POWER ELECTRONICS I

AC-DC Converters

Three-Phase Rectifiers

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Questions Lecture Four

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

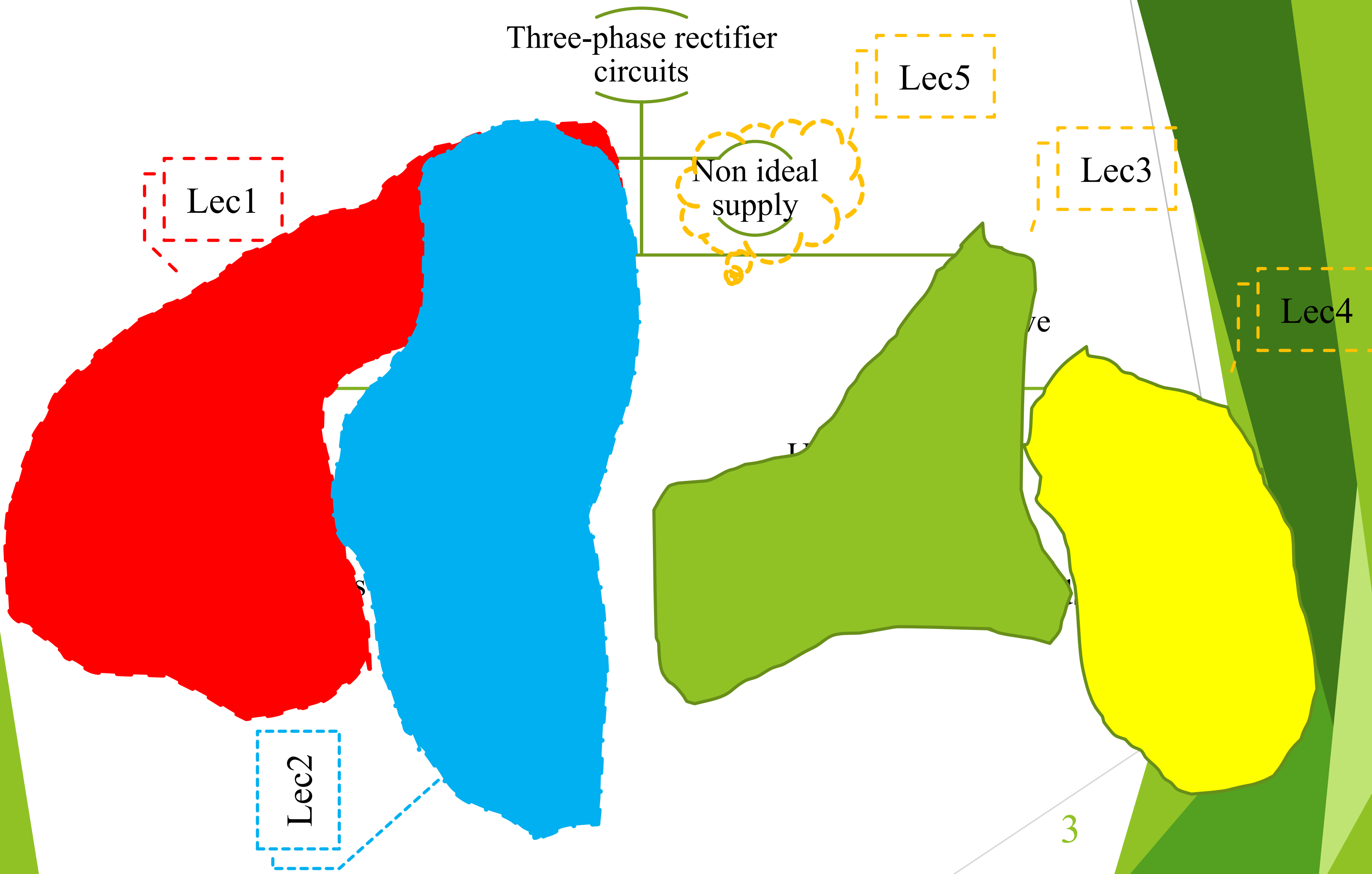
Q_2) Draw a relation between the rectification efficiency and firing angles for R-load and highly inductive loads.

Q_3) Draw a relation between the average output voltage and firing angles for R-load and highly inductive loads.

Q_4) Draw the load voltage and current waveforms if a freewheeling diode is connected incase RL-loads.

Q_5) Draw the load voltage and current waveforms at for RL-loads if T2, T4, T6 are replaced with diodes At $\alpha = 30, 60, 90$

Three-phase rectifier Plan



Lecture three: Three-phase half-wave rectifiers with noni deal supply

Construction
- Circuit diagram
- Components

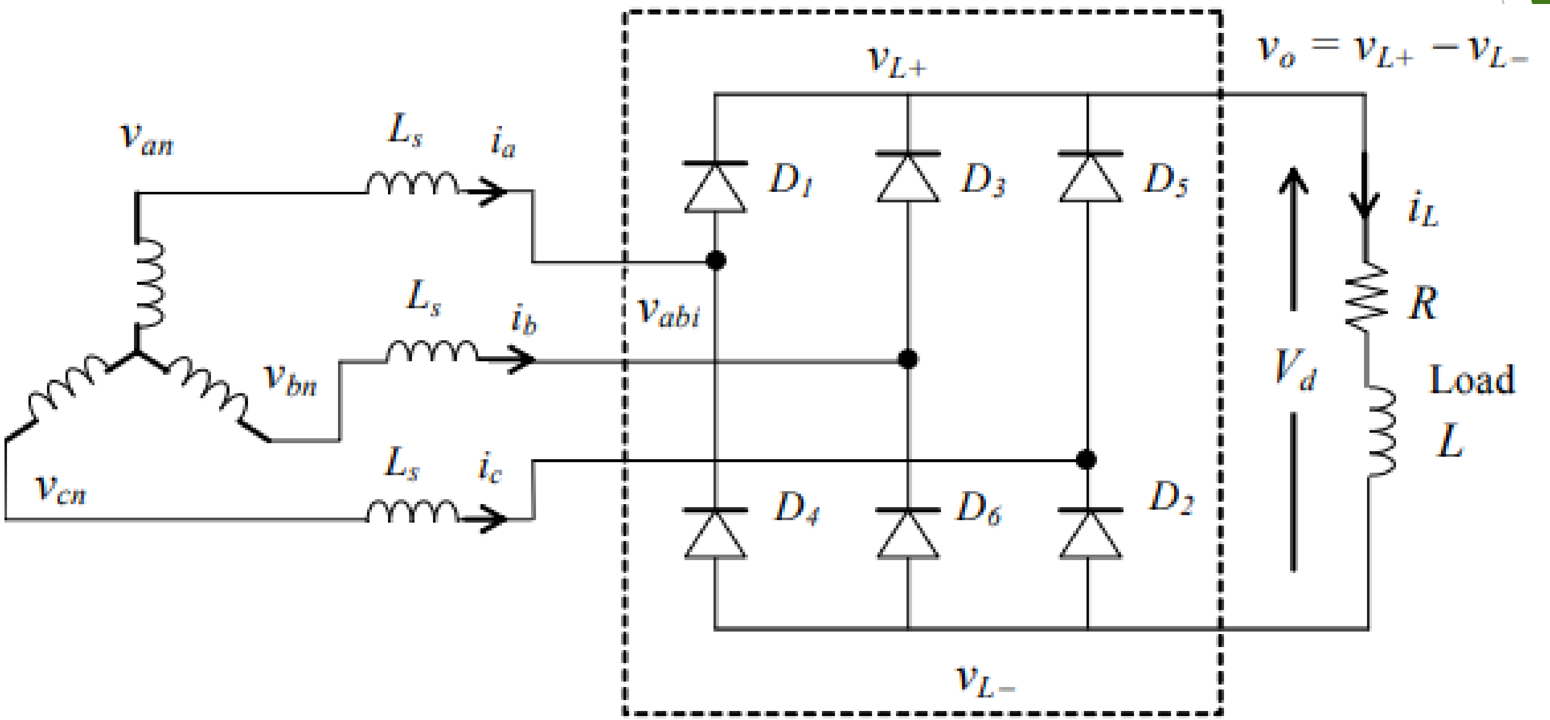
Operation
- Output waveforms with highly inductive load.

Analysis
- Analysis of three-phase half wave controlled circuit
- Analysis of three-phase half wave uncontrolled circuit

End
- Summery
- Questions

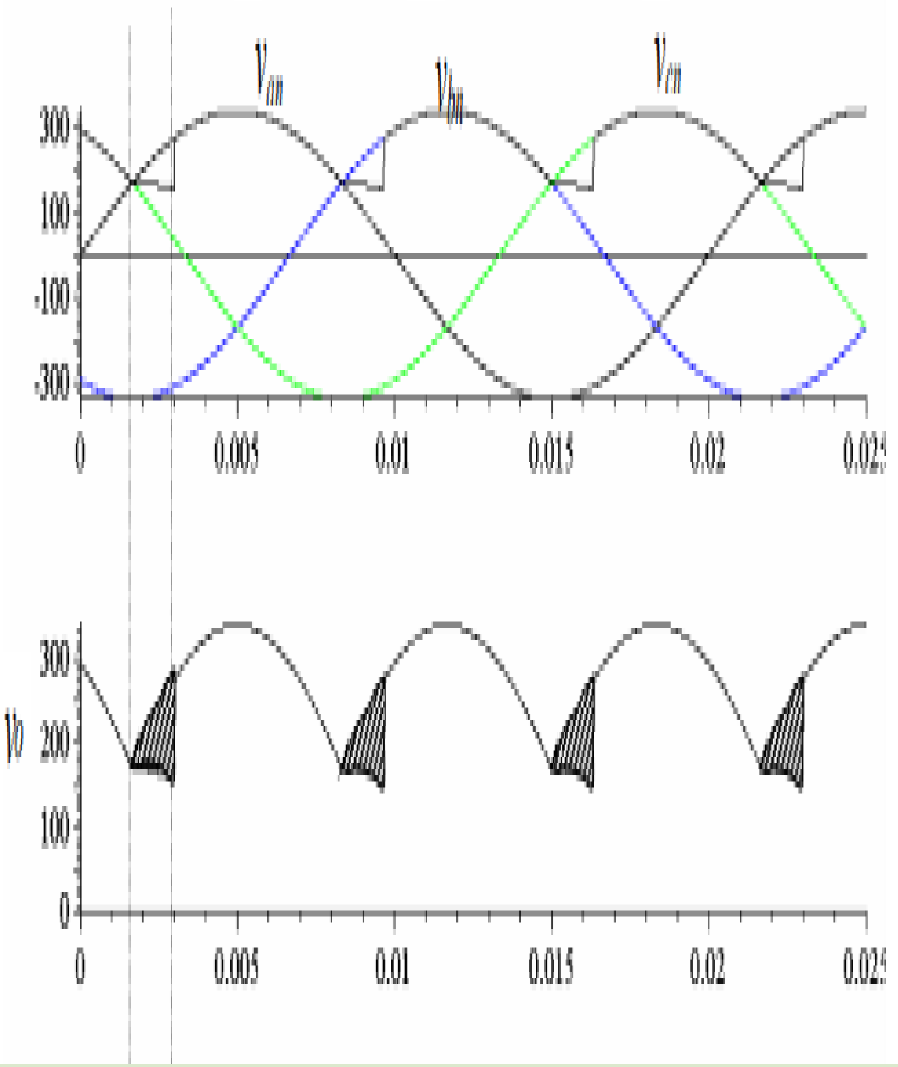
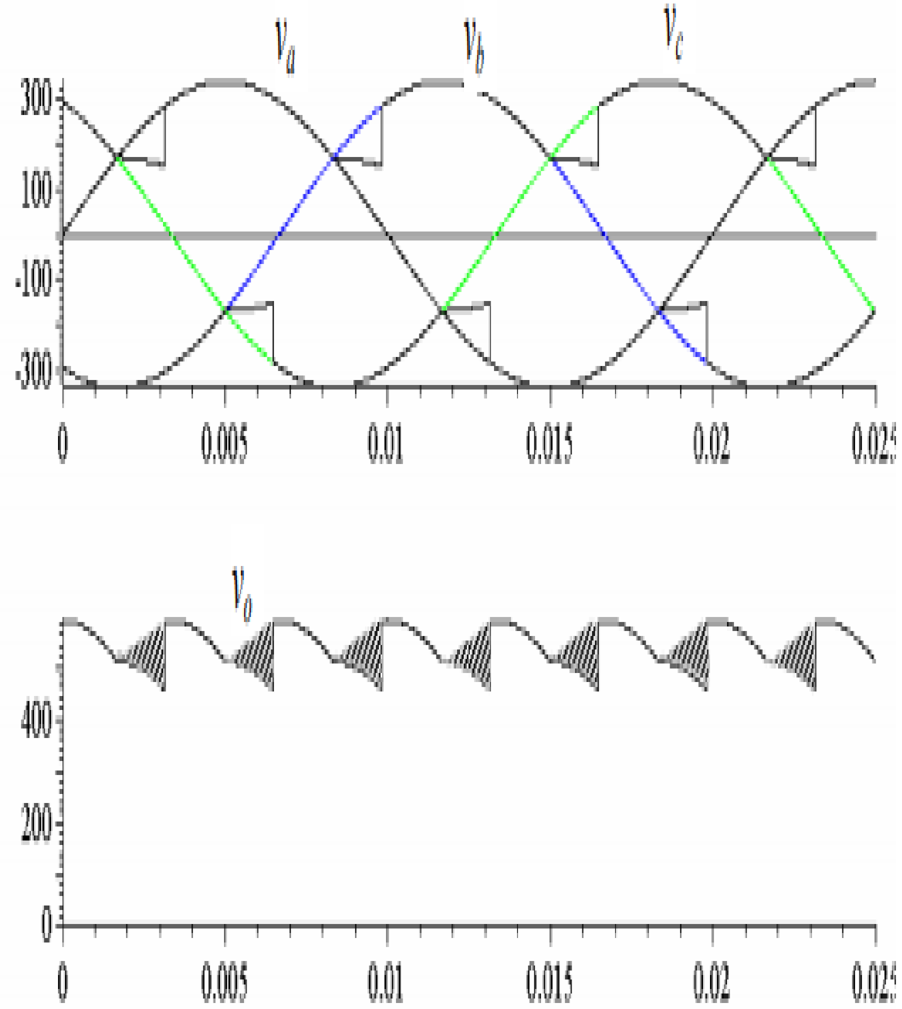
Construction

Power circuits and its components



Operation

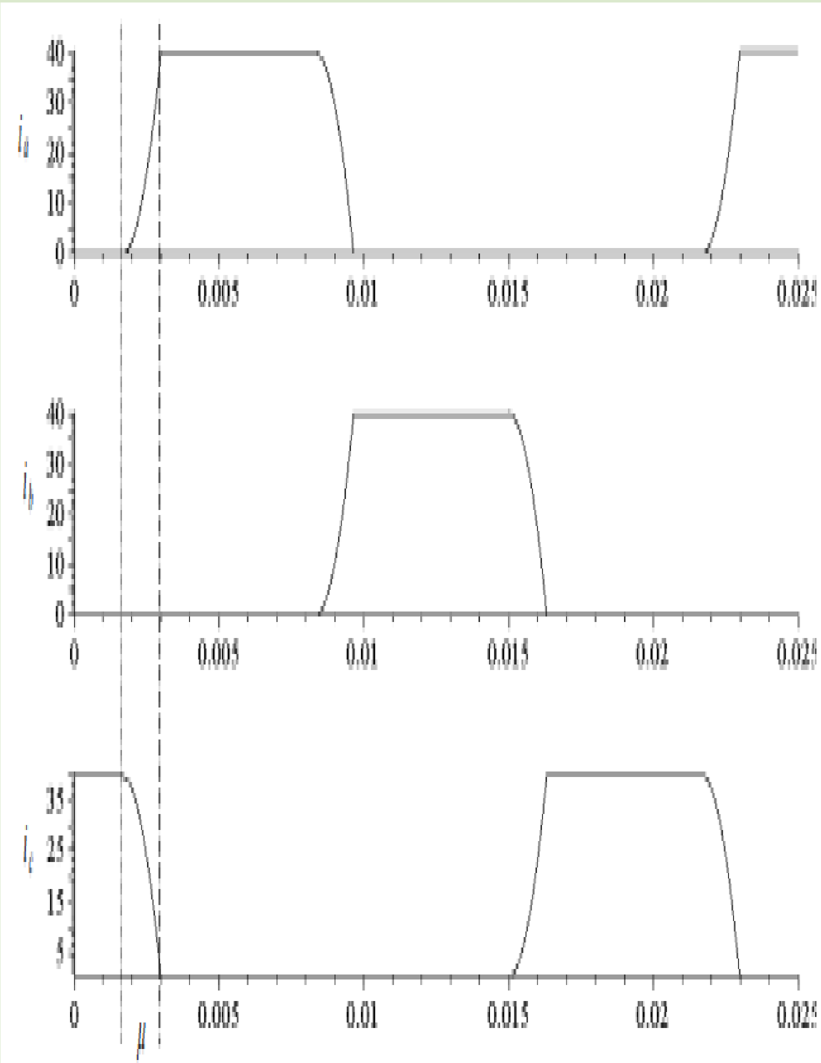
Output Voltage waveforms

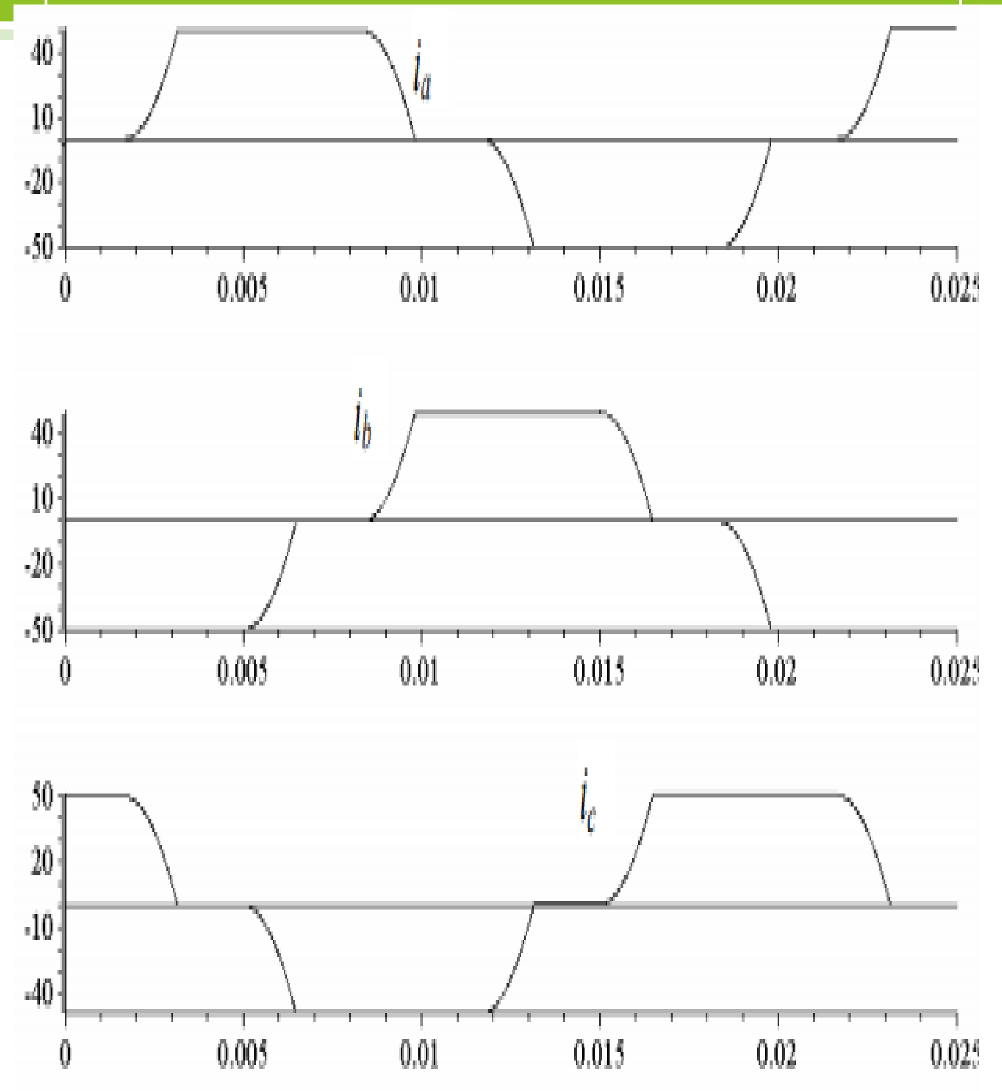
Half-wave	Full-wave
	

Operation

Currents waveforms

Half-wave	Full-wave

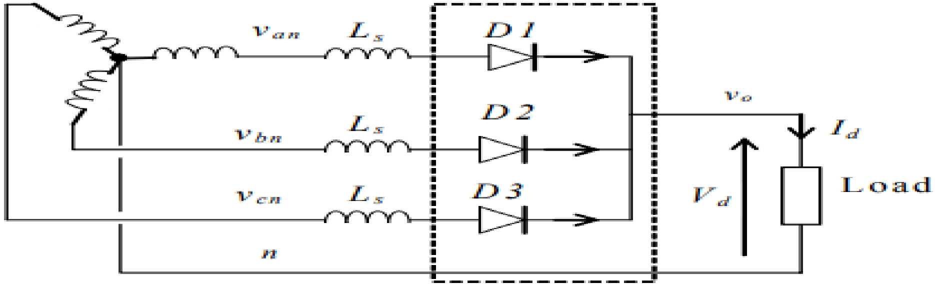




Analysis: Half-wave rectifier

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- Output Load voltage

During the overlap period 0:μ

$$v_{an} = L_s \frac{di_a}{dt} + v_o$$

$$v_{bn} = L_s \frac{di_b}{dt} + v_o$$

Assuming that I_d remains constant during the overlap time, so

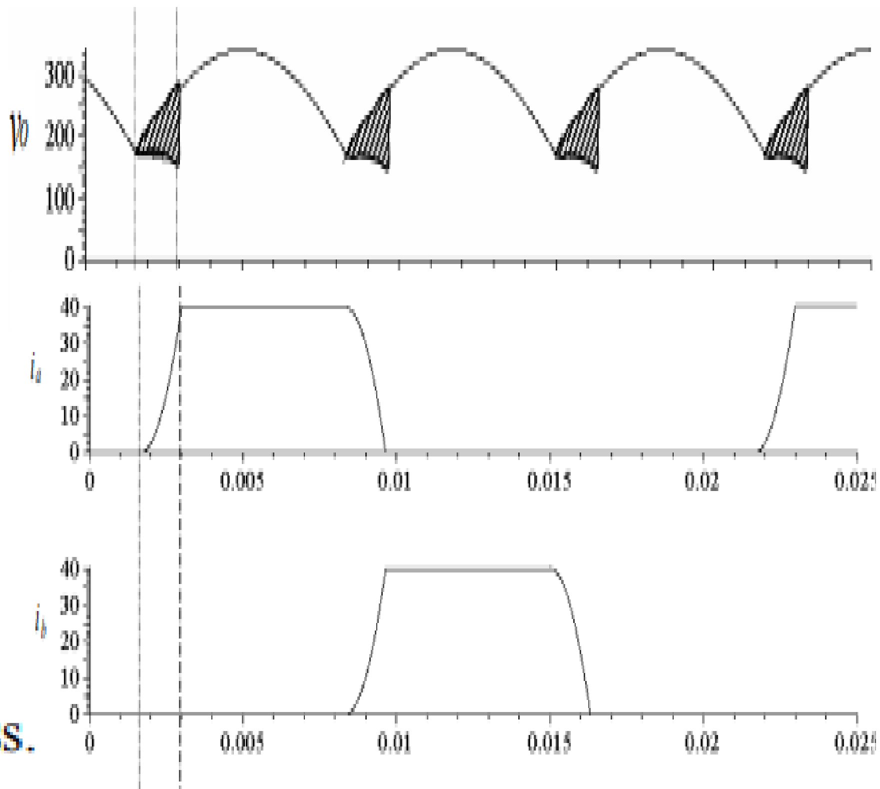
$$i_a + i_b = \bar{I}_d ,$$

Differentiate both sides

$$\frac{di_a}{dt} = -\frac{di_b}{dt}.$$

Adding the voltage equations and canceling the equal but opposite terms,

$$v_o = \frac{v_{an} + v_{bn}}{2}$$, during the overlap process.

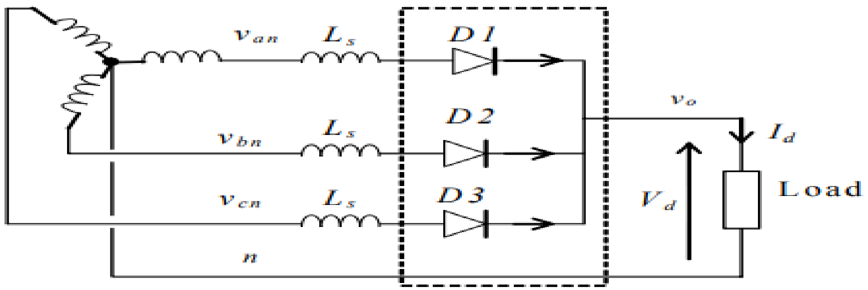


Analysis: Half-wave rectifier

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

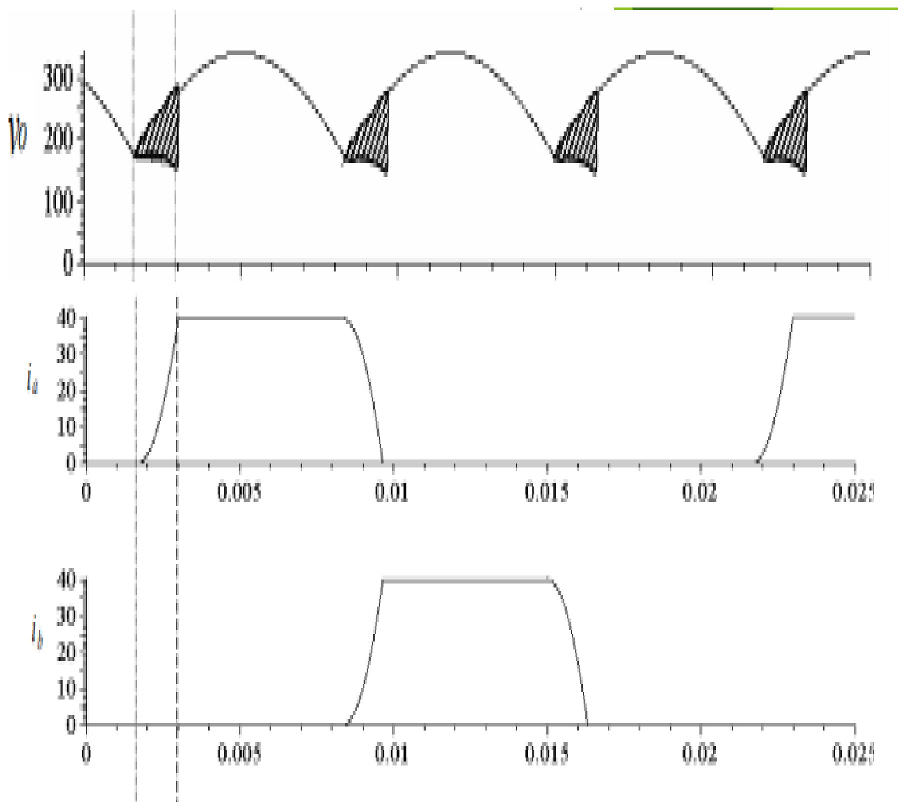
The part of the positive voltage pulse lost due to overlap starting from angle $\omega t = \pi/6$ is given by:

$$v_{bn} - \frac{v_{bn}+v_{an}}{2} = \frac{v_{bn}-v_{an}}{2} = L_s\frac{di}{dt}$$



The area (shaded) inside the voltage pulse lost due to overlap is given by:

$$\int_{\frac{\pi}{6}}^{\frac{\pi}{6}+\mu}\left(\frac{v_{bn}-v_{an}}{2}\right)d(\omega t) = \omega L_s\int_0^{I_d} di = \omega L_s I_d$$



Note that $(v_b - v_a)$ is the line-line voltage v_{ba}. The integral on the right hand side by shifting the origin by $\pi/6$ to the left. Thus

Analysis: Half-wave rectifier

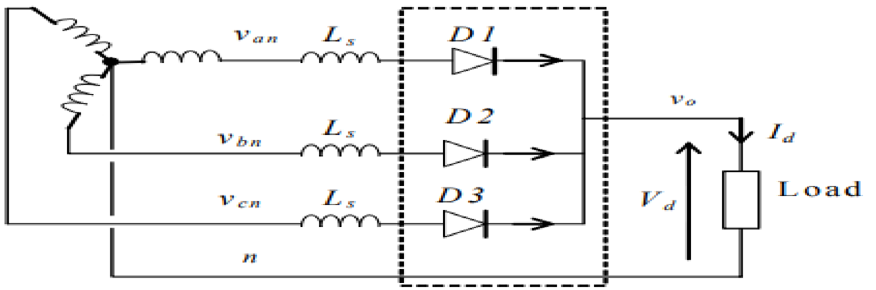
$V_a(\omega t)=V_m\sin(\omega t)$, $V_b(\omega t)=V_m\sin(\omega t-2\pi/3)$, $V_c(\omega t)=V_m\sin(\omega t-4\pi/3)$

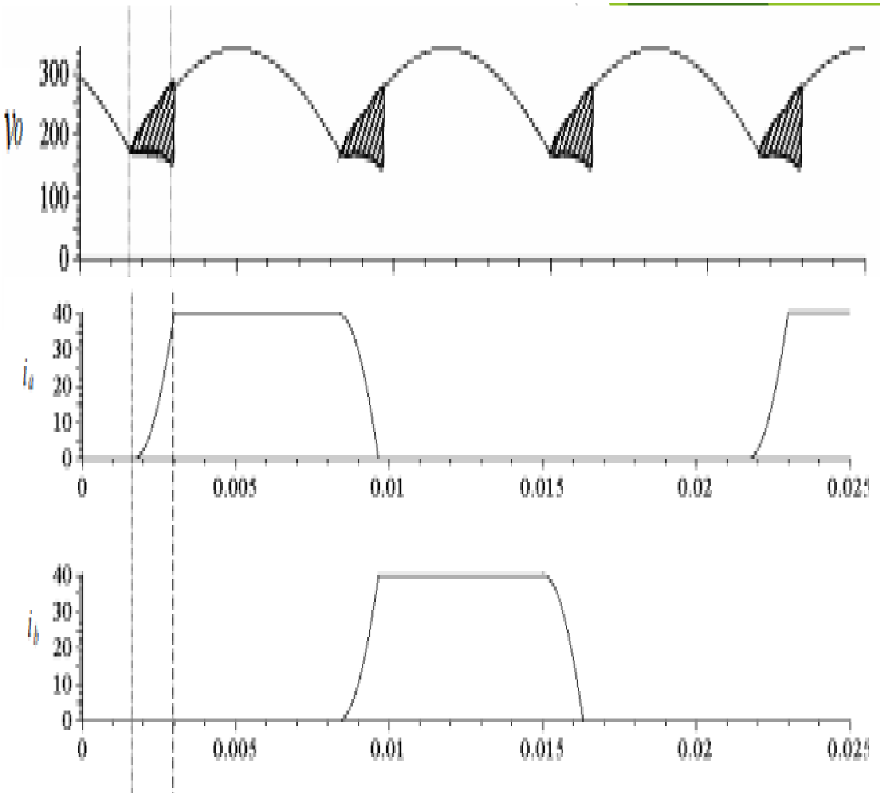
$$\int_0^{\mu}\frac{\sqrt{3}V_{max}}{2}\sin\omega t\,d(\omega t)=\omega L_s I_d$$

$$\therefore 1-\cos\mu=\frac{2\omega L_s}{V_{max\,l-l}}I_d$$

where $V_{max\,l\text{-}l}=\sqrt{3}\,V_{max}$

$$\cos\mu=1-\frac{2\omega L_s}{V_{max\,l-l}}I_d$$





The dc output voltage

$$V_d=\frac{3\sqrt{3}V_{max}}{2\pi}-\frac{3\omega L_s}{2\pi}I_d=\frac{3V_{max\,l-l}}{2\pi}\left(1-\frac{\omega L_s}{V_{max\,l-l}}I_d\right)$$

Analysis: Half-wave Controlled rectifier

1- The Load voltage incase HWCR ☺ :

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

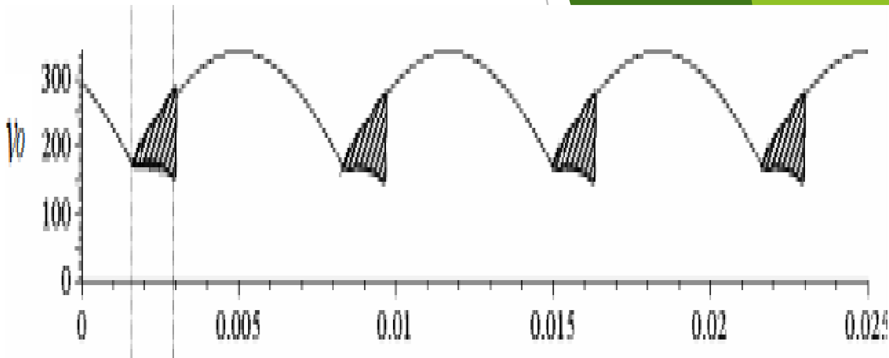
$$\int_{\alpha}^{\alpha+\mu}\frac{\sqrt{3}\,V_{max}}{2}\sin\omega t\,d(\omega t)=\omega L_s I_d$$

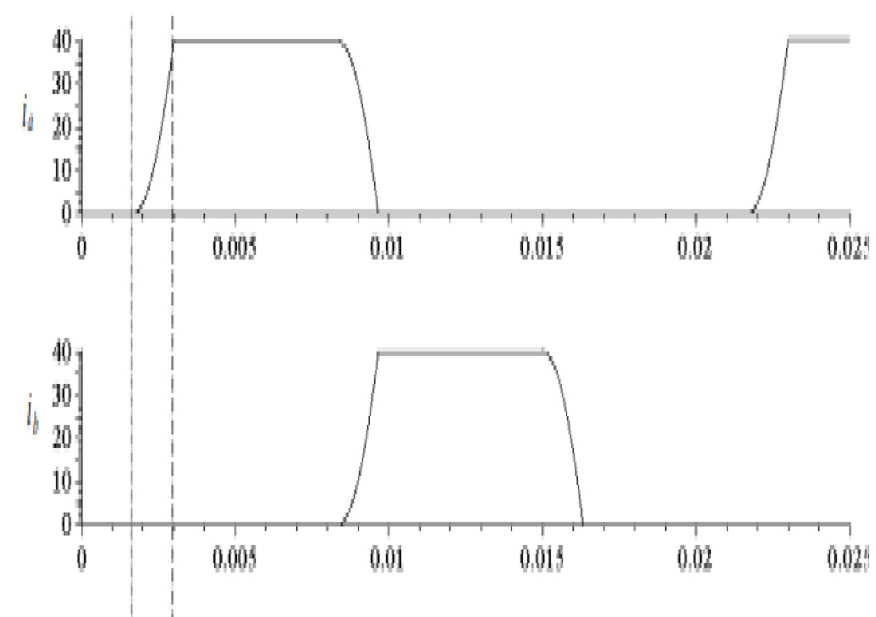
Cos (α) Cos (α+μ)

$$\therefore 1-\cos\mu=\frac{2\omega L_s}{V_{max\,l-l}}I_d$$

$$\text{Cos}(\alpha+\mu)=\text{Cos}(\alpha)-\frac{2\omega L_s}{V_{max\,l-l}}I_d$$

$$\mu=\alpha-\cos^{-1}\left(\text{Cos}(\alpha)-\frac{2\omega L_s}{V_{max\,l-l}}I_d\right)$$





The dc output voltage

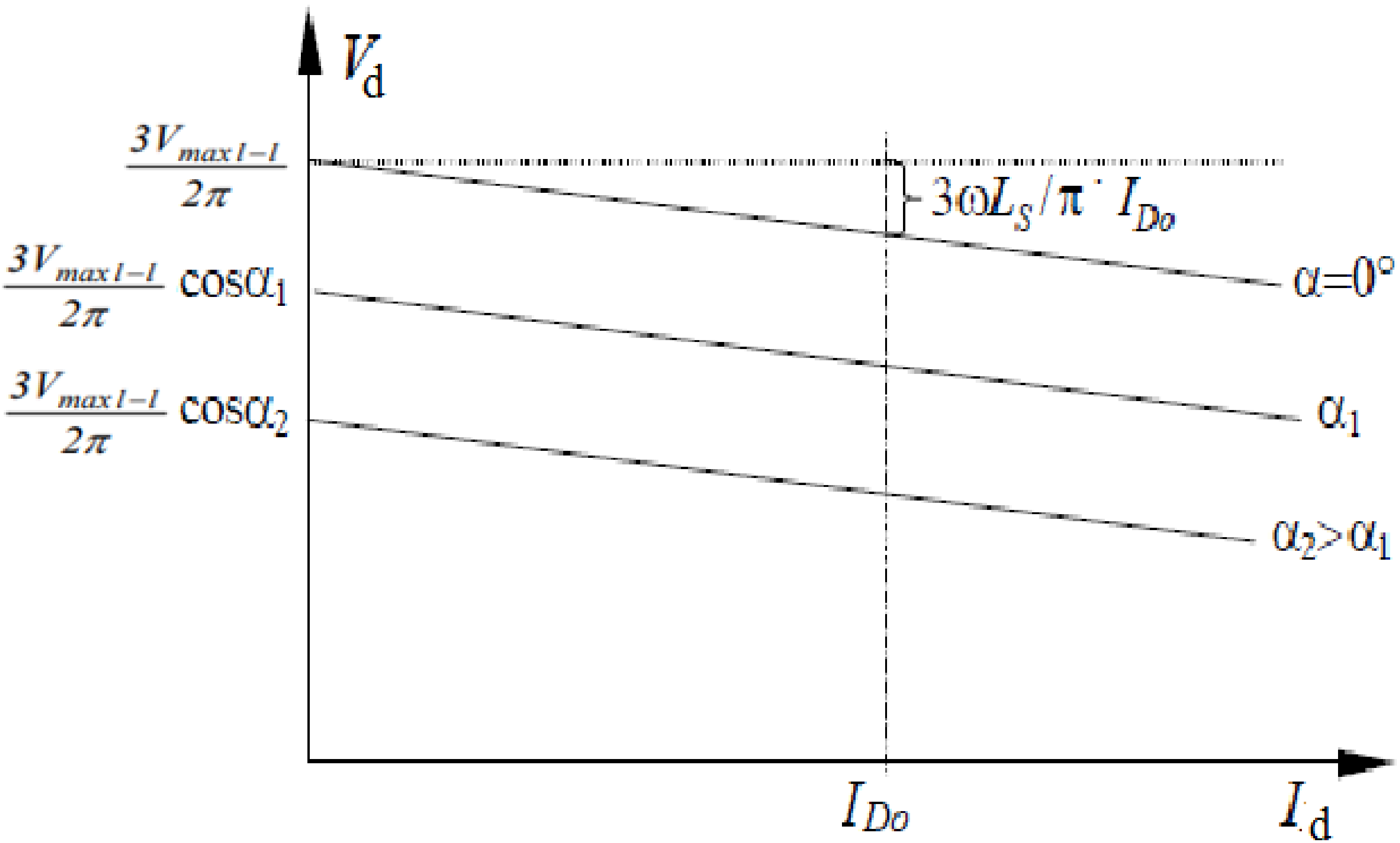
*Cos (α) Cos (α)

$$V_d=\frac{3\sqrt{3}\,V_{max}}{2\pi}-\frac{3\omega L_s}{2\pi}I_d=\frac{3V_{max\,l-l}}{2\pi}\left(1-\frac{\omega L_s}{V_{max\,l-l}}I_d\right)$$

$$V_d=\frac{3\cdot V_{ml}}{4\pi}\left[\cos\alpha+\cos(\alpha+\mu)\right]$$

Analysis: Half-wave Controlled rectifier

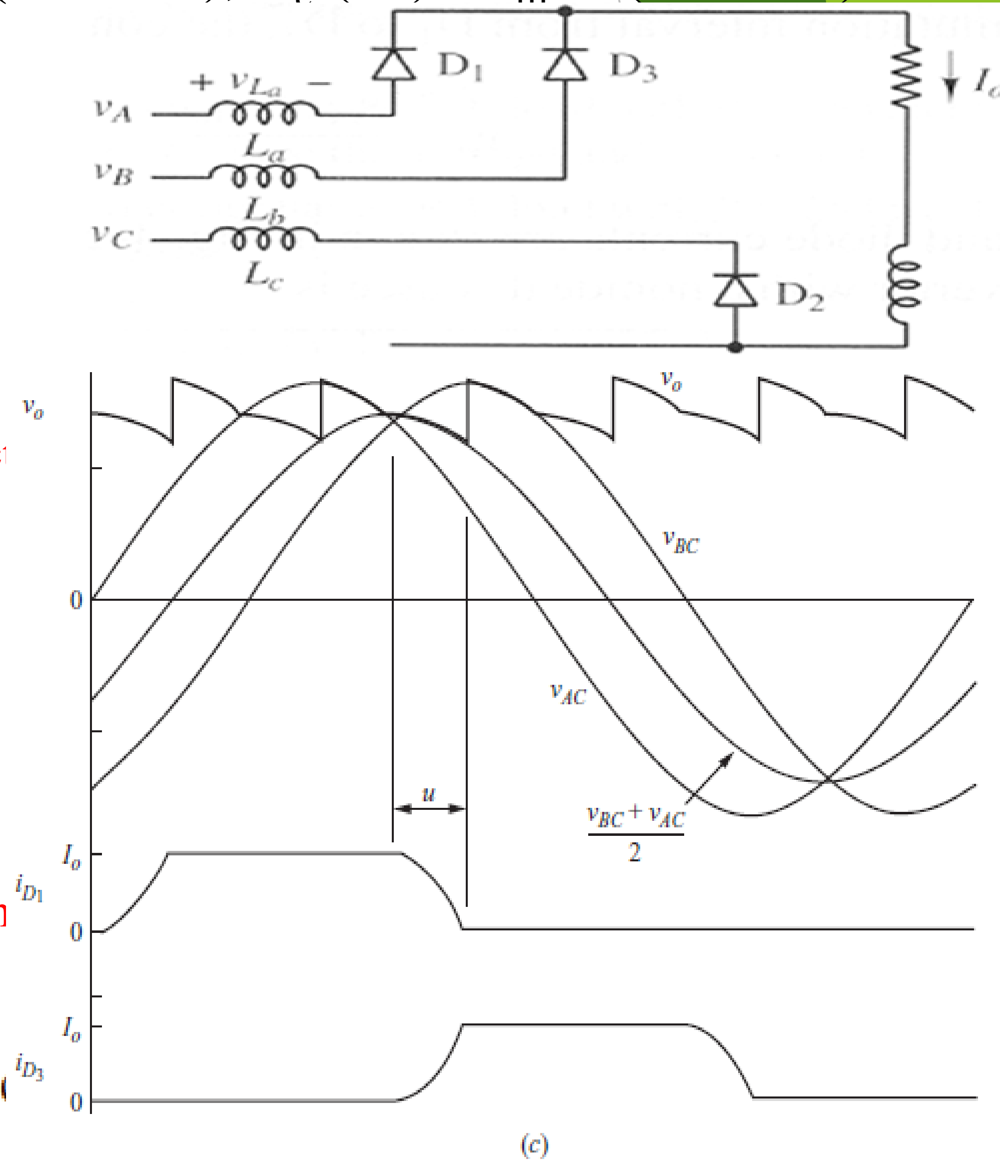
Regulation characteristic of the rectifier



Analysis: Full-wave rectifier

1- Supply voltages:

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



During the overlap period 0:μ

$$v_{an} = L_s \frac{di_a}{dt} + v_o$$

$$v_{bn} = L_s \frac{di_b}{dt} + v_o$$

when D_1 and D_3 are in overlap due to the source inductance L_s and where all voltages are with respect the fictitious neutral point. Vo

$$i_a + i_b = \bar{I}_d \,,$$

Differentiate both sides

$$\frac{di_a}{dt} = -\frac{di_b}{dt}.$$

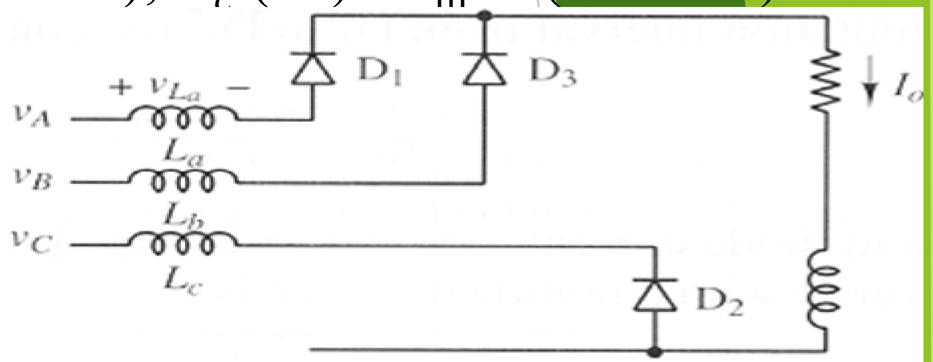
Adding the voltage equations and canceling th equal but opposite terms,

$$v_o = \frac{v_{an}+v_{bn}}{2}$$, during the overlap pro

Analysis: Full-wave rectifier

1- Supply voltages:

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



During the overlap period 0:μ

$$v_b - \frac{v_b + v_a}{2} = \frac{v_b - v_a}{2} = L_s \frac{di}{dt}$$

Integrating for the duration of the overlap

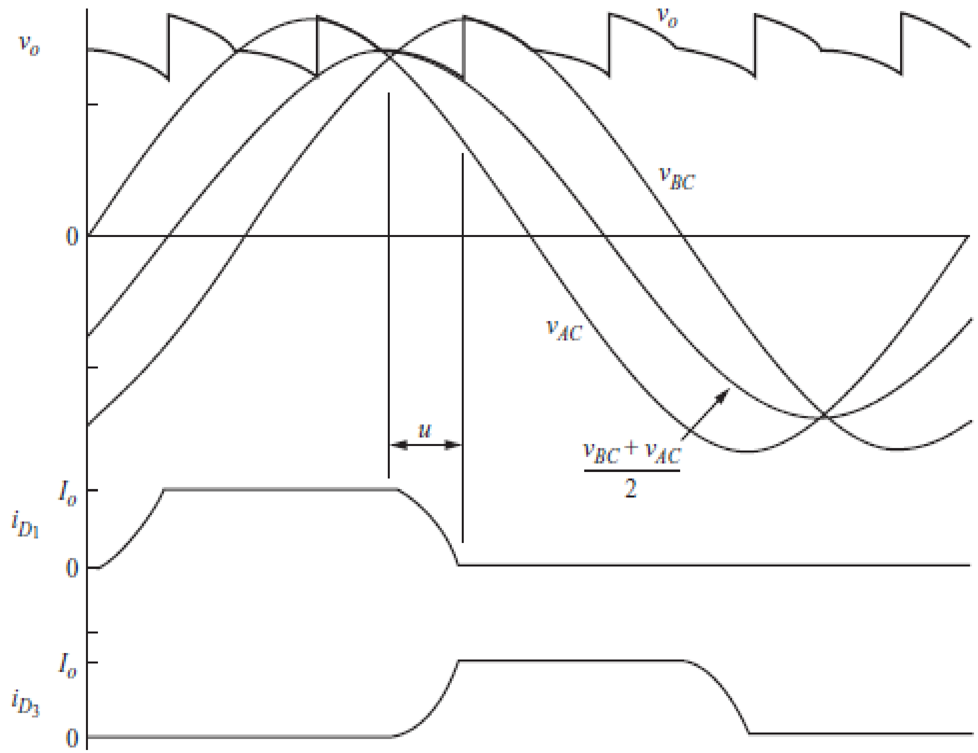
$$\int_{\frac{\pi}{6}}^{\frac{\pi}{6}+\mu} \left(\frac{v_b - v_a}{2} \right) d(\omega t) = \omega L_s \int_0^{I_d} di$$

$$\int_0^{\mu} \frac{\sqrt{3} V_{max}}{2} \sin \omega t \, d(\omega t) = \omega L_s I_d$$

$$\therefore 1 - \cos \mu = \frac{2\omega L_s}{V_{max\, l-l}} I_d$$

$$\cos \mu = 1 - \frac{2\omega L_s}{V_{max\, l-l}} I_d$$

Compare with HWR

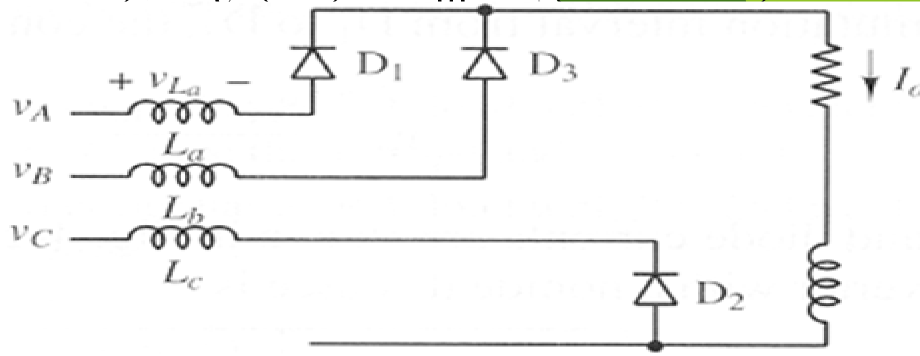


(c)

Analysis: Full-wave rectifier

1- Supply voltages:

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



The dc output voltage V_d is given by

$$V_d=\frac{3V_{max\,l-l}}{\pi}-\frac{1}{\pi/3}\int_0^{\mu}\frac{V_{max\,l-l}}{2}\sin\omega t\,d(\omega t)$$

as

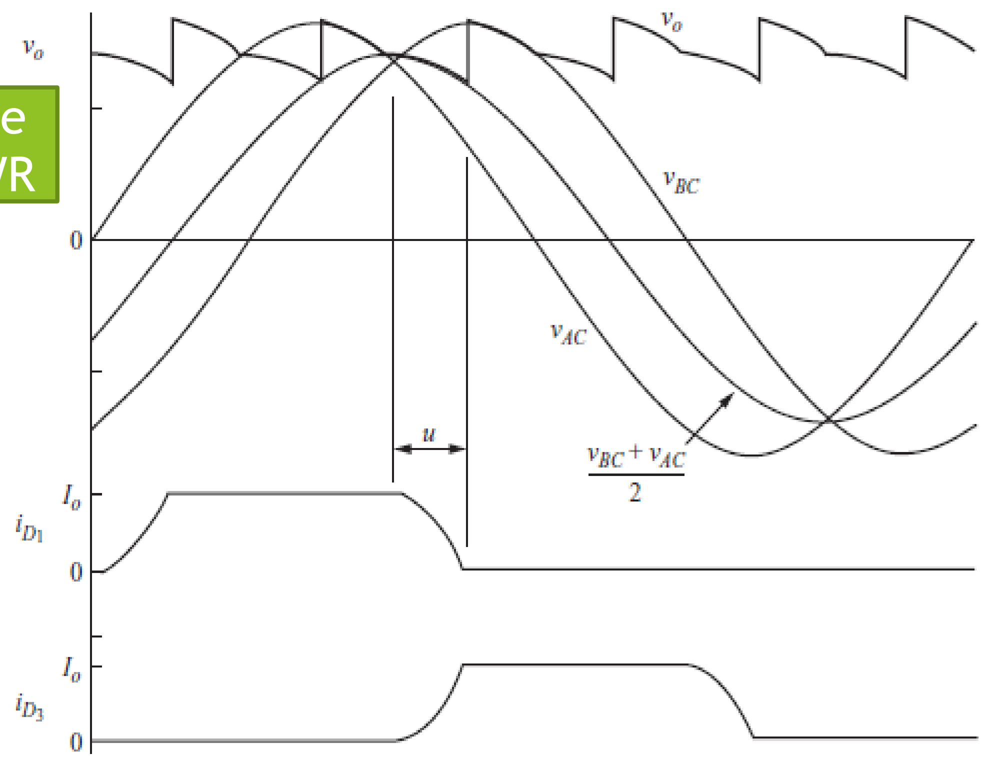
$$\int_0^{\mu}\frac{\sqrt{3}\,V_{max}}{2}\sin\omega t\,d(\omega t)=\omega L_s I_d$$

so

Compare with HWR

$$V_d=\frac{3V_{max\,l-l}}{\pi}-\frac{3\omega L_s}{\pi}I_d$$

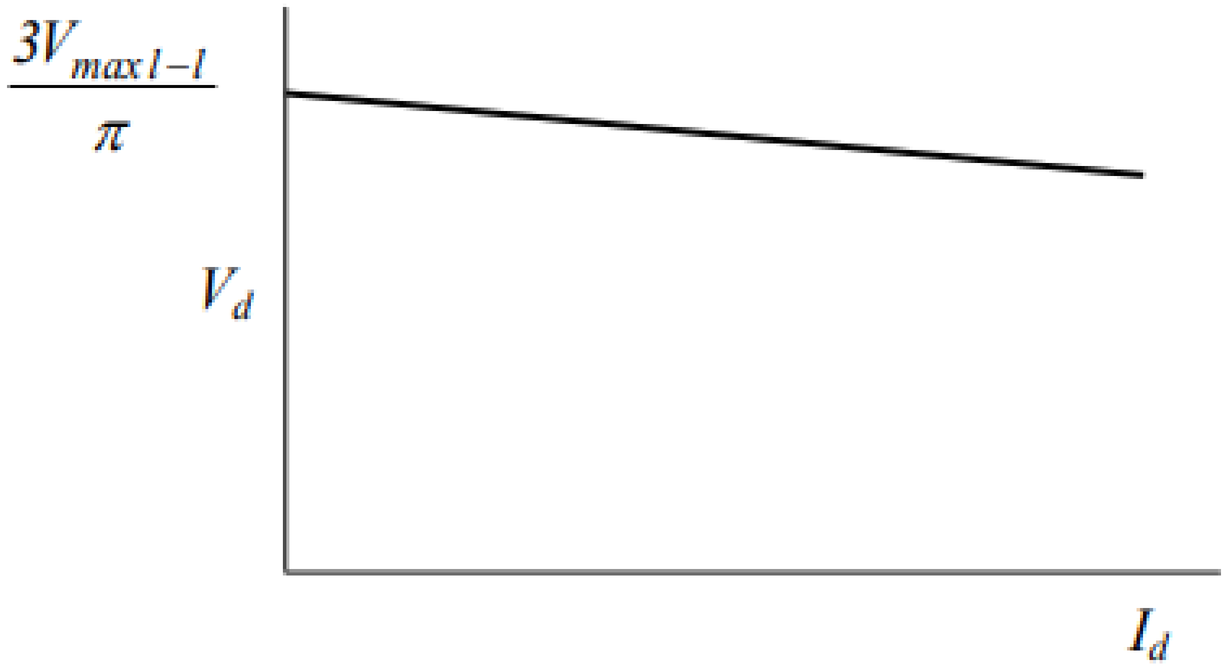
$$V_d=\frac{3V_{max\,l-l}}{\pi}\left(1-\frac{\omega L_s}{V_{max\,l-l}}I_d\right)$$



(c)

Analysis: Full-wave rectifier

Regulation characteristic of the rectifier



Questions

Q_1) what are the effect of source inductance on the load voltage?

Q_2) Deduce the average load voltage of three-phase full wave controlled rectifier with nonideal supply.

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