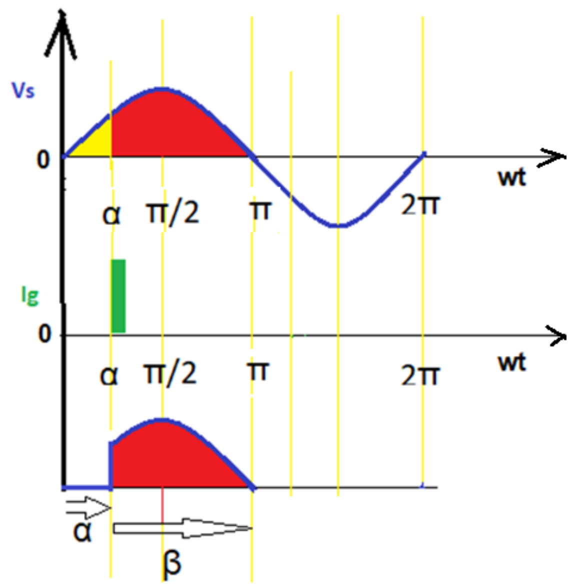
Unit 5: Converters

Module 14: Single Phase Full wave controlled rectifier: Mid-point configuration with resistive load and inductive load

Introduction:

Phase control technique

Unlike diode rectifiers, PCRs or phase controlled rectifiers has an advantage of regulating the output voltage. The diode rectifiers are termed as uncontrolled rectifiers. However if the diodes are replaced with Thyristors such as SCRs then it becomes phase control rectifier. The o/p voltage can be regulated by changing the firing angle of the Thyristors. The main application of these rectifiers is involved in speed control of DC motor.



α = Firing angle

β = Conduction angle

= π - α

What are Controlled Rectifiers?

The term PCR or Phase controlled rectifier is a one type of rectifier circuit in which the diodes are

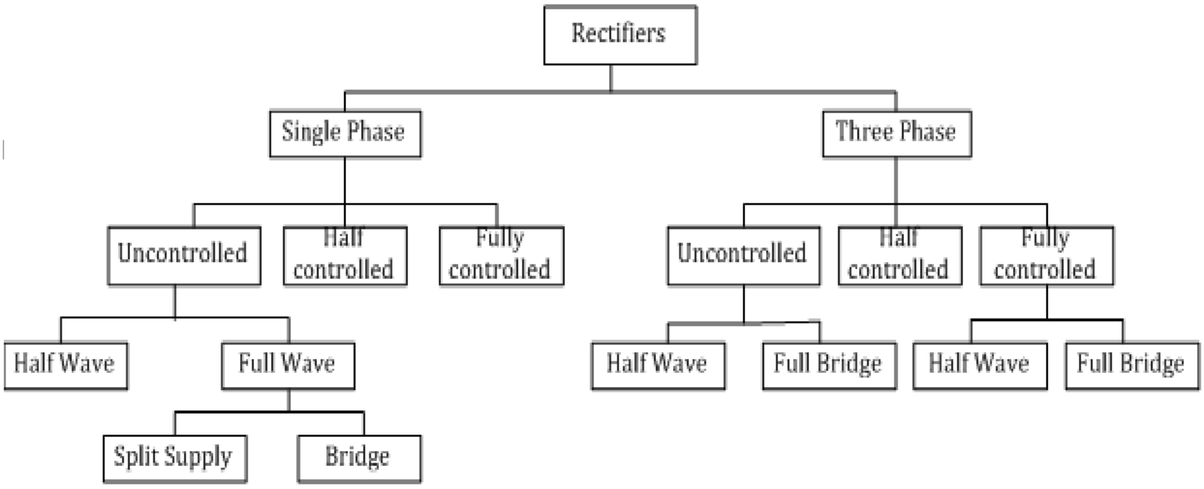
switched by Thyristors or SCRs (Silicon Controlled Rectifiers). Whereas the diodes offer no control over the o/p voltage, the Thyristors can be used to differ the output voltage by adjusting the firing angle or delay. A phase control Thyristor is activated by applying a short pulse to its gate terminal and it is deactivated due to line communication or natural. In case of heavy inductive load, it is deactivated by firing another Thyristor of the rectifier during the negative half cycle of i/p voltage.

- Controlled rectifiers are AC to DC voltage converters.

- The DC output voltage is controlled(varied) by allowing the required amount of Phase through the Load.
- This is achieved by changing the firing angle α of the thyristor.
- This method of Power control is called Phase Control.

Types of Phase Controlled Rectifier

The phase-controlled rectifier is classified into two types based on the type of i/p power supply. And each kind includes a semi, full and dual converter.



Single-phase Controlled Rectifier

This type of rectifier works from single phase AC i/p power supply

Single Phase Controlled Rectifiers are classified into different types

Half wave Controlled Rectifier:

This type of rectifier uses a single Thyristor device to provide o/p control only in one half cycle of input AC supply, and it offers low DC output.

Full wave Controlled Rectifier: This type of rectifier provides higher DC output

- Full wave controlled rectifier with a center tapped transformer requires two Thyristors.
- Full wave bridge controlled rectifiers do not need a center tapped transformer

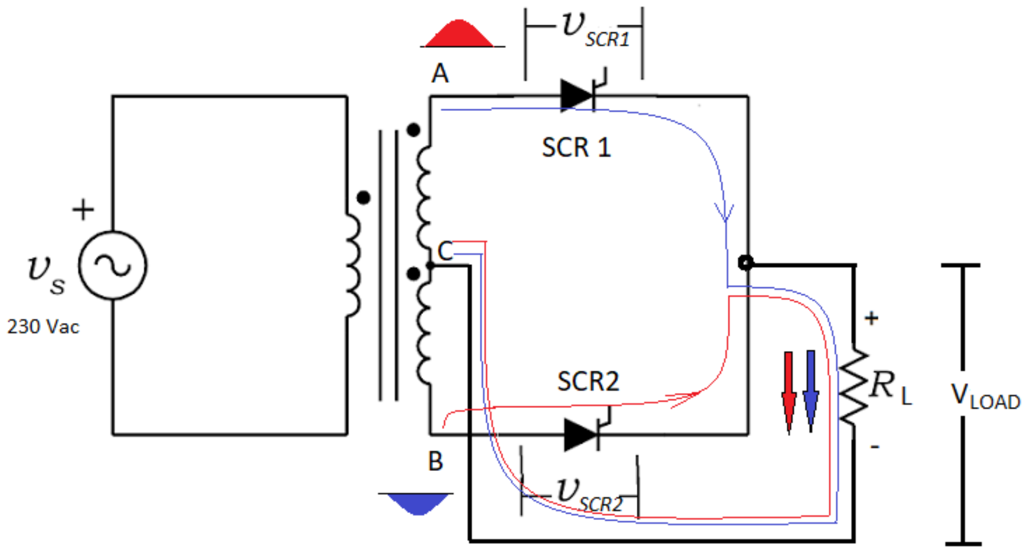
Three-phase Controlled Rectifier

This type of rectifier which works from three phase AC i/p power supply

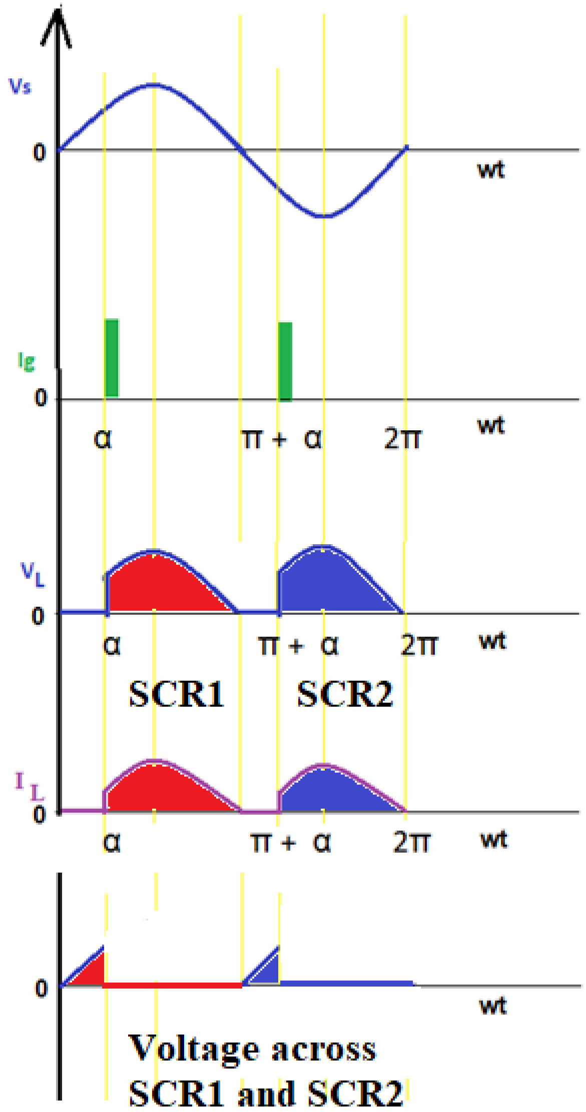
- A semi converter is a one quadrant converter that has one polarity of o/p voltage and current.
- A full converter is a a two quadrants converter that has polarity of o/p voltage can be either +ve or –ve but, the current can have only one polarity that is either +ve or -ve.
- Dual converter works in four quadrants – both o/p voltage and o/p current can have both the polarities.

Single phase full wave controlled rectifier with Resistive load – Mid point configuration (M-2)

- These converters are also referred to as two pulse converters
- This Configuration is generally used for rectifiers of low ratings.



1) During positive half cycle of AC supply, "A" is positive with respect to "B", this makes SCR1 forward biased and SCR2 is reverse biased. But since no triggering pulse is applied, both are in off state. When SCR1 is triggered at firing angle α, current flows through load from "A", SCR1 and back to centre-tap "C" of the transformer. This current flow is continuous till angle π when the supply voltage reverses the polarity and SCR1 is turned off.
2) During negative half cycle of AC supply, "B" is positive with respect to "A", this makes SCR2 forward biased and SCR1 is reverse biased. But since no triggering pulse is applied, both are in off state. When SCR2 is triggered at firing angle α+π, current flows through load from "B", SCR2 and back to centre-tap "C" of the transformer. This current flow is continuous till angle 2π, when the supply voltage reverses the polarity and SCR2 is turned off. The operation is as shown in waveforms.



DC output Voltage and Current of Single phase full wave controlled rectifier with Resistive Load

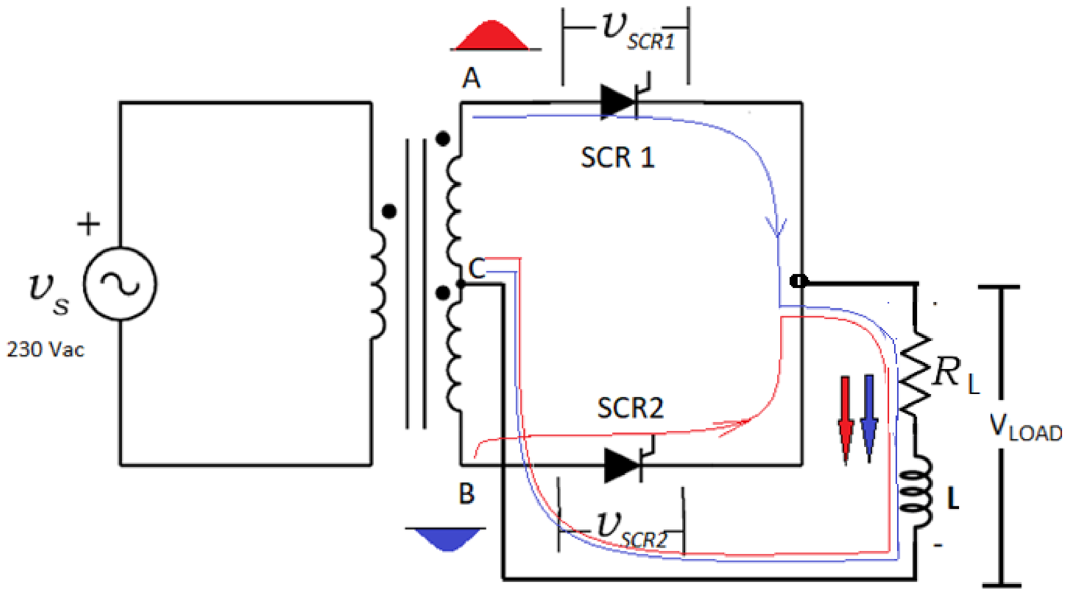
$$V_{dc}=V_o=\frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d(\omega t)=\frac{V_m}{\pi}(1+\cos\alpha)$$

$$I_{dc}=\frac{V_{dc}}{R}=\frac{V_m}{\pi R}(1+cos\alpha)$$

By varying the firing angle α from 0 to 2 π,

The DC output voltage can be varied from 0 to 2Vm/π

Single phase full wave controlled rectifier with Inductive load - Mid point Configuration

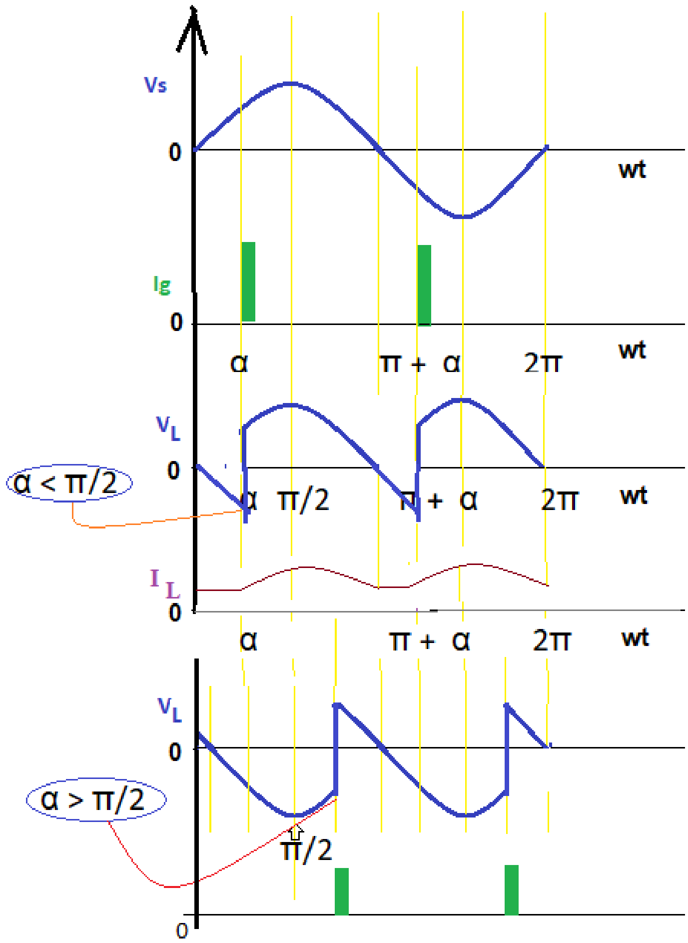


Mode 1: During the positive half cycle SCR1 is triggered into conduction at firing angle α and SCR2 remains Off.

Mode 2: During the onset of negative half cycle Inductor L gives back emf, thus SCR1, maintains forward bias condition and remains in conduction even during negative half cycle.

Mode 3: During the negative half cycle SCR 2 is triggered into conduction at firing angle α +π, this give reverse voltage across SCR1, thus SCR1 gets turned off

Mode 4: During the onset of next positive half cycle Inductor L gives back emf, thus SCR2, maintains forward bias condition and remains in conduction even during negative half cycle.



Average Output Voltage and Current

$$V_{dc} = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_m sin\omega t\ d\omega t = \frac{2V_m}{\pi} cos\alpha$$

$$I_{dc} = \frac{V_{dc}}{R} = \frac{2V_m}{\pi R} cos\alpha$$

The average output voltage lies between - 2Vm/π to + 2Vm/π

For $0^0 < \alpha < 90^0$ Vout is +ve

For $90^0 < \alpha < 180^0$ Vout is -ve

Applications of Phase Controlled Rectifiers

POWER CONTROL

Widely used in speed control of DC motors.

- Paper mills
- Textile mills using DC motor drives and DC motor **control**
- Steel mills
- AC fed traction system using a DC traction motor.
- Electro-metallurgical and Electrochemical processes
- Battery charging
- Front end of UPS and SMPS