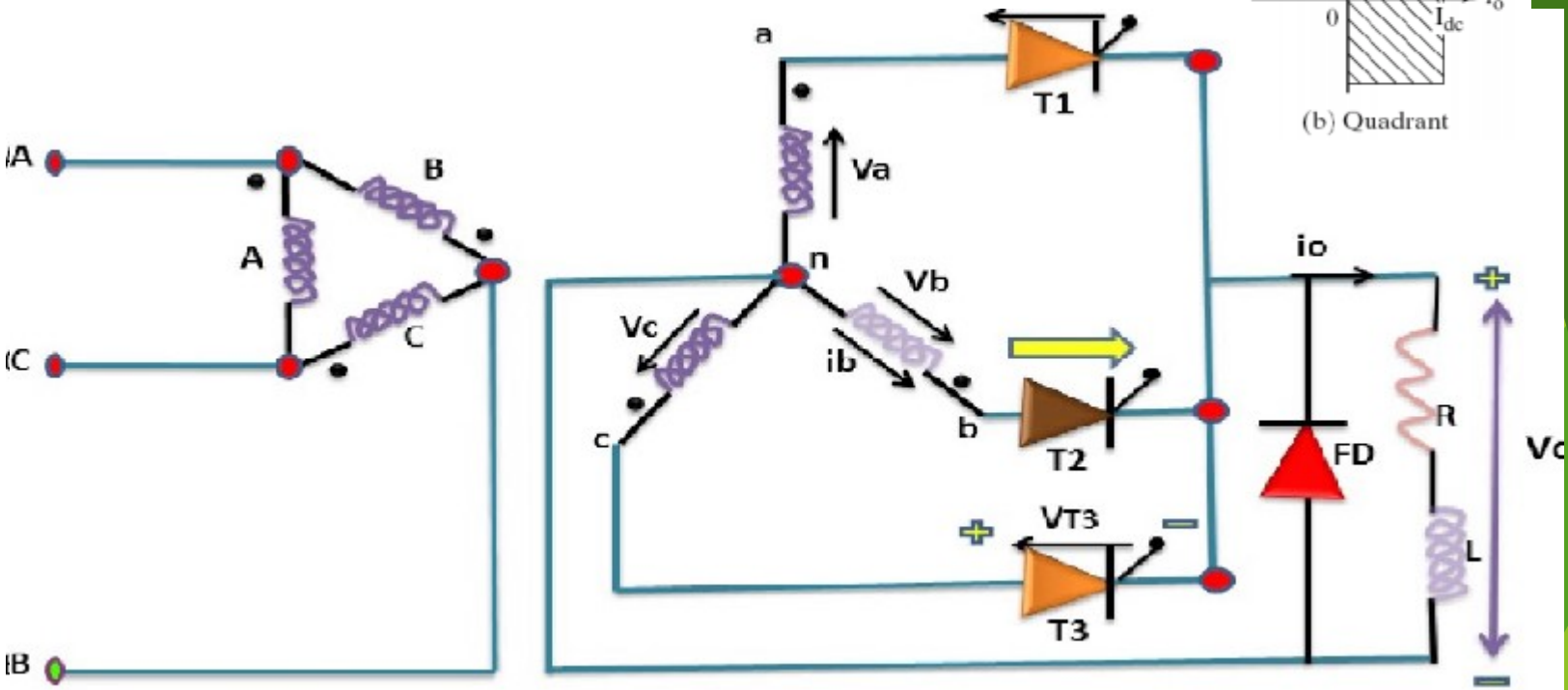
End
- Highly inductive loads with freewheeling diode
- summery
- Questions

Construction

Power circuit and its components



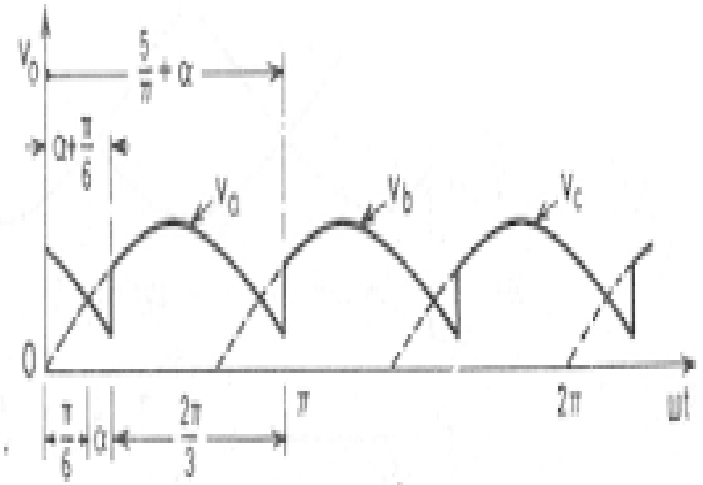




Operation

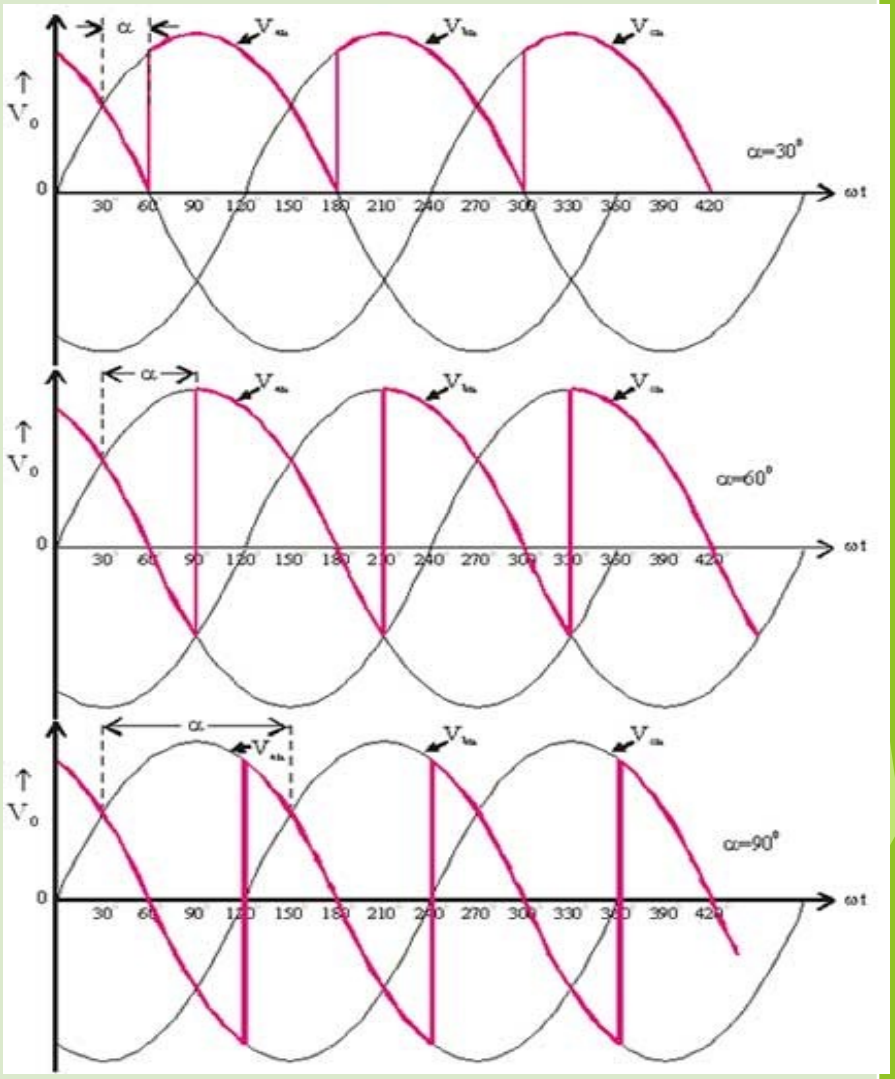
Output Voltage waveforms

R-Loads



output voltage waveforms for (i) $0 < \alpha < 30°$ and (ii) $30 < \alpha < 150°$

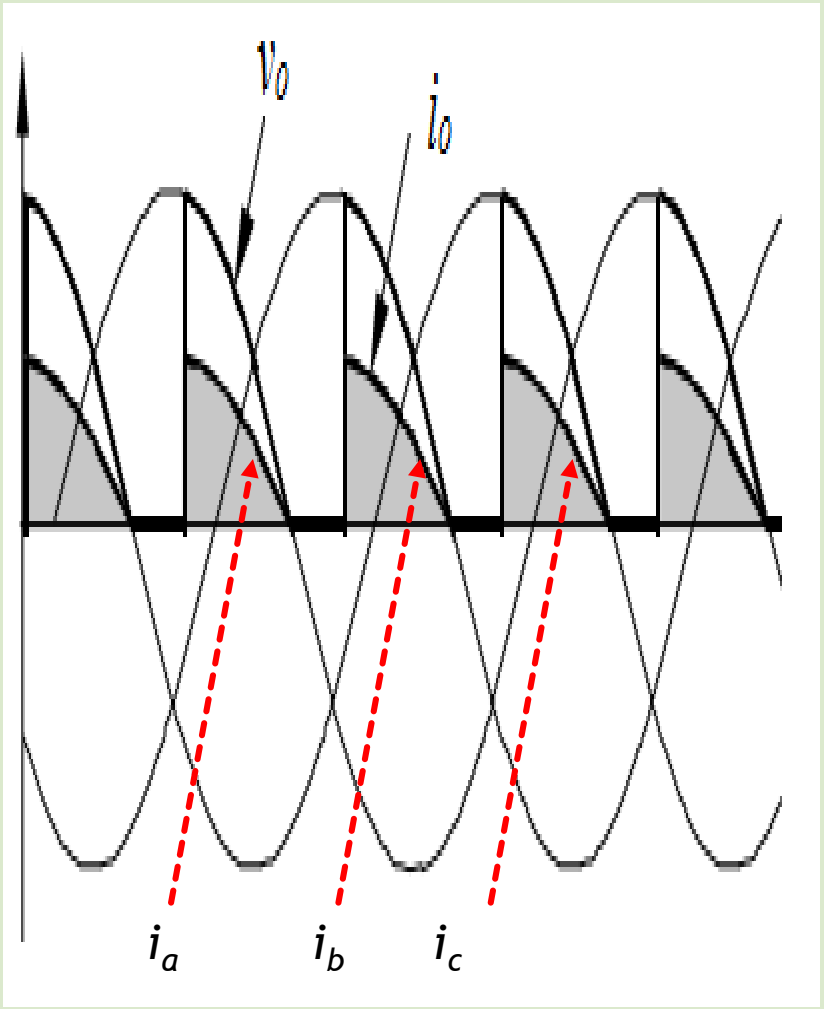
Highly inductive Loads



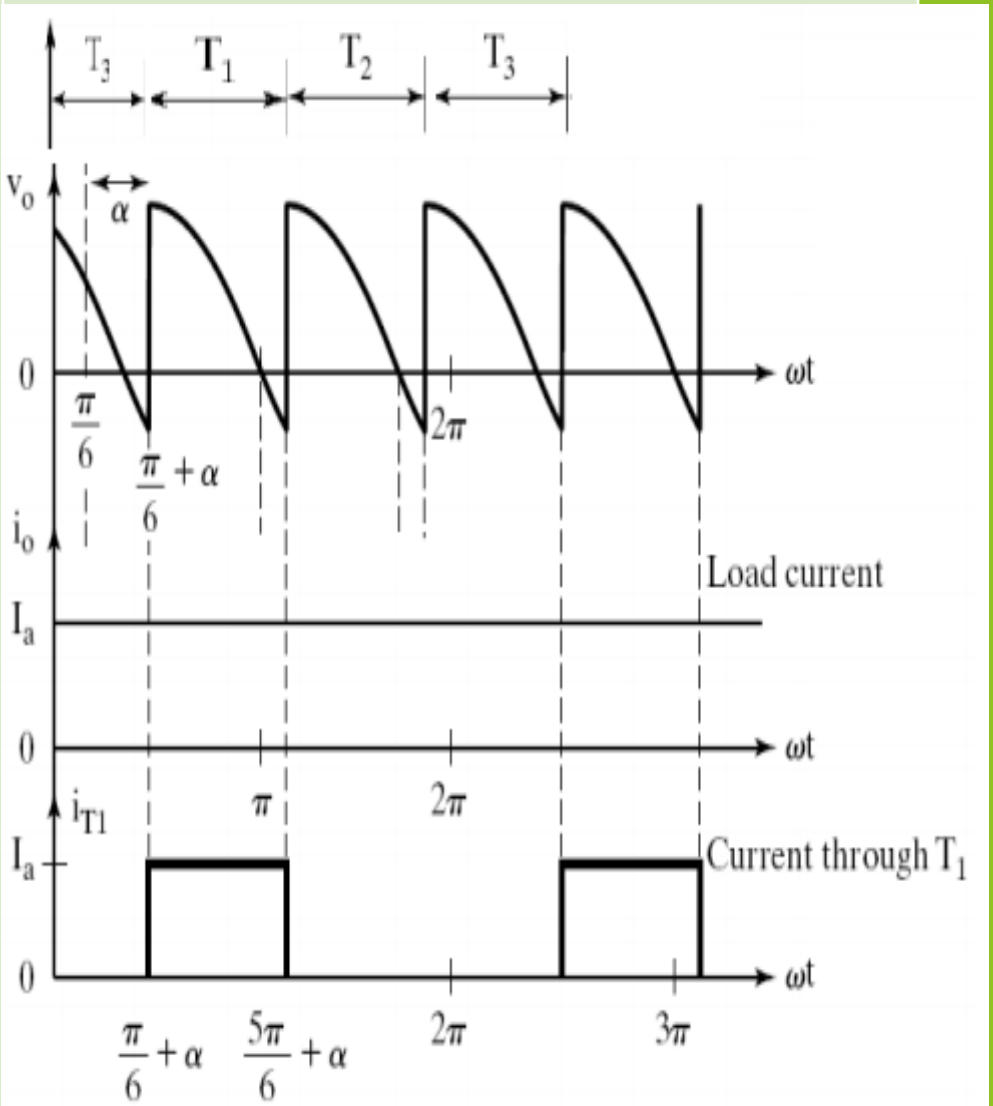
Operation

Currents waveforms

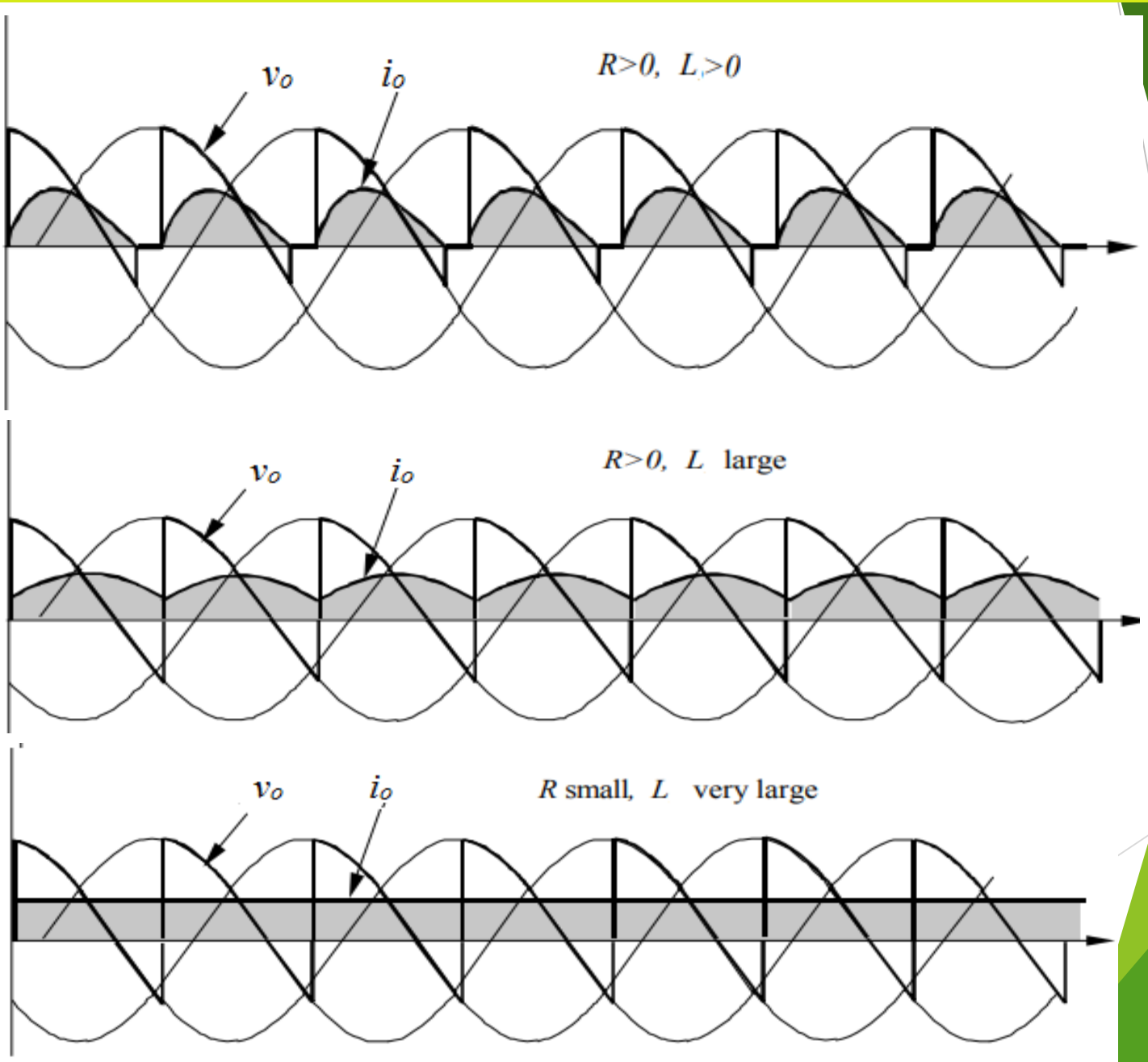
R-Loads



Highly inductive Loads



Operation: Different cases



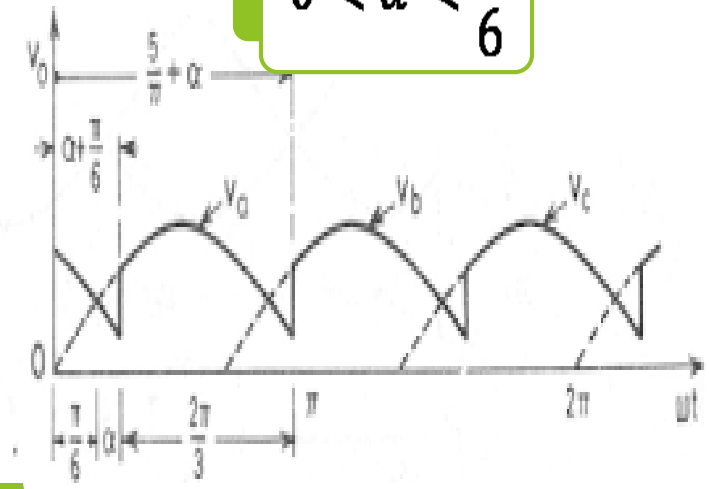
Analysis: Resistive Loads

1- Supply voltages:

$V_a(\omega t)=V_m\sin(\omega t)$, $V_b(\omega t)=V_m\sin(\omega t-2\pi/3)$, $V_c(\omega t)=V_m\sin(\omega t-4\pi/3)$

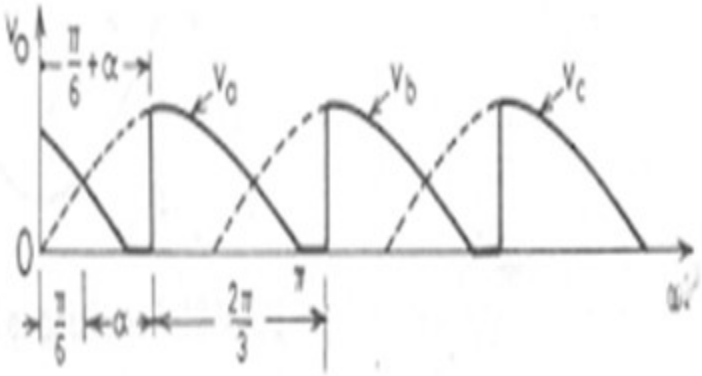
2- Average Load Voltage

$0 < \alpha < \frac{\pi}{6}$



$$V_{o,avg}=\frac{3}{2\pi}\int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} v_a\,d\omega t=\frac{3\sqrt{3}V_m}{2\pi}\cos(\alpha)$$

$\frac{\pi}{6} < \alpha < \frac{5\pi}{6}$



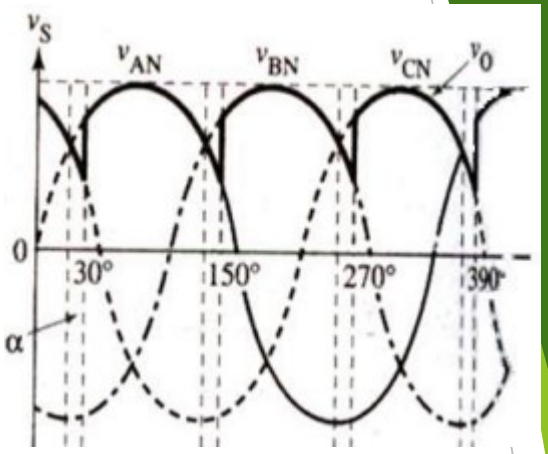
$$V_{o,avg}=\frac{3}{2\pi}\int_{\frac{\pi}{6}+\alpha}^{\pi} v_a\,d\omega t=\frac{3V_m}{2\pi}\left(1+\cos\left(\frac{\pi}{6}+\alpha\right)\right)$$

Analysis: Resistive Loads

3- RMS Load voltage

i) $\alpha \leq \frac{\pi}{6}$

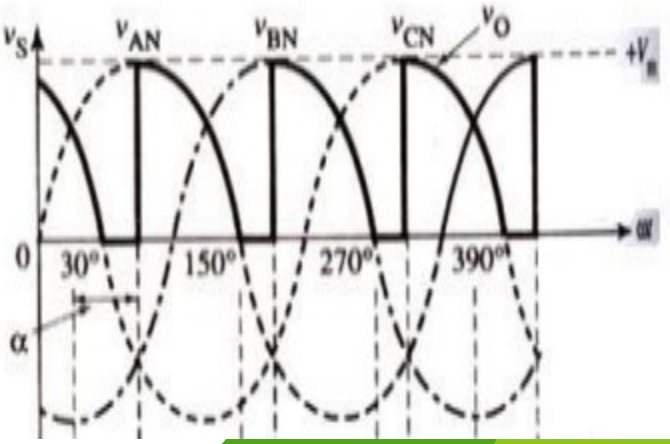
$$V_{rms} = \sqrt{\frac{3}{2\pi}\int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} (V_m sin\omega t)^2 d\omega t} = \sqrt{3}V_m\sqrt{\frac{1}{6}+\frac{\sqrt{3}}{8\pi}cos2\alpha}$$



ii) $\frac{\pi}{6} < \alpha < \frac{5\pi}{6}$

$$V_{rms} = \sqrt{\frac{3}{2\pi}\int_{\frac{\pi}{6}+\alpha}^{\pi} (V_m sin\omega t)^2 d\omega t} = \sqrt{\frac{3V_m^{\,2}}{4\pi}\int_{\frac{\pi}{6}+\alpha}^{\pi} (1 - cos2\omega t) d\omega t}$$

$$V_{rms} = V_m\sqrt{\frac{3}{4\pi}(\frac{5\pi}{6} - \alpha + \frac{1}{2}\sin(\frac{\pi}{3} + 2\alpha))} =$$



Analysis: Resistive Loads

4- Average load current

For both cases:

$$I_{o\ avg} = \frac{Vo,avg}{R}$$

5- RMS Load current

For both cases:

$$I_{o,rms} = V_{o,rms}/R$$

Analysis: Resistive Loads

6- Average Supply currents

$$I_{a\ avg} = I_{b\ avg} = I_{c\ avg} = \frac{I_{o\ avg}}{3}$$

7- RMS supply current

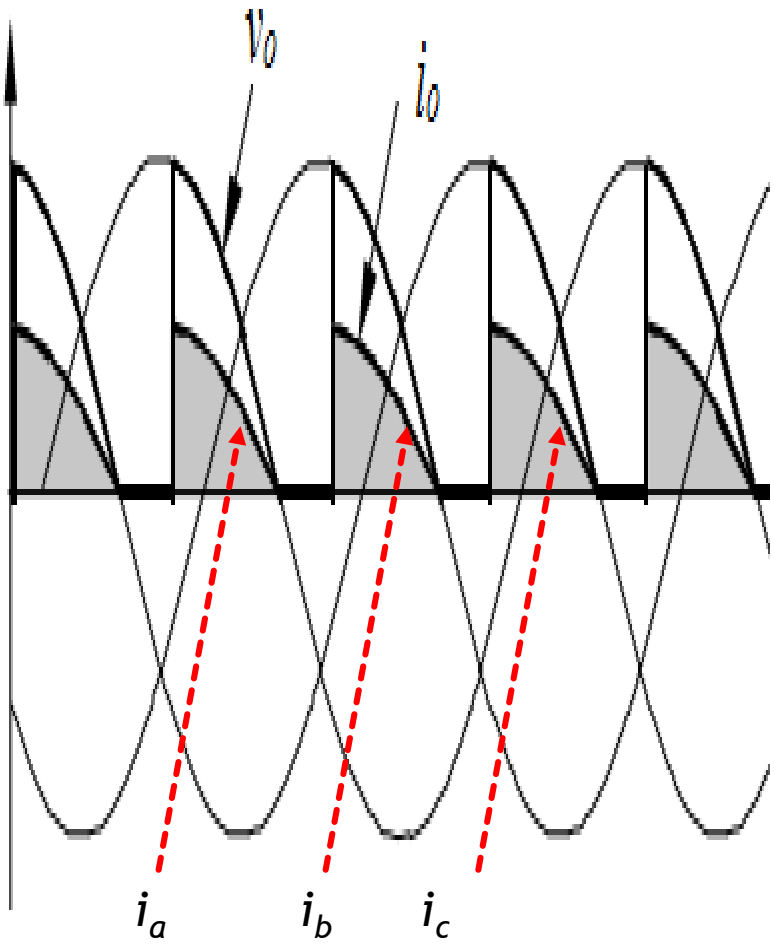
$$I_{s\ rms} = \frac{I_{o,rms}}{\sqrt{3}}$$

8- Output power

$$P_s = P_o = I_{o,rms}^2 R$$

8- Input power factor

$$pf = \frac{P_o}{S} = \frac{I_{o,rms}^2 R}{3V_s I_{o,rms} / \sqrt{3}}$$



Analysis: Highly Inductive Loads

1- Average Load Voltage and current

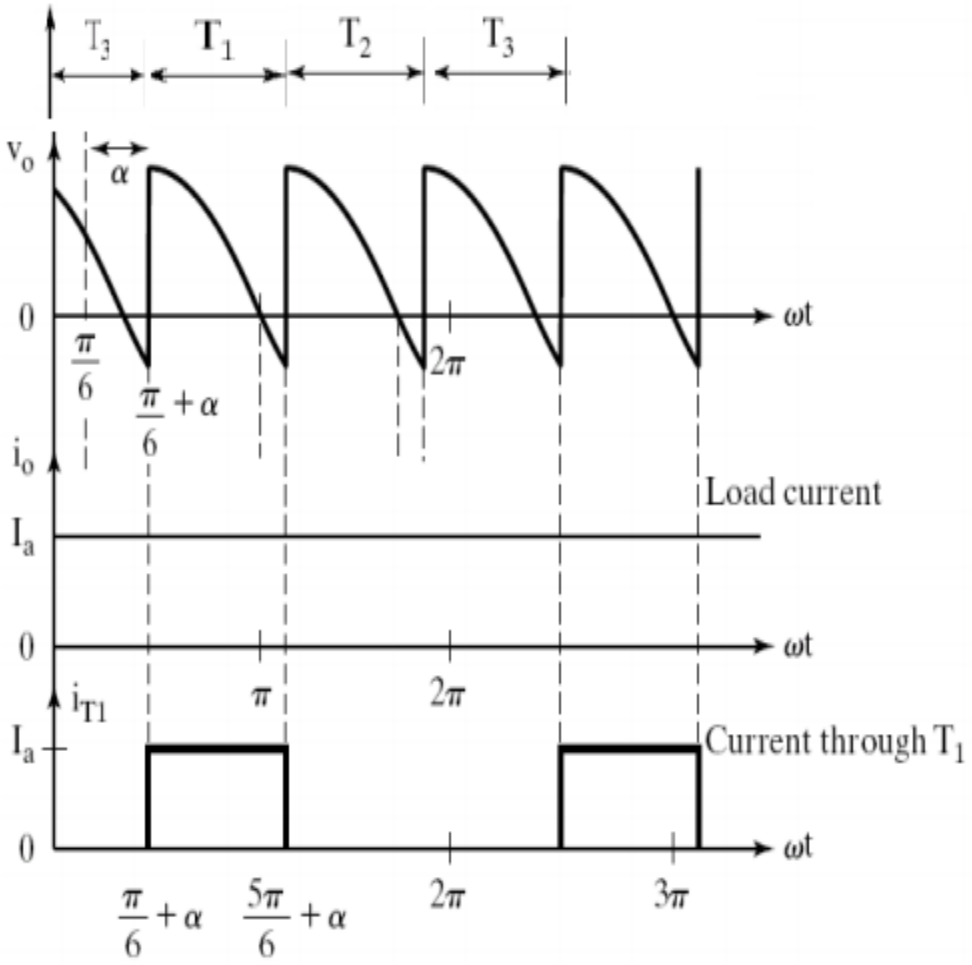
Load current is always continuous. The dc component of the output voltage is the average value, and load current is the resistor voltage divided by resistance.

$$V_{o,aavg} = \frac{3}{2\pi}\int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} V_m \sin\omega t \, d\omega t = \frac{3\sqrt{3}V_m}{2\pi}\cos\alpha$$

$$I_{o,avg} = \frac{V_{dc}}{R} = \frac{3\sqrt{3}V_m}{2\pi R}\cos\alpha$$

Comment!

$$I_{o,avg} = I_{o,rms}$$



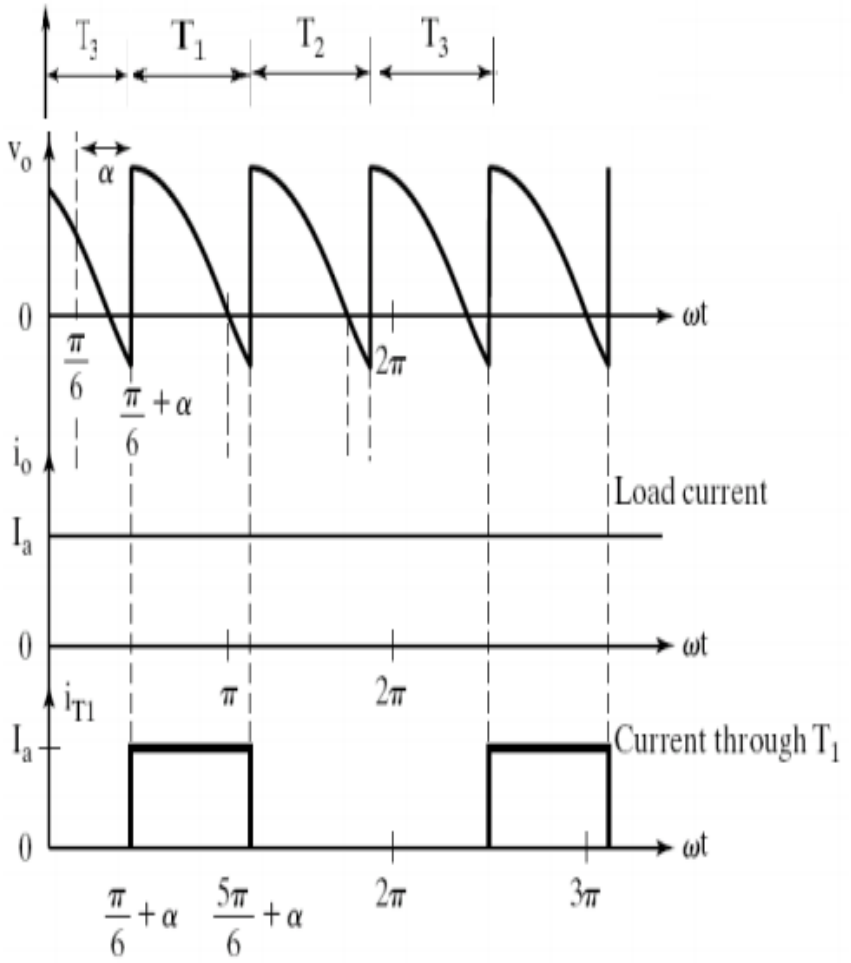
Analysis: Highly Inductive Loads

2- RMS Load voltage

$$V_{rms} = \sqrt{\frac{3}{2\pi}\int_{\frac{\pi}{6}+\alpha}^{\frac{5\pi}{6}+\alpha} (V_m sin\omega t)^2 d\omega t} = \sqrt{3}V_m\sqrt{\frac{1}{6}+\frac{\sqrt{3}}{8\pi}cos2\alpha}$$

Can we say $I_{o,rms}$=

$$I_{rms} = \frac{V_m}{\sqrt{R^2 + (\omega L)^2}}\sqrt{\frac{1}{6}+\frac{\sqrt{3}}{8\pi}cos2\alpha}$$



Analysis: Highly Inductive Loads

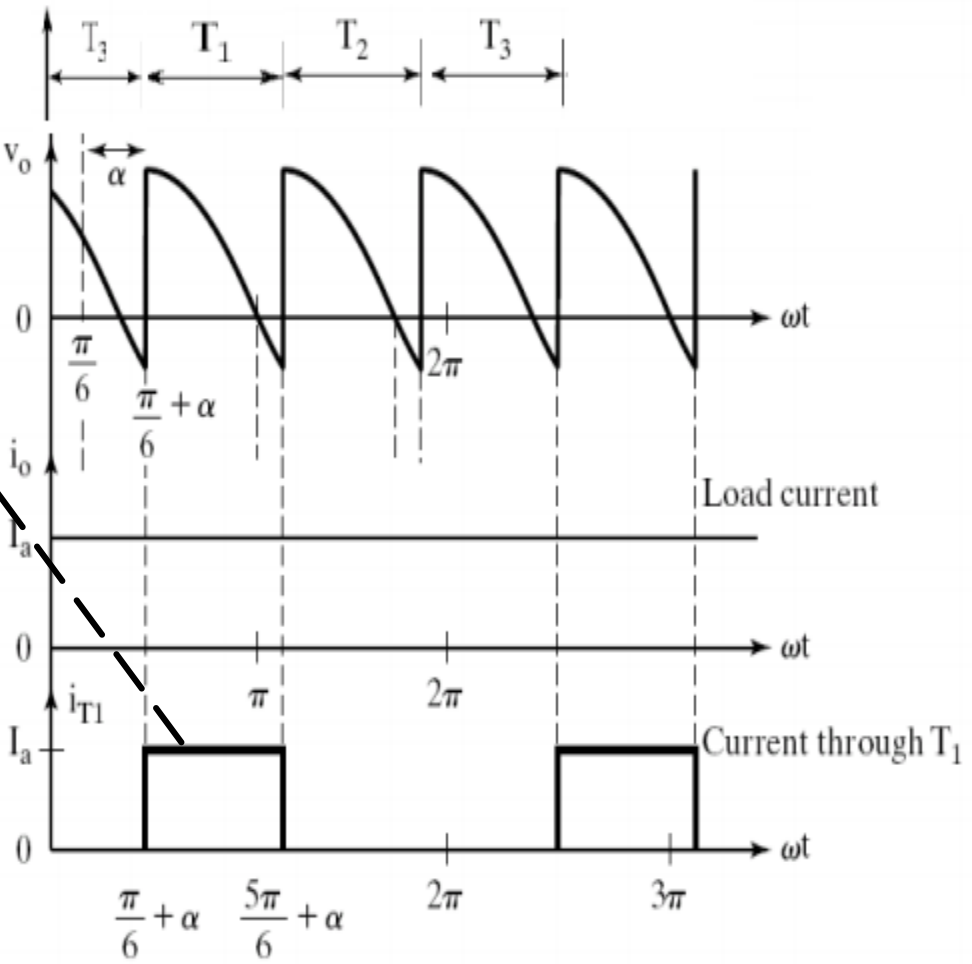
5- Average Supply currents

$$I_{a\ avg} = I_{b\ avg} = I_{c\ avg} = \frac{I_{o\ avg}}{3}$$

6- RMS supply current

Comment!

$$I_{s\ rms} = \frac{I_{o,avg}}{\sqrt{3}}$$



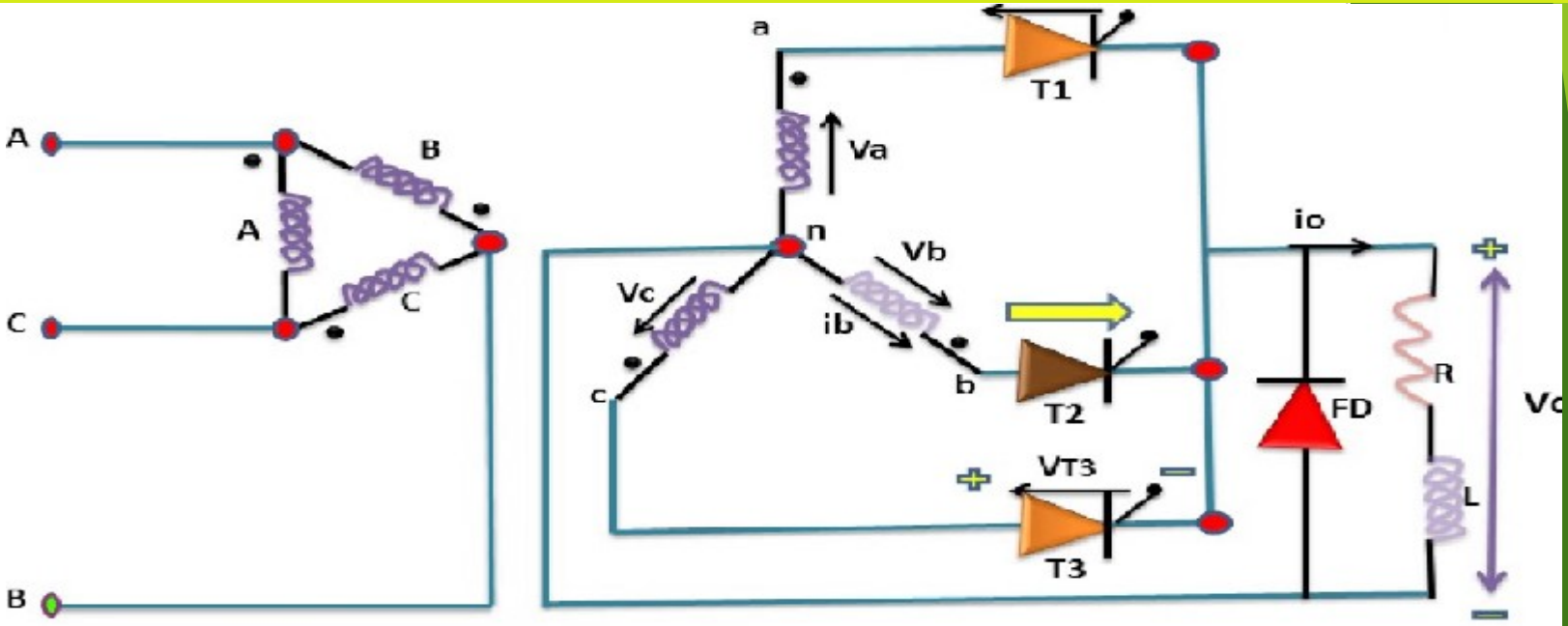
7- Output power

$$P_s = P_o = I_{o,\text{avg}}^2 R$$

8- Input power factor

$$pf = \frac{P_o}{S} = \frac{I_{o,\text{avg}}^2 R}{3V_s I_{o,avg}/\sqrt{3}}$$

Analysis: Highly Inductive Loads with freewheeling diode



$\alpha \leq \frac{\pi}{6}$ The analysis is the same as highly inductive load

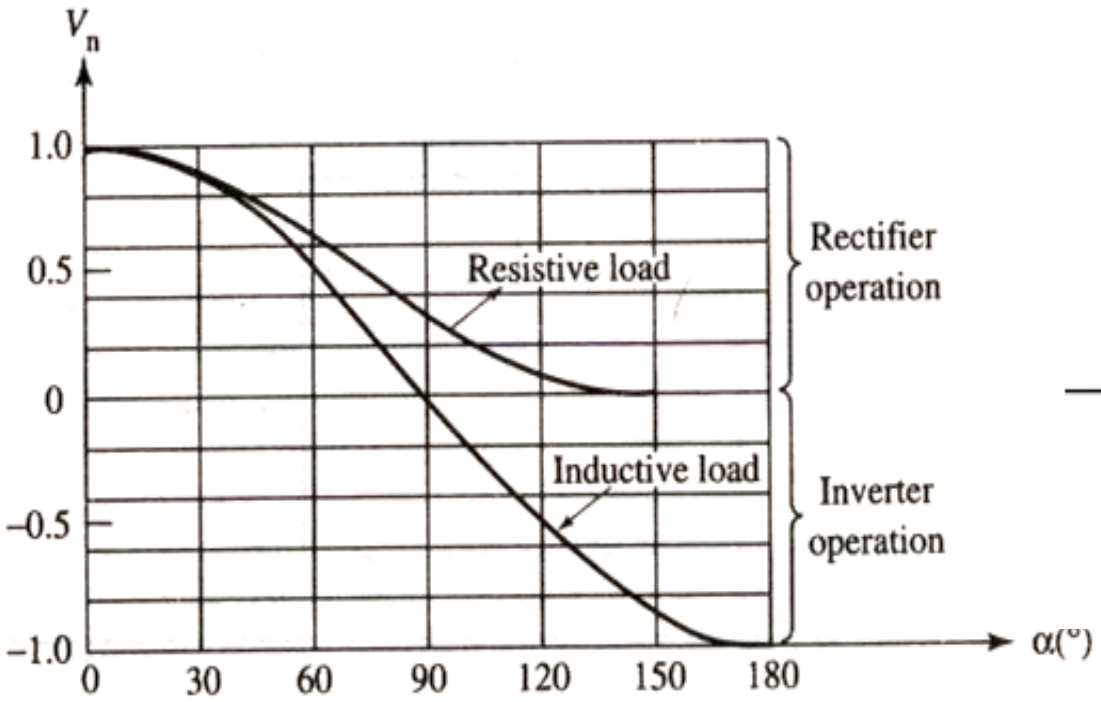
Why?

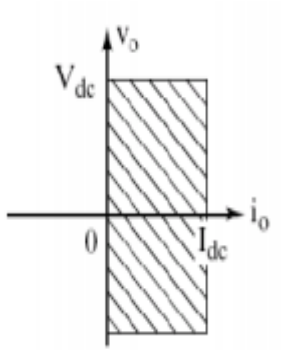
$\frac{\pi}{6} < \alpha$

- *Load voltage waveform the same as:* Controlled R-load
- *Load current waveform the same as:* Controlled RL-load

Summery

Control Charcteristics of Three-phase Half-wave controlled rectifier





(b) Quadrant

Questions

Q_1) what are the rating values of the Thyrsitors in the converter?

Q_2) Draw the waveforms of the Thyristor voltage and current

Q_3) What is the control range of α in the pervious case studies?

Q_4) Write an expression of the instantaneous load current for all pervious case studies

Q_5) what are the rating values of the freewheeling diode in the three-phase half-wave control rectifier with highly inductive loads?