POWER ELECTRONICS I

AC-DC Converters

Three-Phase Rectifiers

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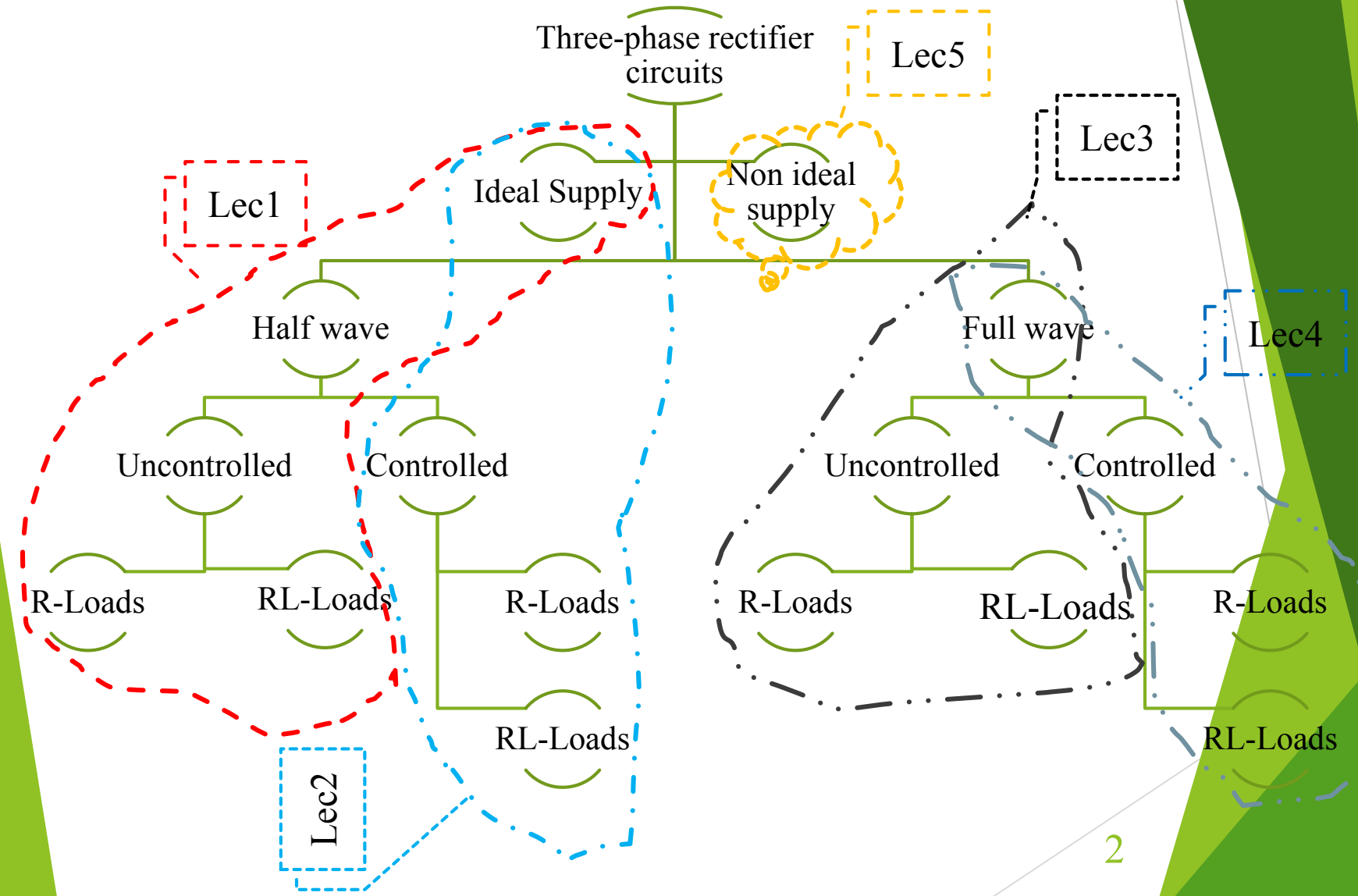
Three-phase rectifier Plan



Lec (6): Control of DC Motor and Open discussion

Lecture one: Three-phase half-wave uncontrolled rectifiers

Introduction
- Advantages
- Disadvantages
- Types in industry

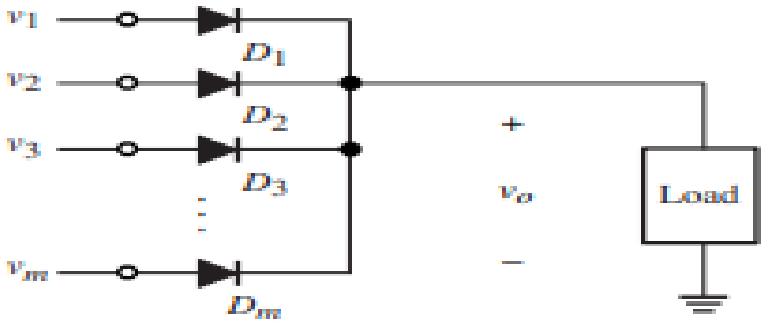
Construction
- Circuit diagram
- Components

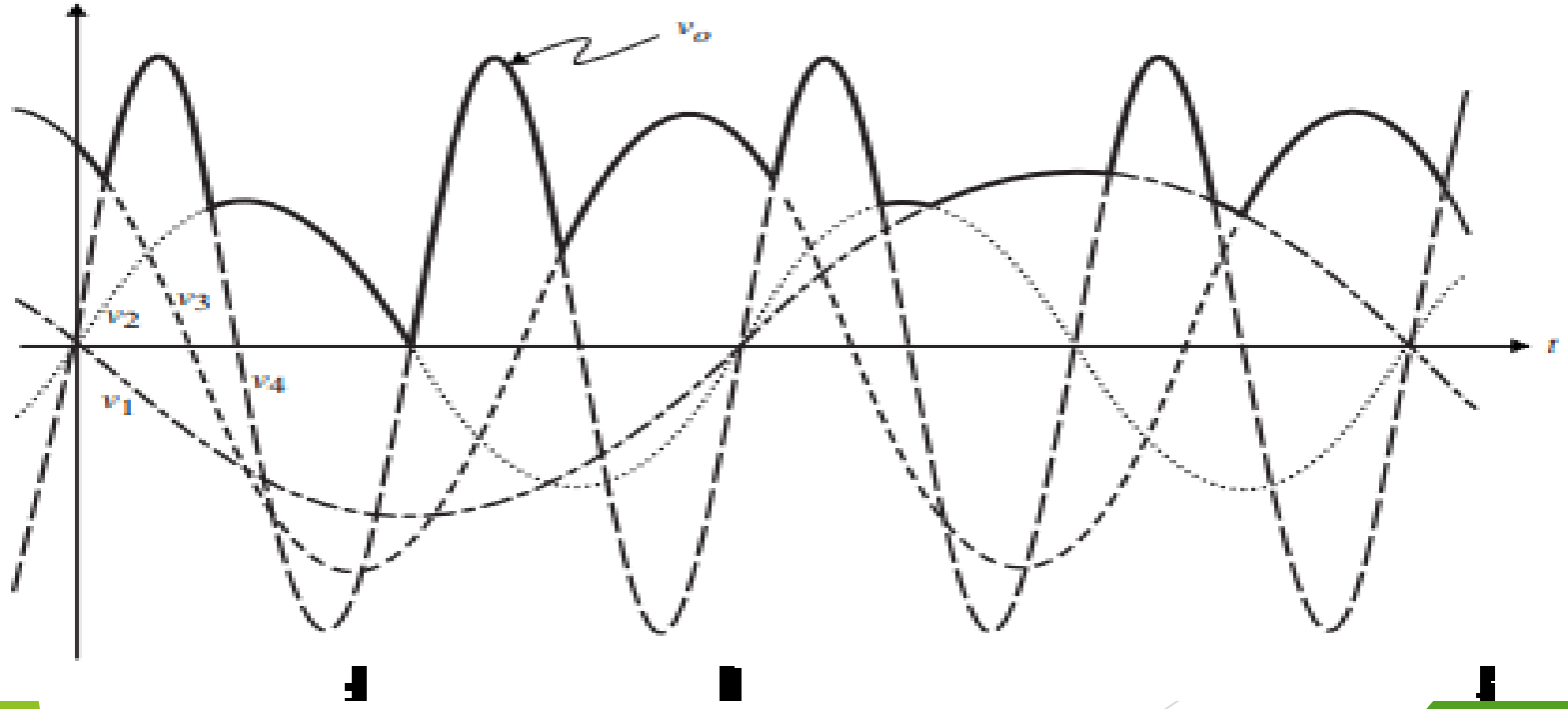
Operation
- Three-phase supply (phase voltage)
- Output waveforms

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

End
- Summery
- Questions

Main idea: Random m-phase sinusoidal input

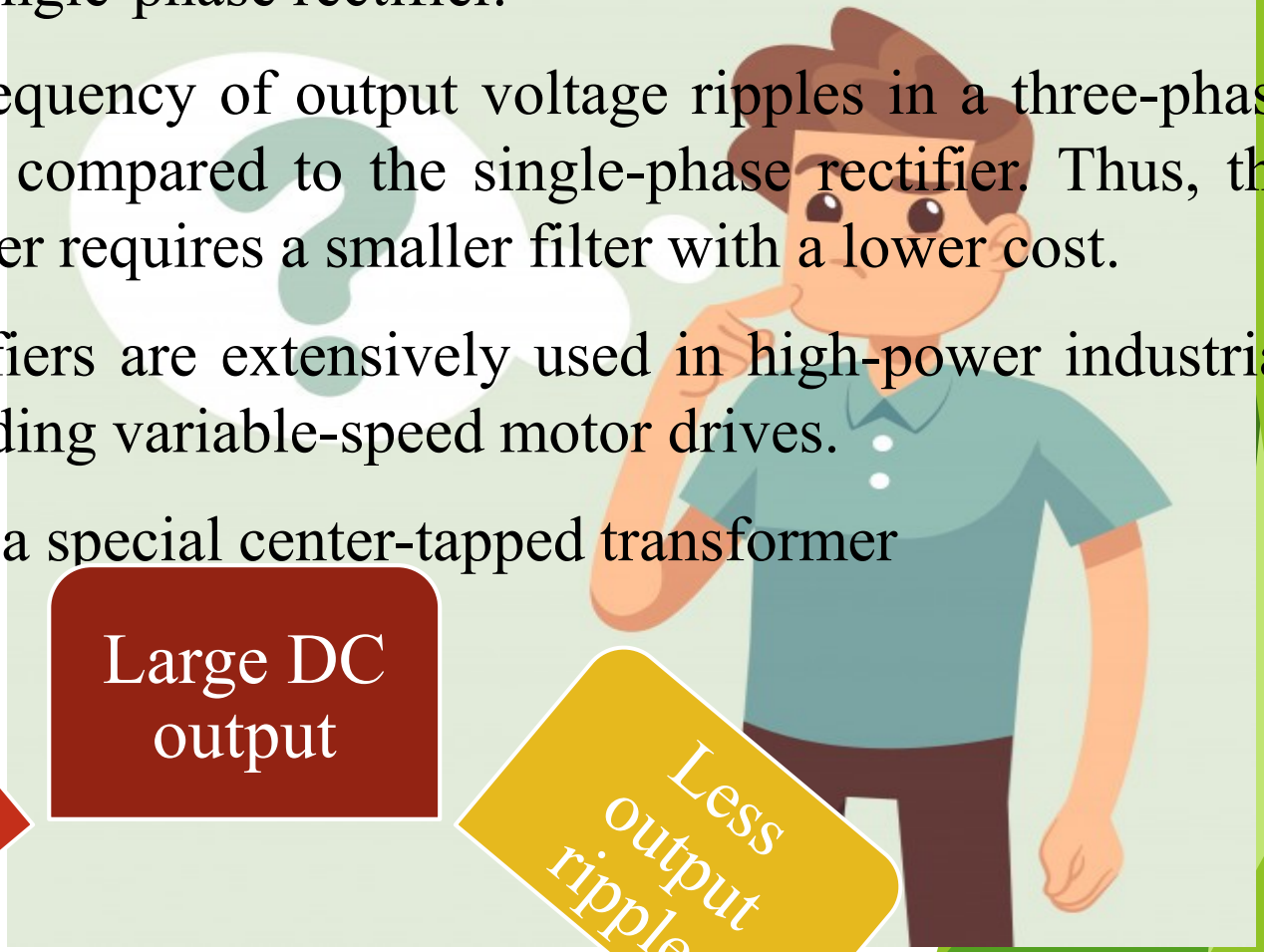




Introduction

Why three-phase rectifiers ?

- Three-phase rectifiers provide higher average output voltage compared to the single-phase rectifier.
- The harmonics frequency of output voltage ripples in a three-phase rectifier is higher compared to the single-phase rectifier. Thus, the three-phase rectifier requires a smaller filter with a lower cost.
- Three-phase rectifiers are extensively used in high-power industrial applications including variable-speed motor drives.
- It doesn't require a special center-tapped transformer



High efficiency

Large DC output

Less output ripples

Disadvantages:

- Three-phase rectifiers require higher rating of the power electronics switches (Diodes and Thyristors)
  - ✓ PIV, RMS and Average Current,….
- Higher rating switches tends to high cost and large size.
- Complex control, difficult protection, and large heatsink,

High Switch Rating

High Cost

Complex Control

Types in Industry

- 35 A , 1000V Three Phase Bridge Rectifier: (2.63$)
  - ✓ work on all battery banks.
  - ✓ work on all AC generators that produce 35 Amps or less
- 200 A 1600V Diode Bridge Rectifier:
  - ✓ High Power Rectifier Silicon Full Wave Diode Bridge Rectifier
  - ✓ Wind turbine with permanent magnet synchronous generator.

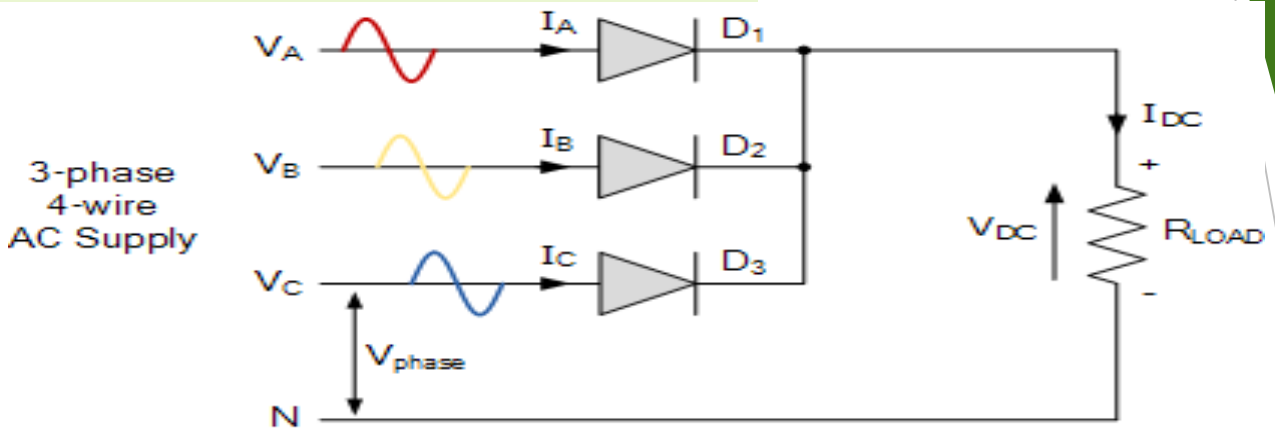
Types in Industry

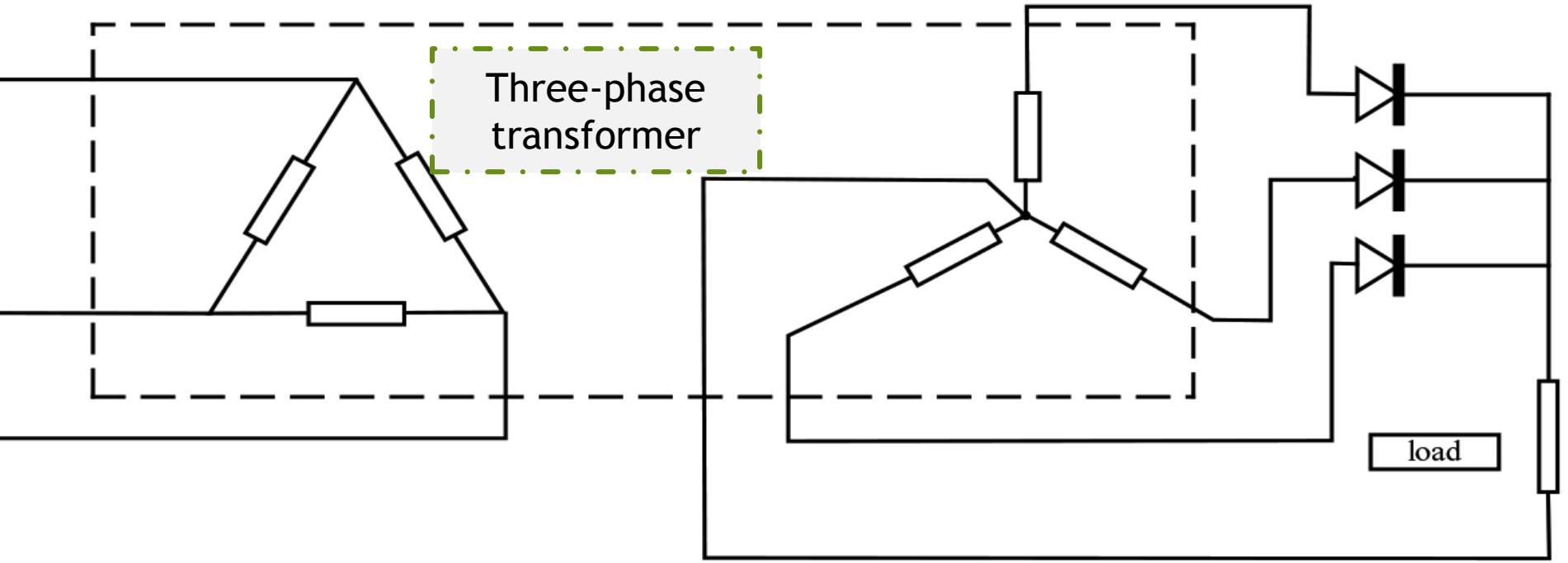
■**Maximum Ratings** (T_a=25℃ Unless otherwise specified)

PARAMETER	SYMBOL	UNIT	SKBPC3504	SKBPC3506	SKBPC3508	SKBPC3510	SKBPC3512	SKBPC3514	SKBPC3516
Device marking code			SKBPC3504	SKBPC3506	SKBPC3508	SKBPC3510	SKBPC3512	SKBPC3514	SKBPC3516
Repetitive Peak Reverse Voltage	V_{RRM}	V	400	600	800	1000	1200	1400	1600
Average Rectified Output Current @60Hz sine wave, R-load, With heatsink Tc=55℃	I_O	A	35						
Surge(Non-repetitive)Forward Current @60Hz Half- sine Wave, 1 cycle, T_a=25℃	I_{FSM}	A	400						
Current Squared Time @1ms≤t<8.3ms Tj=25℃, Rating of per diode	I^2t	A^2S	664						
Storage Temperature	T_{stg}	℃	-55 ~+150						
Junction Temperature	T_j	℃	-55 ~+150						

Construction

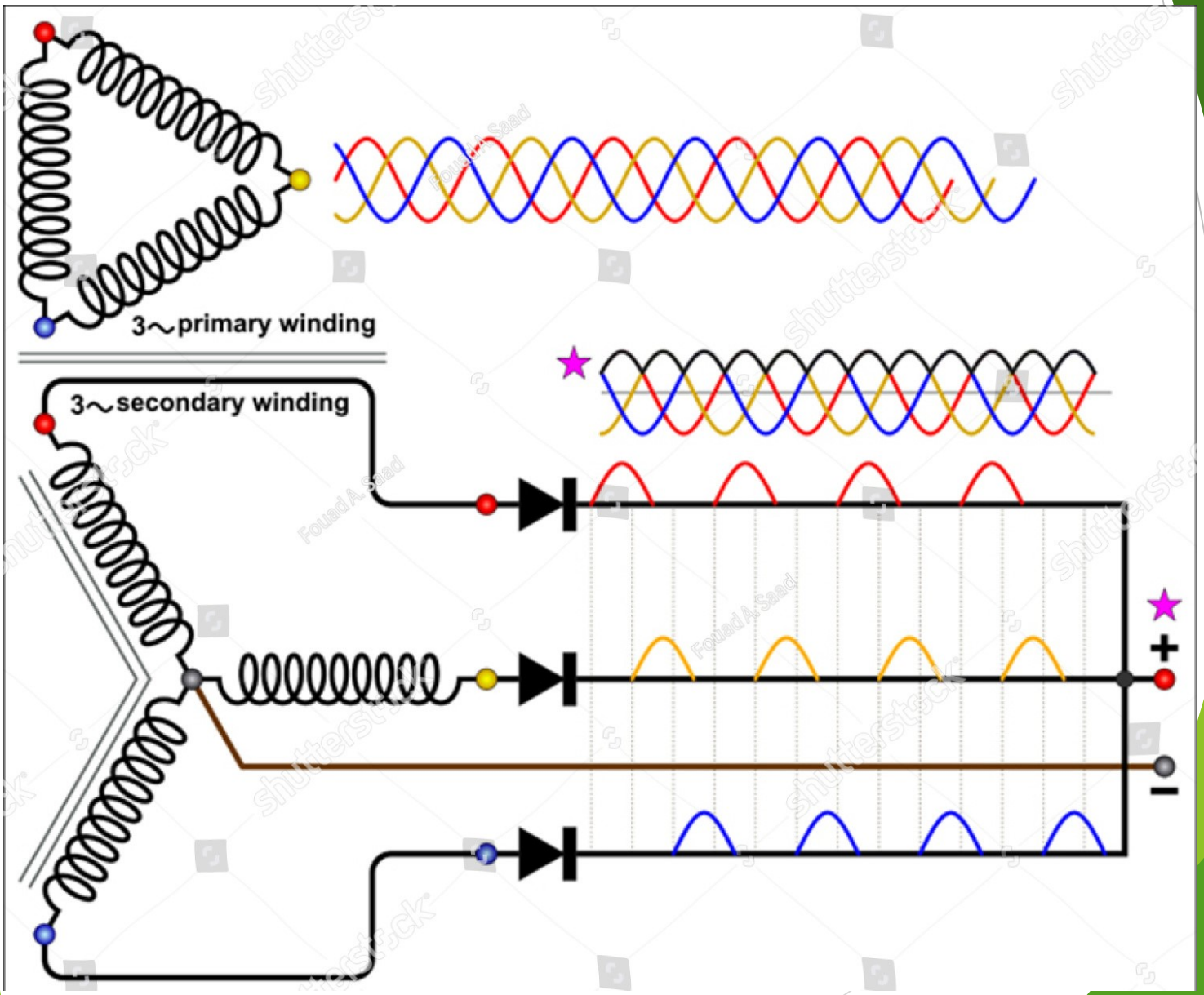
Power circuit and its components





Operation

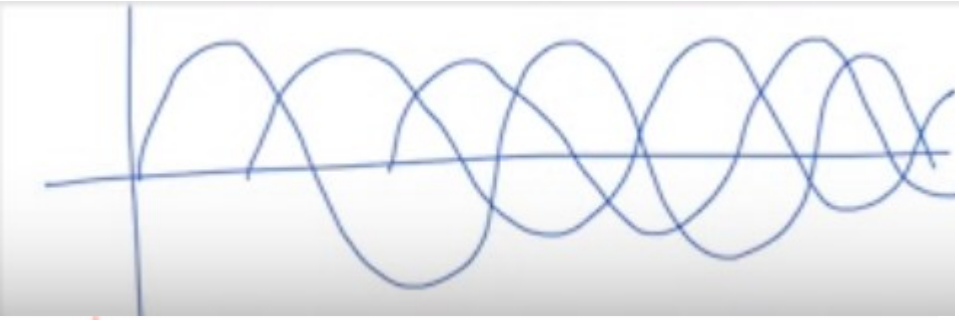
Output voltage

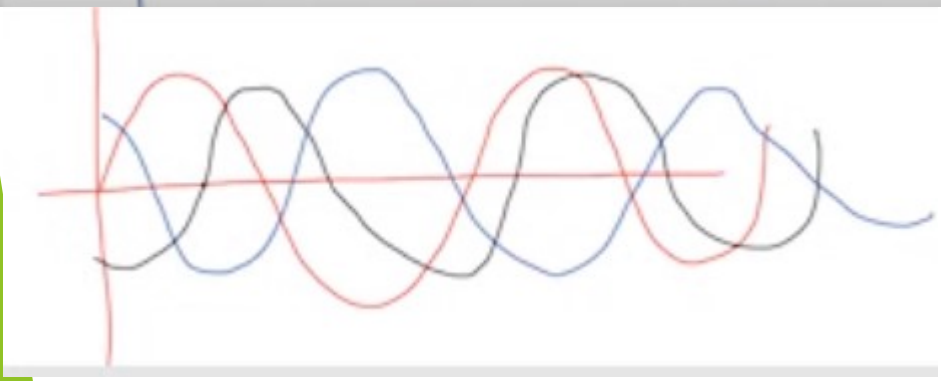


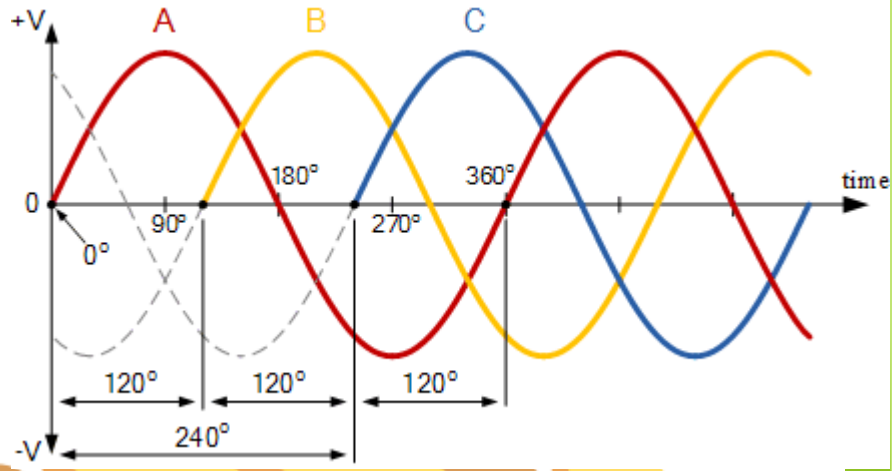
Operation

Draw three-phase waveforms

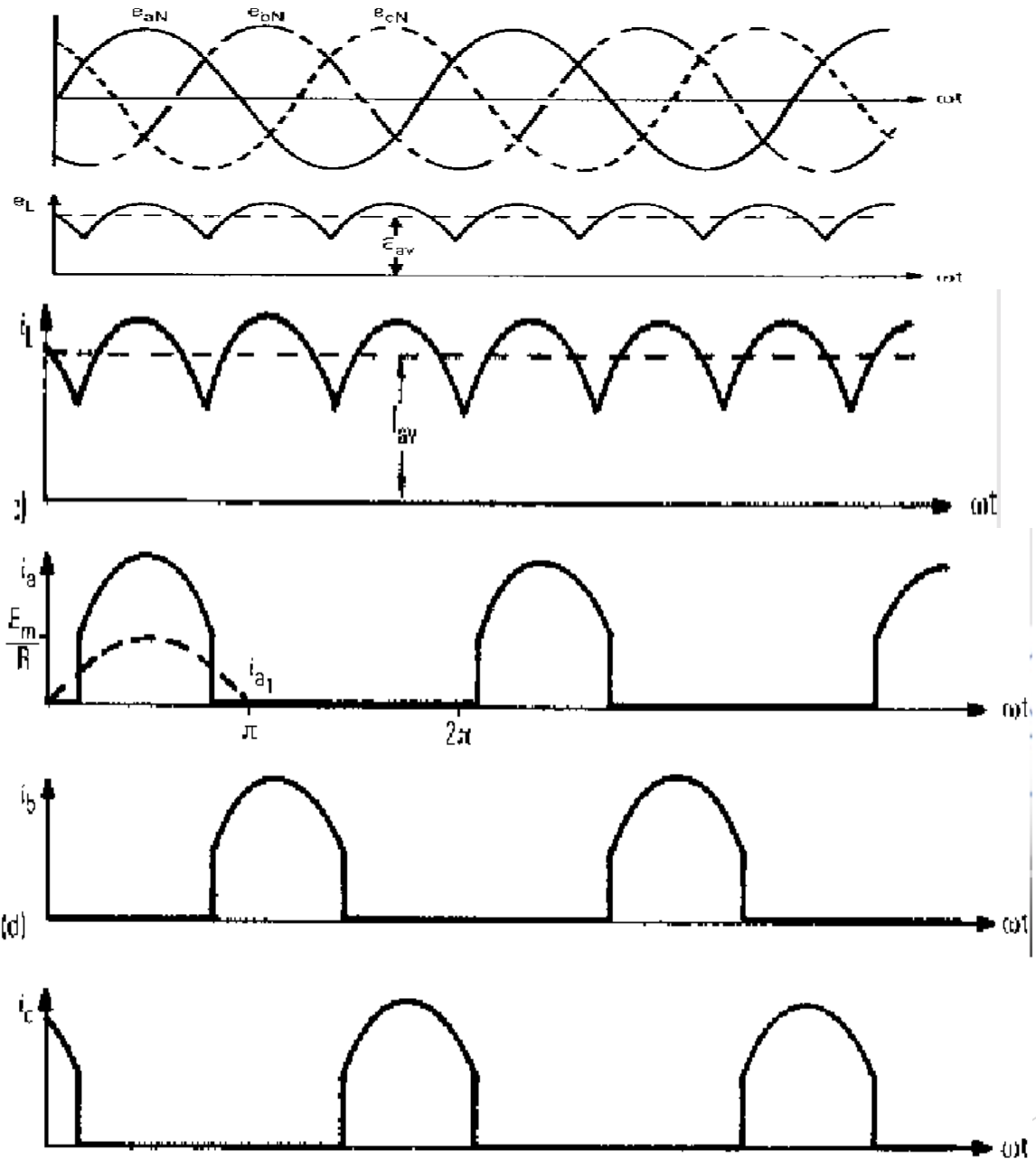
Drawing of some students :

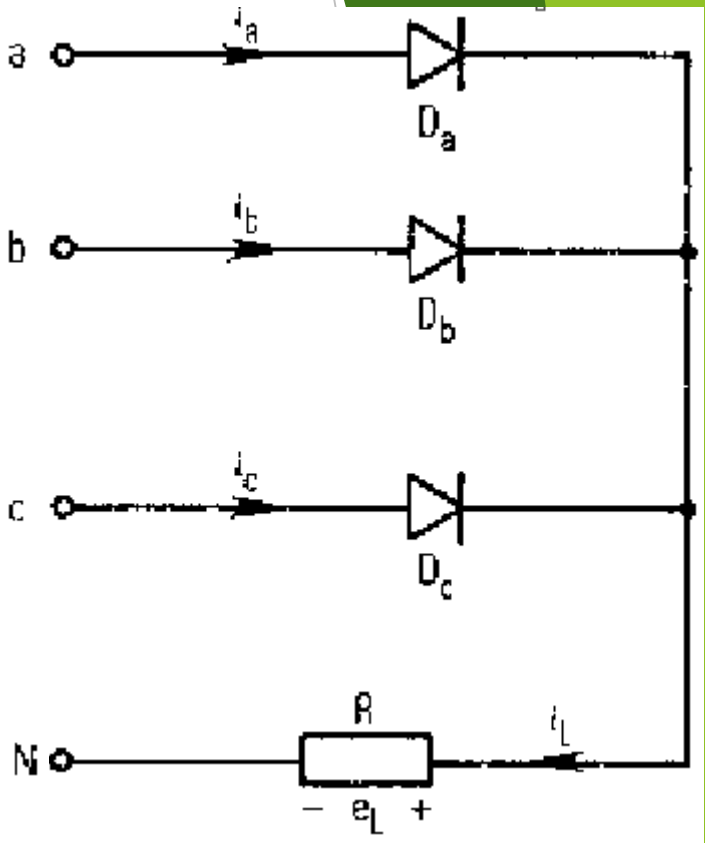


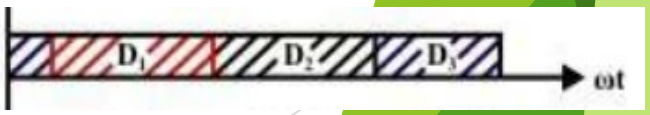




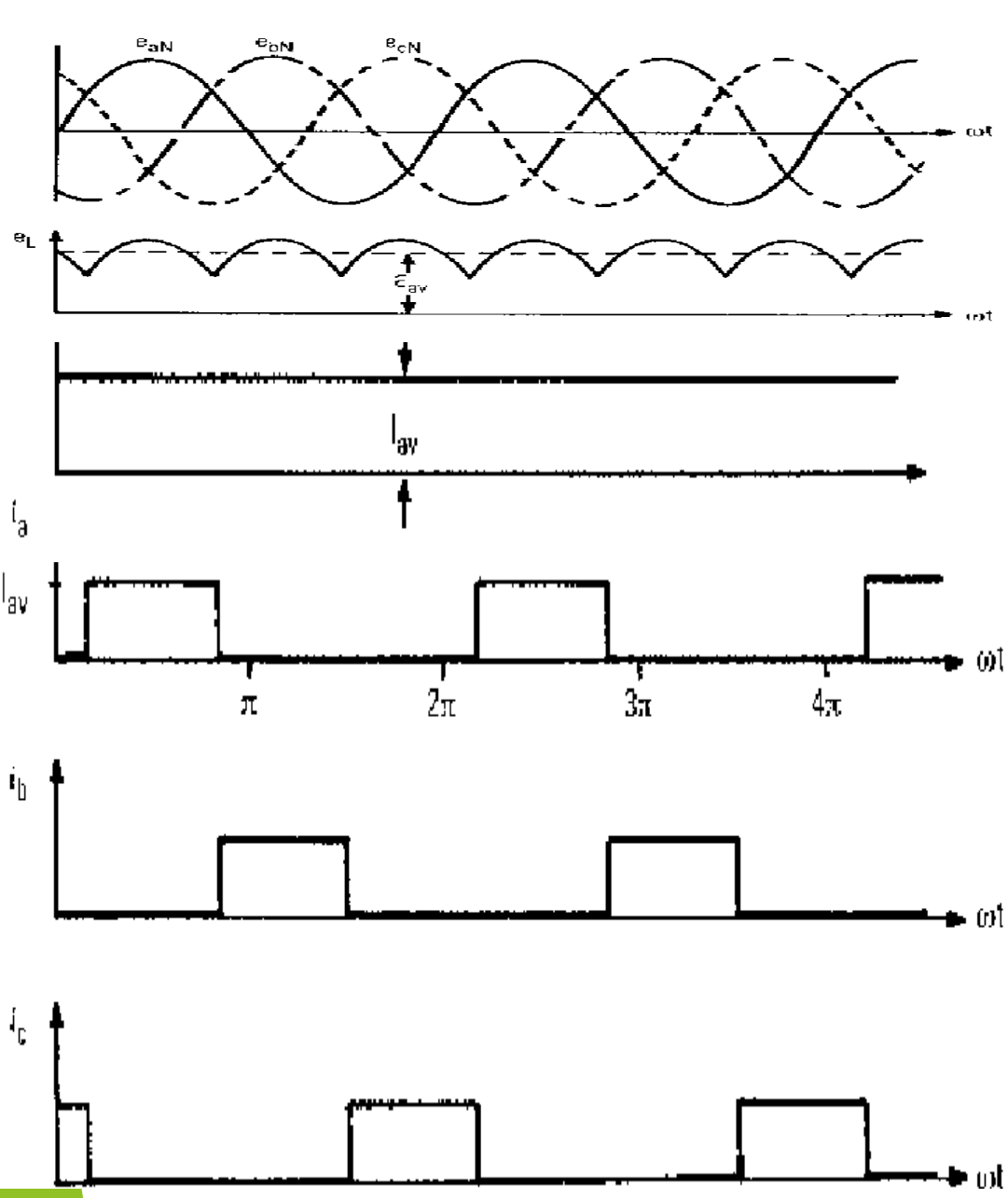
Operation: Resistive Loads

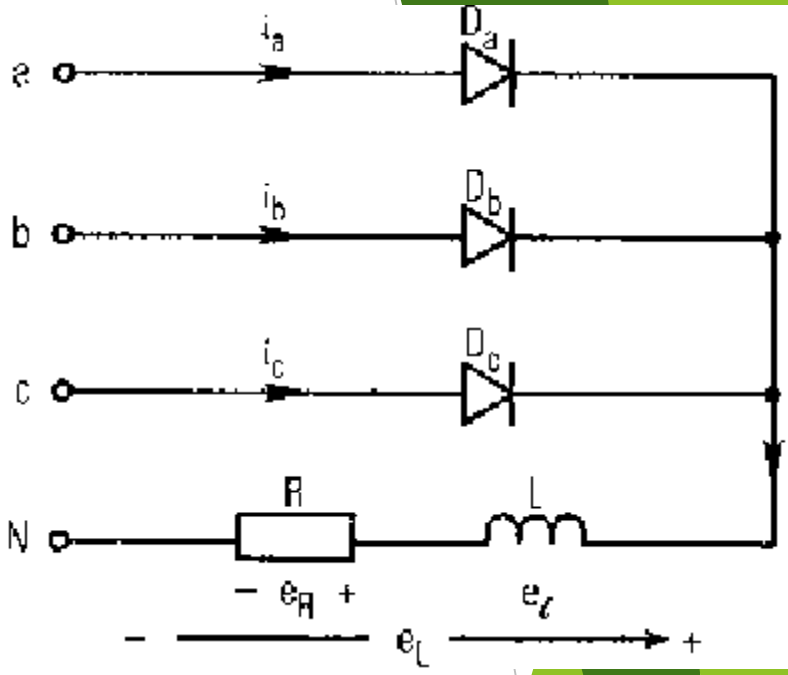






Operation: Highly Inductive Loads





Analysis: Resistive Loads

1- Supply voltages:

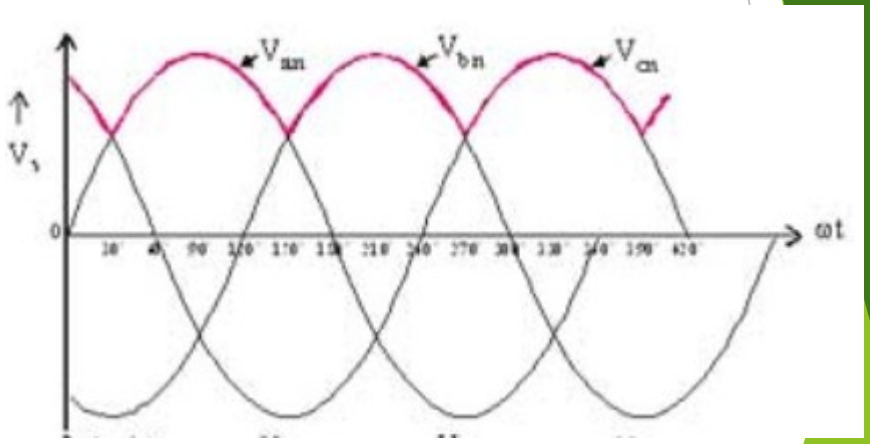
$V_a(\omega t)=V_m\sin(\omega t)$,
$V_b(\omega t)=V_m\sin(\omega t-2\pi/3)$
$V_c(\omega t)=V_m\sin(\omega t-4\pi/3)$

2- Average Load Voltage

$$V_{o,avg} = \frac{3}{2\pi}\int_{\pi/6}^{5\pi/6} V_a(\omega t)d\omega t$$

$$= \frac{3}{2\pi}\int_{5\pi/6}^{3\pi/2} V_b(\omega t)d\omega t$$

$$= \frac{3}{2\pi}\int_{3\pi/2}^{13\pi/6} V_c(\omega t)d\omega t$$



$$V_{o,avg} = \frac{3\sqrt{3}V_m}{2\pi}$$

$$V_{o,avg} = \frac{3\sqrt{6}V_s}{2\pi}$$

$$V_{o,avg} = 1.169V_s$$

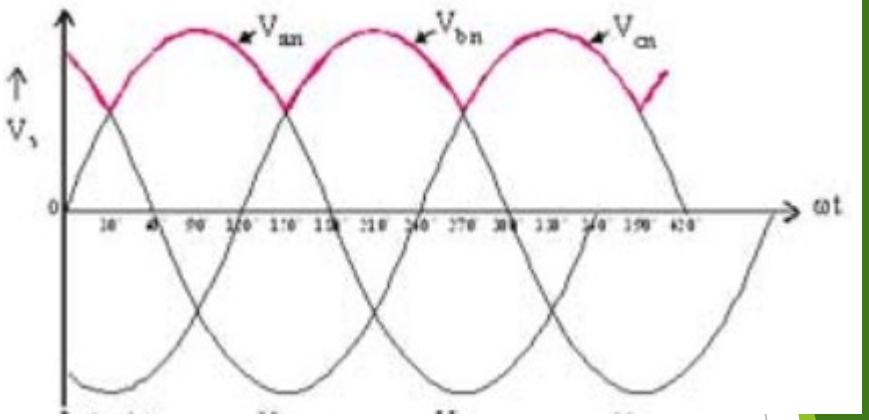
Comment!

Analysis: Resistive Loads

3- RMS Load voltage

$$V_{o.rms} = \left[\frac{3}{2\pi}\int_{\pi/6}^{5\pi/6} 2V_s^2 \sin^2\omega t \, d(\omega t)\right]^{\frac{1}{2}}$$

$$= \left[1 + \frac{3\sqrt{3}}{4\pi}\right]^{\frac{1}{2}} V_S$$



4- Average load current

$$I_{o\ avg} = \frac{Vo,avg}{R} = \frac{3\sqrt{3}V_m}{2\pi R}$$

5- RMS Load current

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

Analysis: Resistive Loads

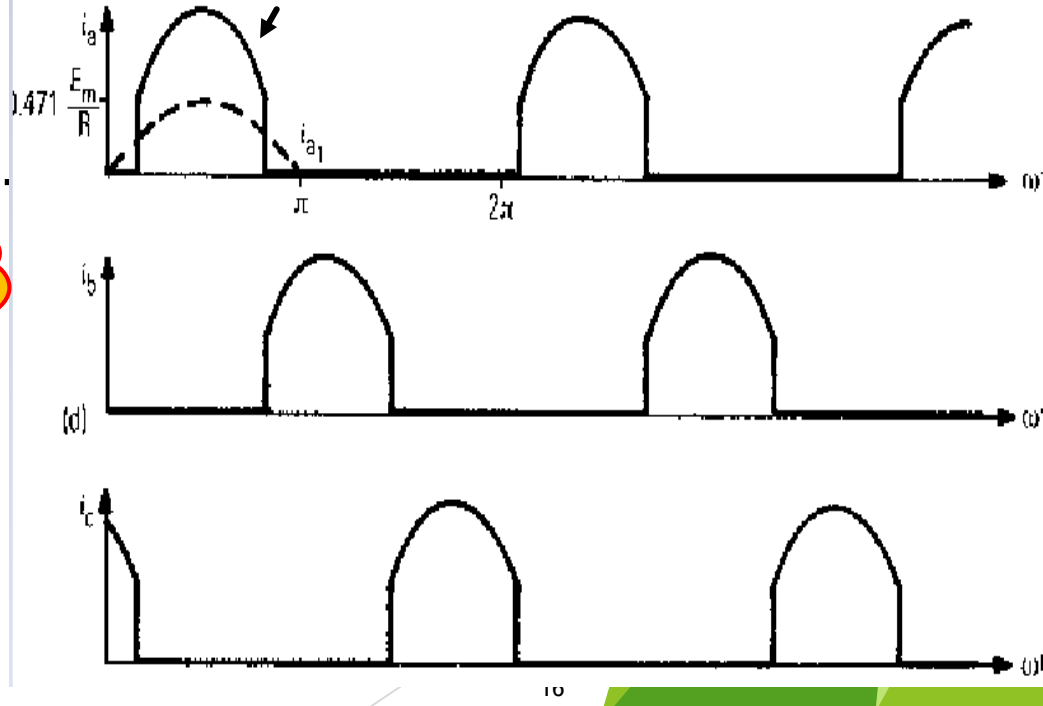
6- Average Supply currents

Comment!

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

7- RMS supply current

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



8- Output power

Comment!

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

9- 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

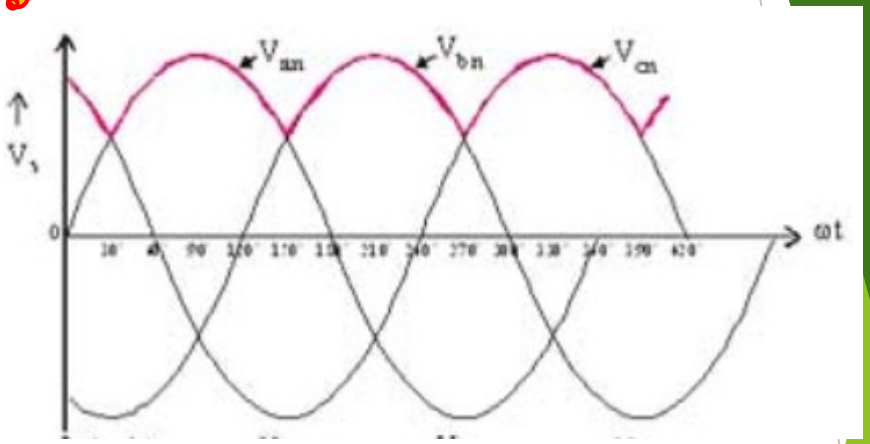
1- Average Load Voltage

Comment!

$$V_{o,\ avg} = \frac{3\sqrt{3}V_m}{2\pi}$$

$$V_{o,\ avg} = \frac{3\sqrt{6}V_s}{2\pi}$$

$$V_{o,\ avg} = 1.169V_s$$

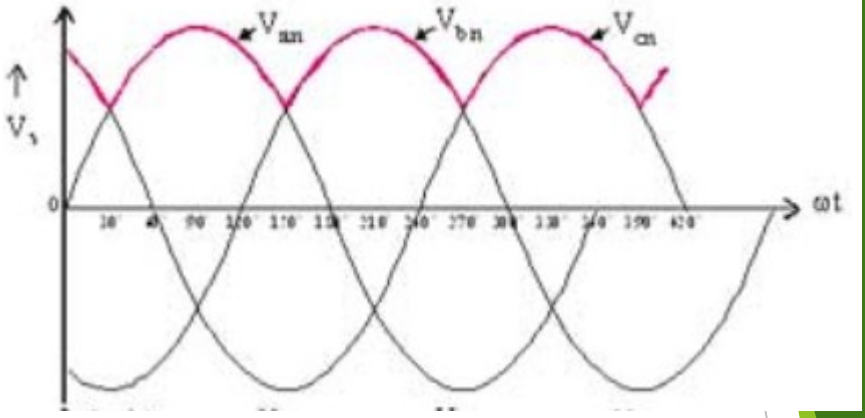


Analysis: Highly Inductive Loads

2- RMS Load voltage

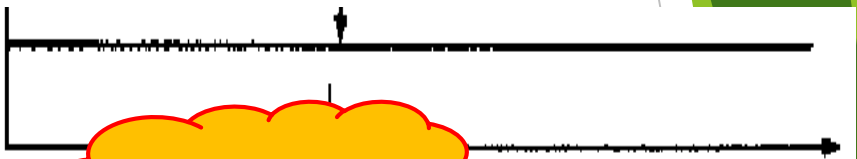
$$V_{o.rms} = \left[\frac{3}{2\pi}\int_{\pi/6}^{5\pi/6} 2V_s^2 \sin^2\omega t \, d(\omega t)\right]^{\frac{1}{2}}$$

$$= \left[1 + \frac{3\sqrt{3}}{4\pi}\right]^{\frac{1}{2}} V_S$$



3- Average load current

$$I_{o\ avg} = \frac{Vo,avg}{R} = \frac{3\sqrt{3}V_m}{2\pi R}$$



Comment!

Comment!

4- RMS Load current

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

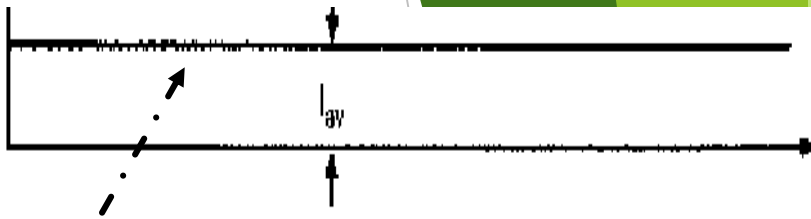
Converter efficiency:

$$\eta = \frac{P_{dc}}{P_{o,rms}} = \frac{V_{o,avg}\, I_{o,avg}}{V_{o,rms} I_{o,rms}}$$

Analysis: Highly Inductive Loads

5- Average Supply currents

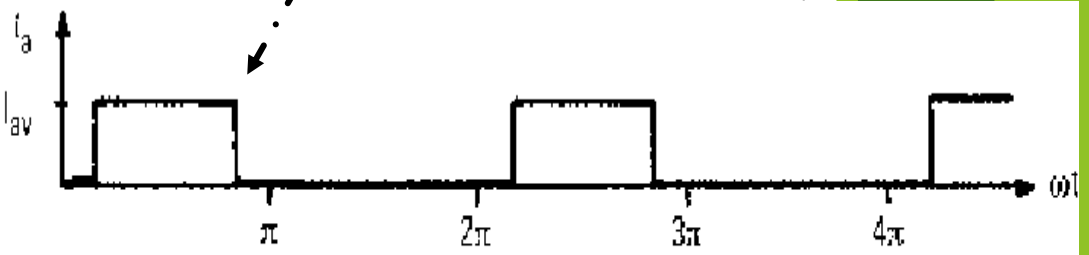
$$I_{a\ avg} = I_{b\ avg} = I_{c\ avg} = \frac{I_{o\ avg}}{3}$$



Comment!

6- RMS supply current

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



7- Output power

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

8- Input power factor

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

Summery

	R-Load	Highly inductive load
$V_{o,avg}$	The same waveforms so the same average values $V_{o,avg} = \frac{3\sqrt{3}V_m}{2\pi}$	
$V_{o,rms}$	$= \left[1 + \frac{3\sqrt{3}}{4\pi}\right]^{\frac{1}{2}} V_S$	
$I_{o,avg}$	$I_{o,avg} = \frac{Vo,avg}{R} = \frac{3\sqrt{3}V_m}{2\pi R}$	
$I_{o,rms}$	$V_{o,rms}/R$	$I_{o,avg}$
$I_{s,avg}$	$I_{o,avg}/3$	
$I_{s,rms}$	$I_{o,rms}/sqrt(3)$	$I_{o,avg}/sqrt(3)$

Questions

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