Assignment 3

1. A heavily inductive load of R = 5 Ω is to be supplied with a DC voltage of 200 V, using three-phase bridge rectifier. Calculate:

   (a) The DC load current.

   (b) The RMS current of any diode.

   (c) The transformer secondary phase current.

   (d) The transformer secondary line voltage.

   (e) PRV of any diode.

2. Repeat Q1 above if the rectifier is three-phase half-wave type.

2.6 Single-Phase Half-Wave Controlled Rectifier

A way to control the output of a single-phase half-wave rectifier is to use a thyristor instead of a diode. A basic single-phase half-wave controlled rectifier with a resistive load is shown in Figure 2.16.

During the positive half cycle of the input voltage, thyristor T1 is forward biased and current flows through the load when the thyristor is fired (at $wt = \alpha$). The thyristor conducts only when the anode is positive with respect to cathode (forward biased), and a positive pulse signal is applied to the gate, otherwise, it remains in the forward blocking state and blocks the flow of the load current.

In the negative half cycle (i.e., at $wt = \pi - 2\pi$), the thyristor is in the reverse biased condition and no current flows through the load. Thus, varying the firing angle at which the thyristor starts conducting in positive half cycle controls the

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average DC output voltage. The voltage and current waveforms on resistive load and the voltage waveform on the thyristor are shown in Figure 2.17.

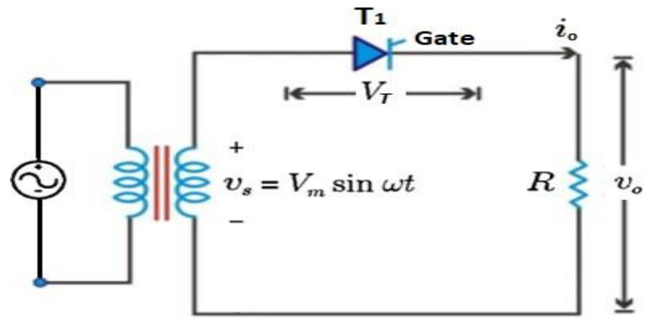


Figure 2.16: A basic single-phase half-wave controlled rectifier with a resistive load.

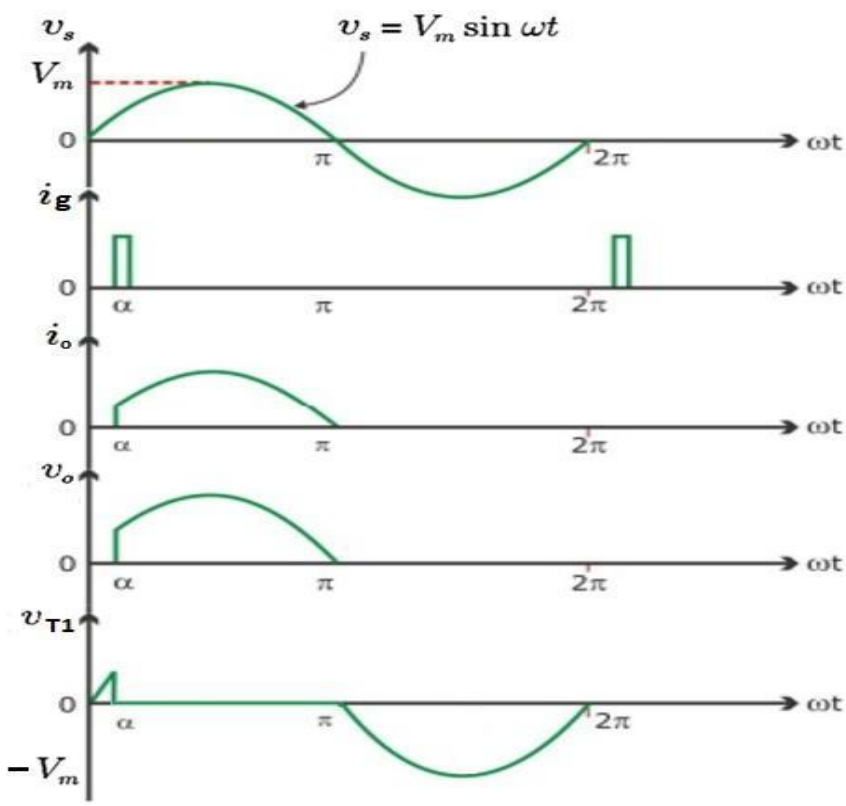


Figure 2.17: The waveforms of the single-phase half-wave controlled rectifier with a resistive load.

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

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

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

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

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

Example 7: 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 load voltage and current.

Solution:

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

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

2.7 Single-Phase Full-Wave Bridge Controlled Rectifier

A basic 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.

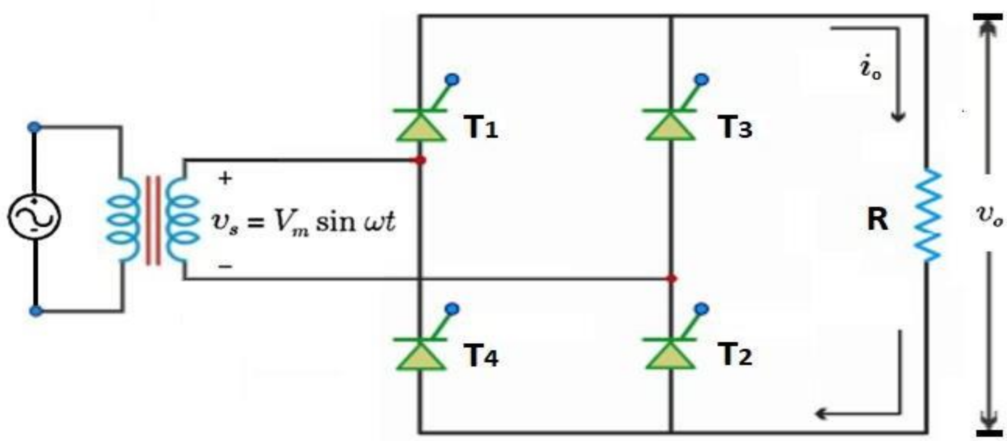


Figure 2.18: A single-phase full-wave bridge controlled rectifier with a resistive load.

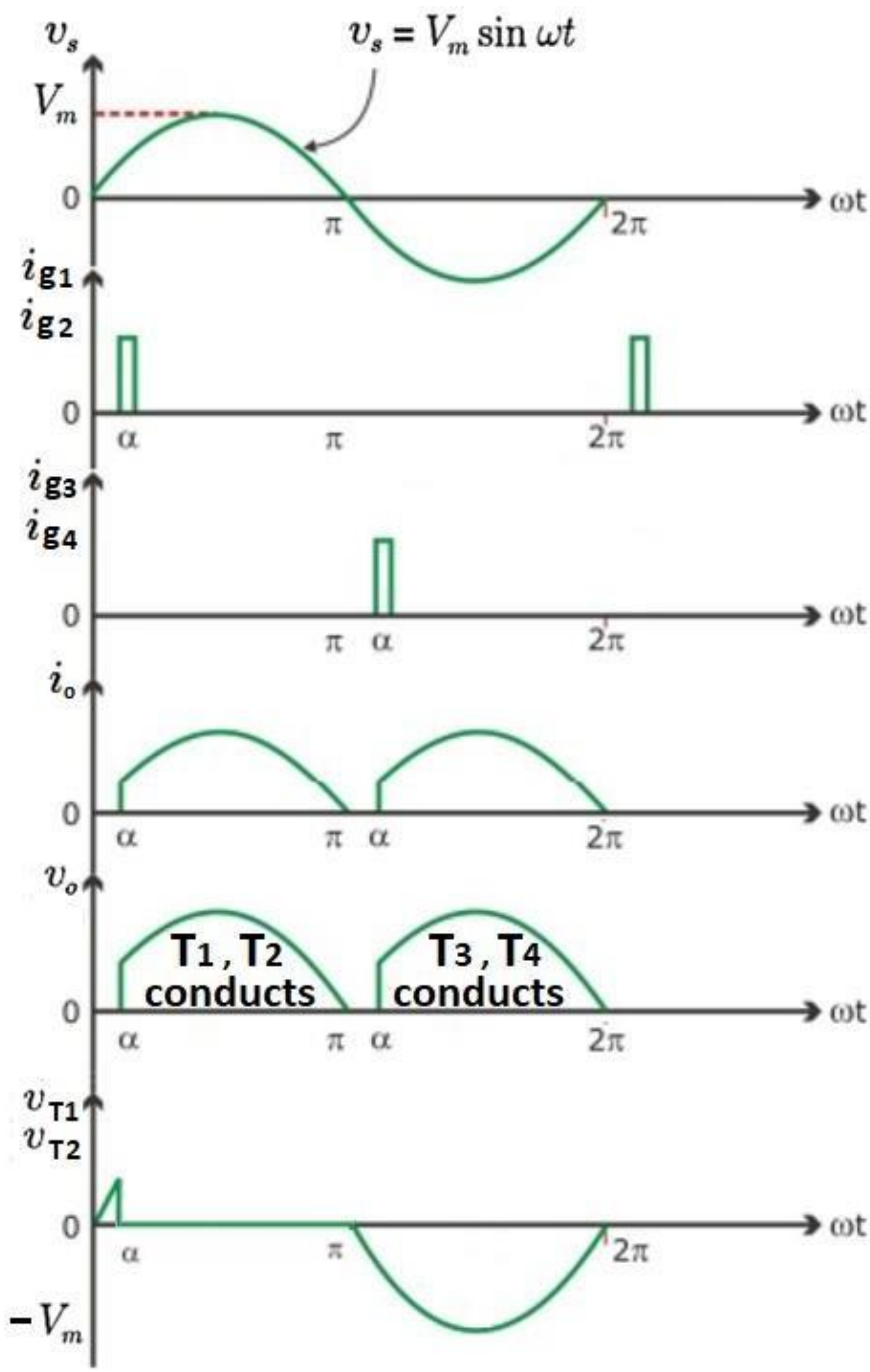


Figure 2.19: The waveforms of the single-phase full-wave bridge uncontrolled rectifier with a resistive load.

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

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

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 8: 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.

Solution:

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

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

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

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.

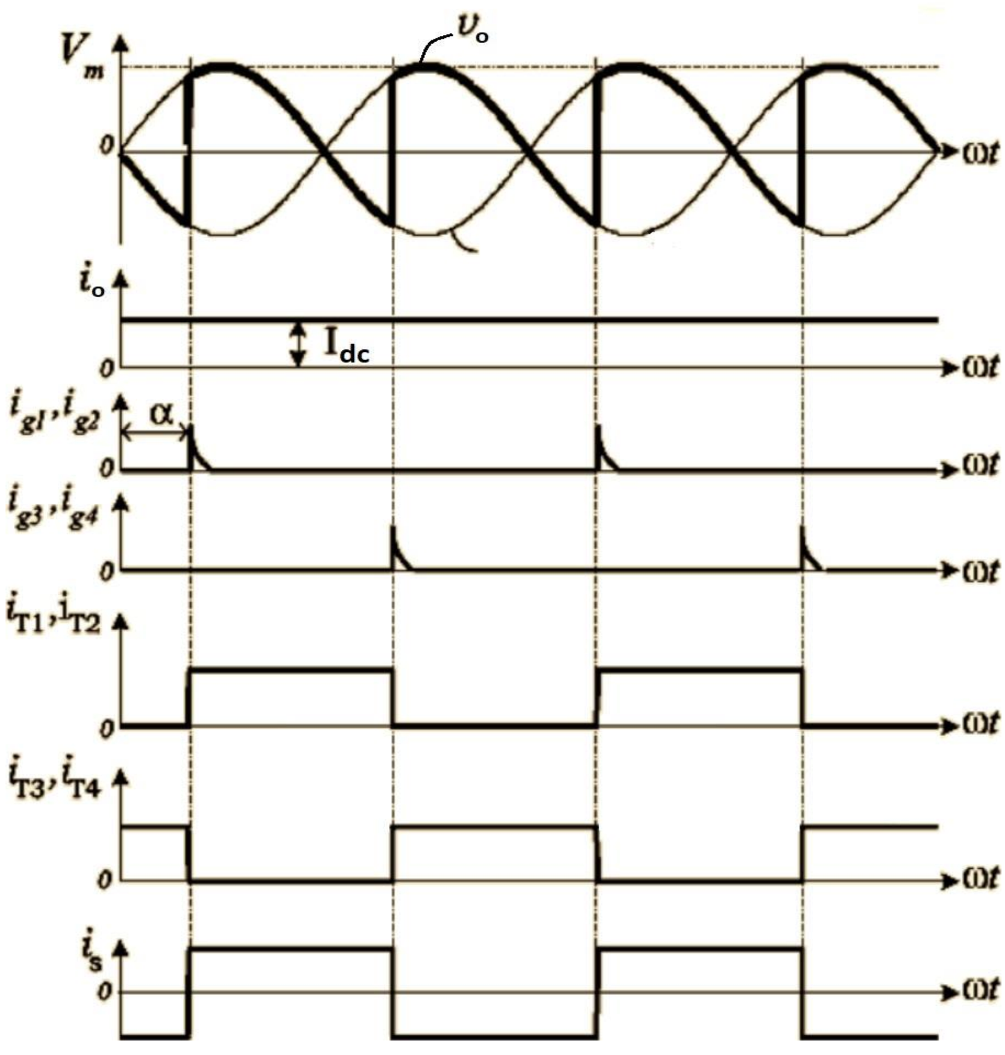


Figure 2.20: The waveforms of the single-phase full-wave bridge controlled rectifier loaded with highly inductive load.

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

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

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

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

$$I_{RMS(Load)} = I_{DC(Load)}$$

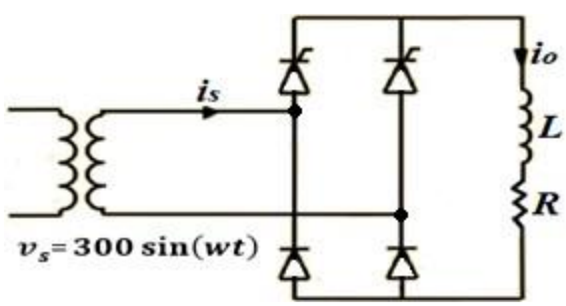
Assignment 4

1. For the rectifier circuit shown in Figure below, $\alpha = 90^o$, L is very high.

   (a) Trace i_s waveform.

   (b) Calculate $V_{load\ (mean)}$.

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



2. 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,

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(a) Calculate the required delay angle.

(b) Trace the thyristor current and voltage waveforms.

3. For the circuit shown in Figure below, TH is triggered reference to each zero cross over point, If $\alpha = 60^o$,

(a) Trace i_S and i_{TH} waveforms.

(b) Calculate $V_{load(mean)}$.

(c) How much α must be varied to compensate for 5% increase of the supply voltage.