3.1 Single-phase Controlled Rectifier

3.1.1 Single-phase half wave Controlled Rectifier

Figure 3.1 depicts the circuit diagram of a Single Phase Half Wave Controlled Rectifier with resistive load (triggering circuit not shown in the figure). The circuit is energized by the line voltage or transformer secondary voltage, $v = V_{max} \sin \omega t$.

It is assumed that the peak supply voltage never exceeds the forward and reverse-blocking ratings of the thyristor. The thyristor can be triggered at any angle α in the positive half cycle and thus the output voltage can be controlled. The thyristor blocks during the negative half cycle. The various voltage and current waveforms for the Single Phase Half Wave Controlled Rectifier with resistive load circuit are shown in Fig. 3.1.

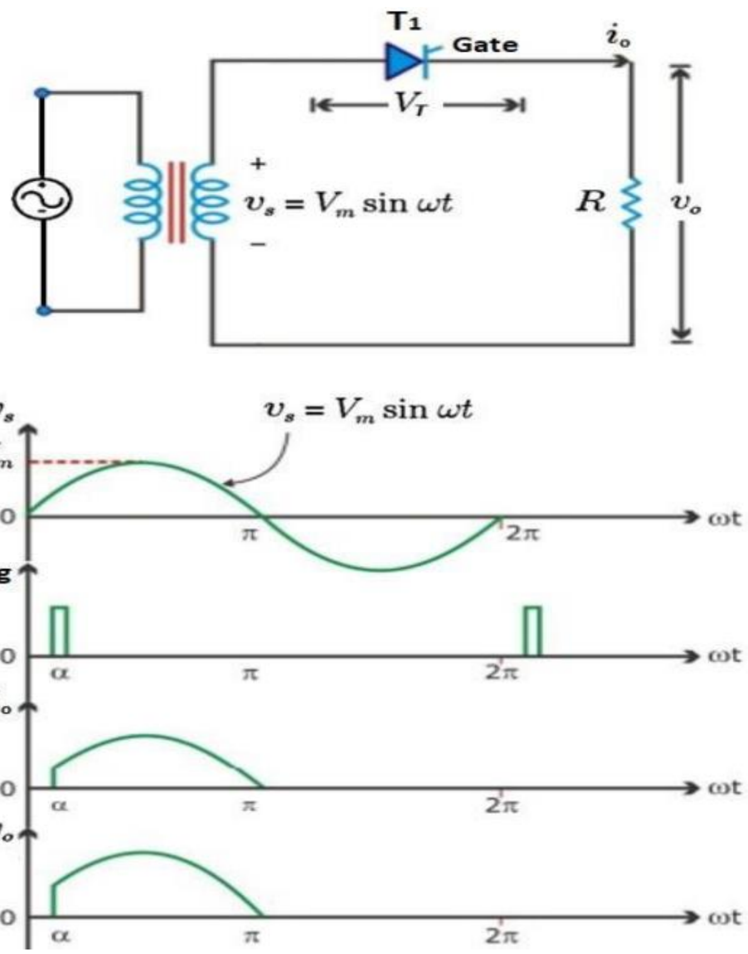

Figure 3.1 Single-phase half wave Controlled Rectifier

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Average load voltage is given by

$$V_{DC(Load)} = \frac{1}{2\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d\omega t = \frac{V_m}{2\pi}(1+\cos(\alpha))$$

$$\boxed{V_{DC(Load)} = \frac{V_m}{2\pi}(1+\cos(\alpha))}$$

The average value of output current, $I_{DC(Load)} = \frac{V_{DC(Load)}}{R}$

$$V_{RMS(Load)} = \sqrt{\frac{1}{2\pi}\int_{\alpha}^{\pi} [V_m \sin(\omega t)]^2\, d\omega t} = \frac{V_m}{2}\sqrt{1-\frac{\alpha}{\pi}+\frac{\sin(2\alpha)}{2\pi}}$$

$$I_{RMS(Load)} = \frac{V_{RMS(Load)}}{R}$$

The output power is given by:

$$P_{DC} = V_{DC} \times I_{DC}$$
$$P_{RMS} = V_{RMS} \times I_{RMS}$$

Example 1: The single-phase half wave rectifier has a purely resistive load of 10 Ω and the delay angle is $\alpha = \pi/2$. If the supply voltage is 220 V, determine the DC ,RMS load voltage ,current and power.

$$V_{DC(Load)} = \frac{V_m}{2\pi}(1+\cos(\alpha)) = \frac{220\sqrt{2}}{2\pi}(1+\cos(90)) = 49.5V$$

$$I_{DC(Load)} = \frac{V_{DC(Load)}}{R} = \frac{49.5}{10} = 4.95A$$

$$P_{DC} = V_{DC} \times I_{DC} = 49.5 \times 4.95 = 245.11 \text{ W}$$

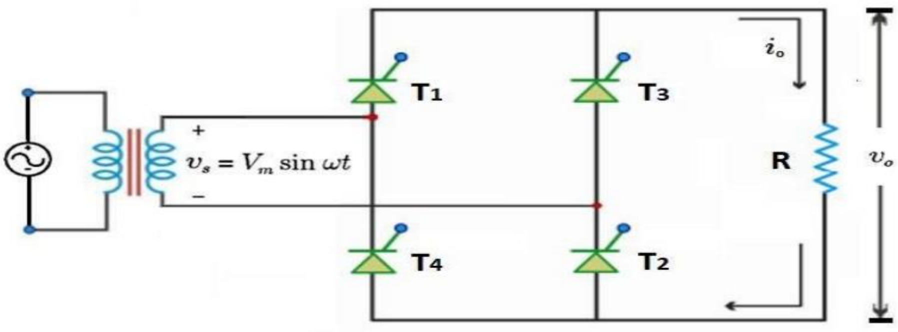
$$V_{RMS} = \frac{V_m}{\pi}\sqrt{1-\frac{\pi}{\frac{\pi}{2}}+\frac{\sin\left(2\left(\frac{\pi}{2}\right)\right)}{2\pi}} = 98.6 \text{ V}$$

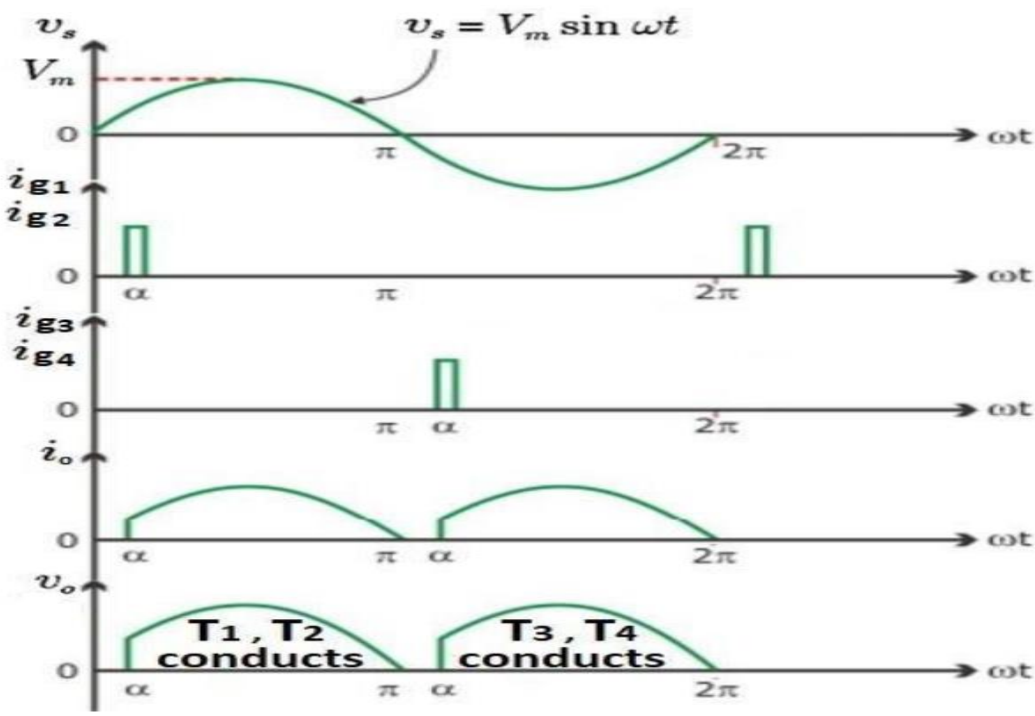
$$I_{RMS} = \frac{V_{RMS}}{R} = 9.86\ A$$

$$P_{RMS} = V_{RMS} \times I_{RMS} = 98.6 \times 9.86 = 973.19\text{W}$$

3.1.2 Single-phase full wave Controlled Rectifier

Fig 3.2 shows abasic single-phase full-wave bridge controlled rectifier with a resistive load is shown in Figure 2.18. This type of rectifier uses four thyristors to control the average load voltage.Thyristors T1 and T2 must be fired at the same time during the positive half cycle of the source voltage to allow conduction of current. Alternatively, thyristors T3 and T4 must be fired at the same time during the negative half cycle of the source voltage. The voltage and current waveforms on resistive load, and the voltage waveform on the thyristor T1 and T2 are shown in Figure 2.19.





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

$$\boxed{V_{DC(Load)} = \frac{V_m}{\pi}(1+\cos(\alpha))}$$

The average value of output current, $I_{DC(Load)} = \frac{V_{DC(Load)}}{R}$

$$V_{RMS(Load)} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} [V_m \sin(\omega t)]^2\, d\omega t} = V_m\sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{\sin(2\alpha)}{4\pi}}$$

$$I_{RMS(Load)} = \frac{V_{RMS(Load)}}{R}$$

Example 2: The single-phase full-wave controlled bridge rectifier has an ac input of 120 V at 60 Hz and a 5 Ω load resistor. The delay angle is 40^0 . Determine the average current in the load and power.

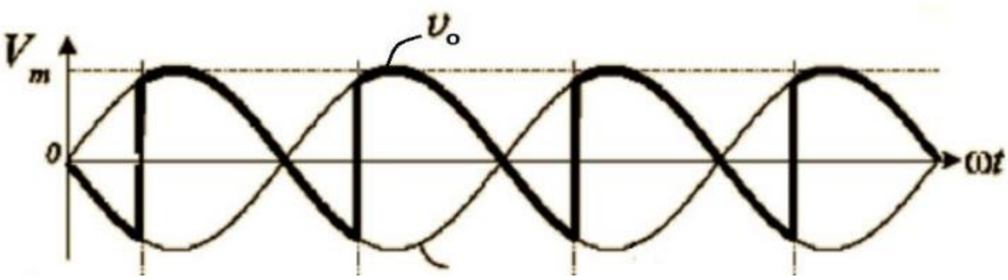
$$V_{DC(Load)} = \frac{V_m}{\pi}(1+\cos(\alpha))$$

$$V_{DC(Load)} = \frac{120\sqrt{2}}{\pi}(1+\cos(40^0)) = 95.4V$$

$$I_{DC(Load)} = \frac{V_{DC(Load)}}{R} = \frac{95.4V}{5\Omega} = 19.1A$$

$$P_{DC} = V_{DC} \times I_{DC} = 95.4 \times 19.1 = 1822.14 \text{ W}$$

The behavior of the full-wave controlled rectifier with R-L load (highly inductive load) is shown in Figure 2.20. The high inductance generates a perfectly filtered current and the rectifier behaves like a current source. With continuous load current, thyristors T1 and T2 remain in the ON-state beyond the positive half-wave of the source voltage. For this reason, the load voltage can have a negative instantaneous value



$$V_{DC(Load)} = \frac{1}{\pi}\int_{\alpha}^{\pi+\alpha} V_m \sin(\omega t)\, d\omega t = \frac{2V_m}{\pi}\cos(\alpha)$$

$$\boxed{V_{DC(Load)} = \frac{2V_m}{\pi}\cos(\alpha)}$$

The average value of output current, $I_{DC(Load)} = \frac{V_{DC(Load)}}{R}$

$$V_{RMS(Load)} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi} [V_m \sin(\omega t)]^2\, d\omega t} = \frac{V_m}{\sqrt{2}}$$

Example 4: The single-phase full wave controlled rectifier has a purely resistive load of 5 Ω and the delay angle is $\alpha = \pi/6$. If the supply voltage is 220 V, determine the DC ,RMS load voltage and current.

$$V_{DC} = \frac{2 \times \sqrt{2} \times 220}{\pi}\cos\left(\frac{\pi}{6}\right) = 198.06\, V$$

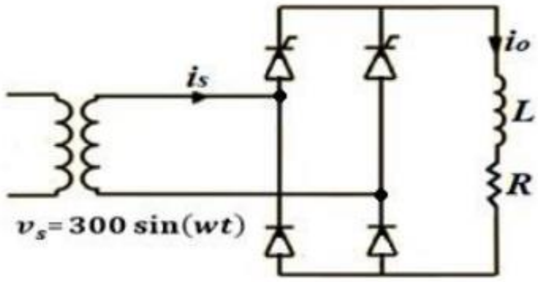
$$I_{DC} = \frac{198}{10} = 19.8A$$

HW1: For the rectifier circuit shown in Figure below, α = 90 , L is very high.

(a) Trace is waveform.

(b) Calculate $Vload$ $(mean)$.

(c) If L = 0, repeat (a) and (b) above.



HW2: A resistive load of R = 100 is to be supplied with a DC voltage of 40V using single-phase half-wave rectifier. If the supply voltage is 120 V,

(a) Calculate the required delay angle.

(b) Trace the thyristor current and voltage waveforms