LECTURE .5 : Single-phase full-wave uncontrolled rectifiers
5.1- Case of Resistive Load

Fig.4.1 (a) presents the circuit connection for a single-phase full-wave, bridge rectifier loaded with a resistive load. It is sometimes referred to as the full-wave bridge rectifier. For this configuration, two diodes always conducting during the same interval to provide a closed loop for the current. D_1 and D_2 conduct whenever the supply voltage (v_S) is positive while D_3 and D_4 conduct whenever the supply voltage (v_S) is negative as illustrated by Fig .4.1 (b).

Since the load is a resistive load. Then, the load current will have the same waveform as the load voltage, $i_o = \dfrac{v_o}{R}$.
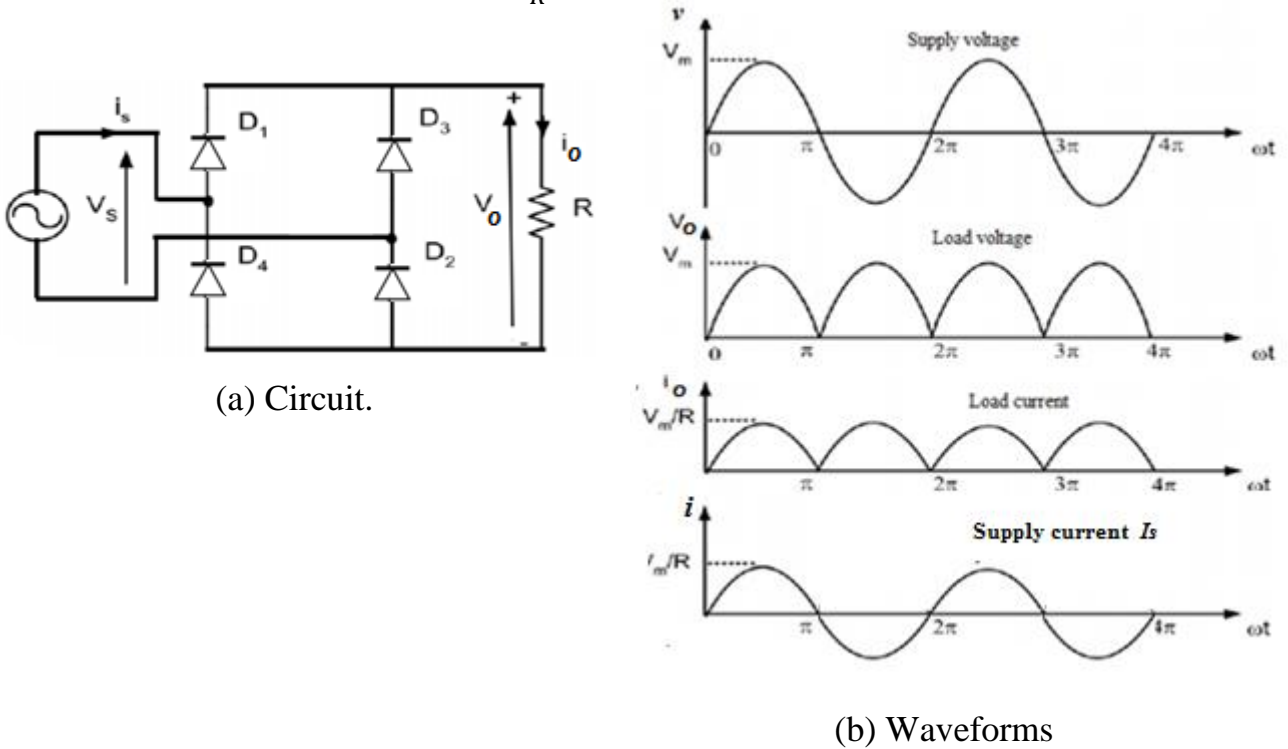

(a) Circuit.

(b) Waveforms

Fig.4.1 Single-phase full-wave rectifier with resistive load.

The average value of the load voltage V_{dc} can be calculated as follows:

$$V_{dc} = \frac{1}{\pi} \int_0^{\pi} V_m sin\omega t \, d\omega t = \frac{V_m}{\pi} (-cos\pi + cos0^o) = \frac{2V_m}{\pi} \qquad (4.1)$$

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The value of (4.1) is seen to be twice the corresponding value of the half – wave rectifier given in eq.(3.3) - lecture .3 .

The average value of the load current I_{dc} is

$$I_{dc} = \frac{V_{dc}}{R} = \frac{2V_m}{\pi R} \qquad (4.2)$$

$$P_{dc} = V_{dc}I_{dc} = \frac{V_{dc}^2}{R} \tag{4.3}$$

The rms value of the load voltage V_{rms} can be calculated as follows:

$$V_{orms} = \sqrt{\frac{1}{\pi}\int_0^\pi v_s^2 (\omega t)d\omega t}$$

$$= \sqrt{\frac{1}{\pi}\int_0^\pi (V_m sin\omega t)^2 \, d\omega t}$$

$$= \sqrt{\frac{(V_m)^2}{\pi}\int_0^\pi \frac{1}{2}(1 - cos2\omega t)d\omega t} = \frac{V_m}{\sqrt{2}} \tag{4.4}$$

The value of V_{orms} is seen to be $\sqrt{2}$ times the corresponding value of the half − wave rectifier given in eq. (3.7) - lecture 3. It should be noted that V_{orms} has the same rms value as a sinusoidal voltage of same maximum value . This means that the rms value is not affected by the polarity of the waveform.

The rms value of the load current I_{orms} is ,

$$I_{orms} = \frac{V_{orms}}{R} = \frac{V_m}{\sqrt{2}R} \tag{4.5}$$

The output a.c. power is given by:

$$P_{ac} = V_{orms}I_{orms} = \frac{V_{orms}^2}{R} = \frac{(0.707V_m)^2}{R} \tag{4.6}$$

The PRV for any diode in this configuration is (V_m) .
The load voltage ripple factor is

$$RF = \frac{\sqrt{V_{orms}^2 - V_{dc}^2}}{V_{dc}} = 0.48$$

Which is smaller than the corresponding RF value of the half − wave rectifier (see example 3.1 in lecture 3).

The supply current I_s is a pure sinusoidal as shown in Fig.4.1 (b). This is because the application of sinusoidal voltage to the resistive load causes sinusoidal supply current which is in − phase with the voltage. The average and rms values of the supply current are,

$$I_{s(av)} = \frac{1}{2\pi}\int_0^{2\pi} V_m sin\omega t \, d\omega t = 0 \tag{4.7}$$

$$I_{s(rms)} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi}(\frac{V_m}{R}sin\omega t)^2\, d\omega t} = \frac{V_m}{\sqrt{2}R} \qquad (4.8)$$

If we neglect the voltage drops across the diodes, the input power will be equal to the output power and therefore the power factor of the circuit will be unity.

5.2 Single-phase Full-Wave Bi-phase (Center tapped) Uncontrolled Rectifier with R- Load

This rectifier is shown in Fig.4.2. The waveforms and analysis are same as for the bridge rectifier of Fig.4.1.
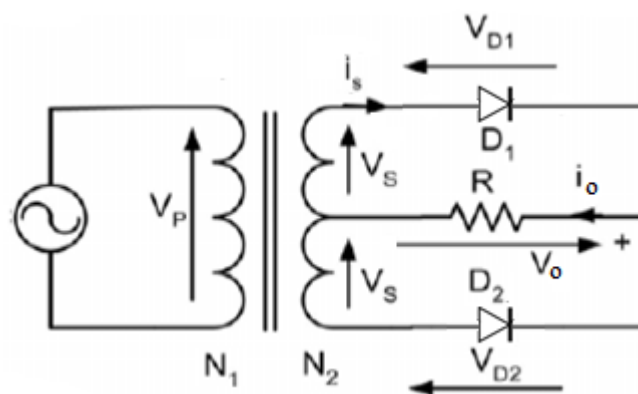

Fig.4.2 Bi – phase (center- tapped) full wave uncontrolled rectifier.

Example 4.1

 For the single - phase, full-wave, uncontrolled rectifier show in Fig.2.8, the supply voltage it 110V, 50Hz .the load resistor is 25Ω.calculate:

(a)The average value of the output voltage and current.

(b)The rms value of the output voltage and current.

(c) The dc power consumed by the load (P_{dc}) and the average value of the power delivered to the load (P_{ac}).

Sketch the appropriate voltage and current waveforms.

Solution

(a) The average value of the load voltage V_{dc}

$$V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_m \sin \omega t\, d\omega t = \frac{2V_m}{\pi} = \frac{2\sqrt{2}x110}{\pi} = 99.035 \text{ V}$$

The average value of the load current

$$I_{dc} = \frac{V_{dc}}{R} = \frac{99.035}{25} = 3.961 \text{ A}$$

(b) the rms value of the load voltage V_{orms} :

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$$V_{orms} = \sqrt{\frac{1}{\pi} \int_0^{\pi} (V_m \sin \omega t)^2 \, d\omega t}$$

$$\frac{V_m}{\sqrt{2}} = \frac{\sqrt{2} x 110}{\sqrt{2}} = 110 \text{ V}$$

$$I_{orms} = \frac{V_{orms}}{R} = \frac{110}{25} = 4.4 \text{ A}$$

(c) The dc power,

$$P_{dc} = \frac{V_{dc}^2}{R} = \frac{(99.035)^2}{25} = 392.31 \text{ W}$$

$$P_{ac} = \frac{V_{orms}^2}{R} = \frac{(110)^2}{25} = 484 \text{ W}$$

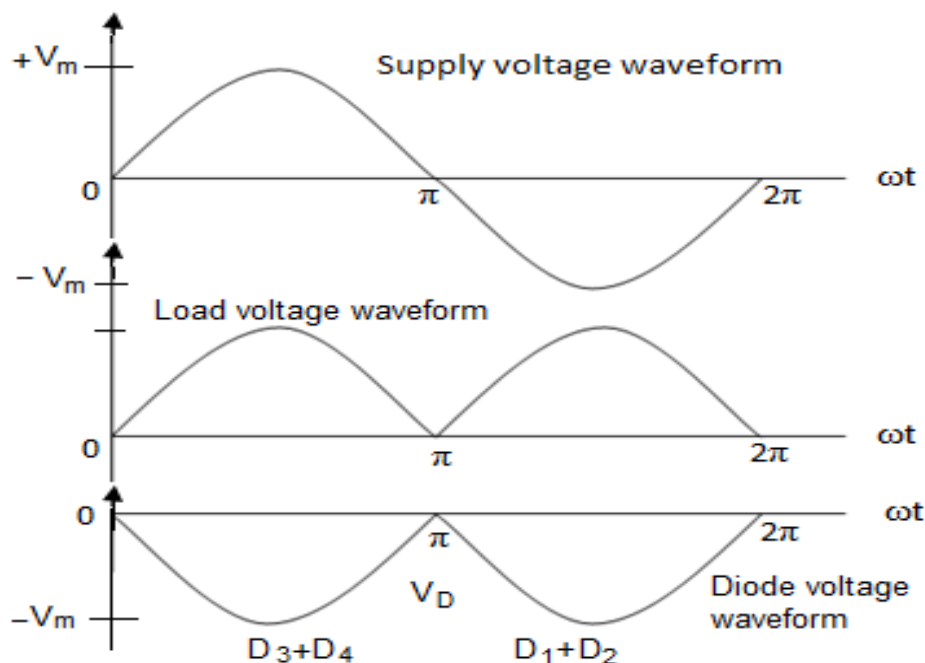The voltage and current waveforms are shown in Fig.4.3.

Fig.4.3 voltage and current waveforms.

5.3 Single-phase full-wave uncontrolled rectifier loaded with highly inductive load

Fig. 4.4 (a) presents the circuit connection for a single-phase, full-wave, rectifier loaded with a highly inductive load. Highly inductive loads are basically *R-L* loads where $L >>> R$. Therefore, the load time constant $\tau = L/R$ is very high and can be considered infinity. Consequently, the load current is assumed constant. For one

total period of operation of this circuit, the corresponding waveforms are shown in Fig. 4.4 (b).

During the conduction of D_1 and D_2 simultaneously the supply voltage appears directly across the load so that the load voltage v_o (ωt) remains the form shown in Fig.4.1(b) (same as the case of resistive load). Hence, the average value of the load voltage V_{dc} can be calculated as follows:

$$V_{dc} = \frac{1}{\pi}\int_0^{\pi} V_m sin\omega t \, d\omega t = \frac{V_m}{\pi}(-cos\pi + cos0^o) = \frac{2V_m}{\pi} \tag{4.9}$$
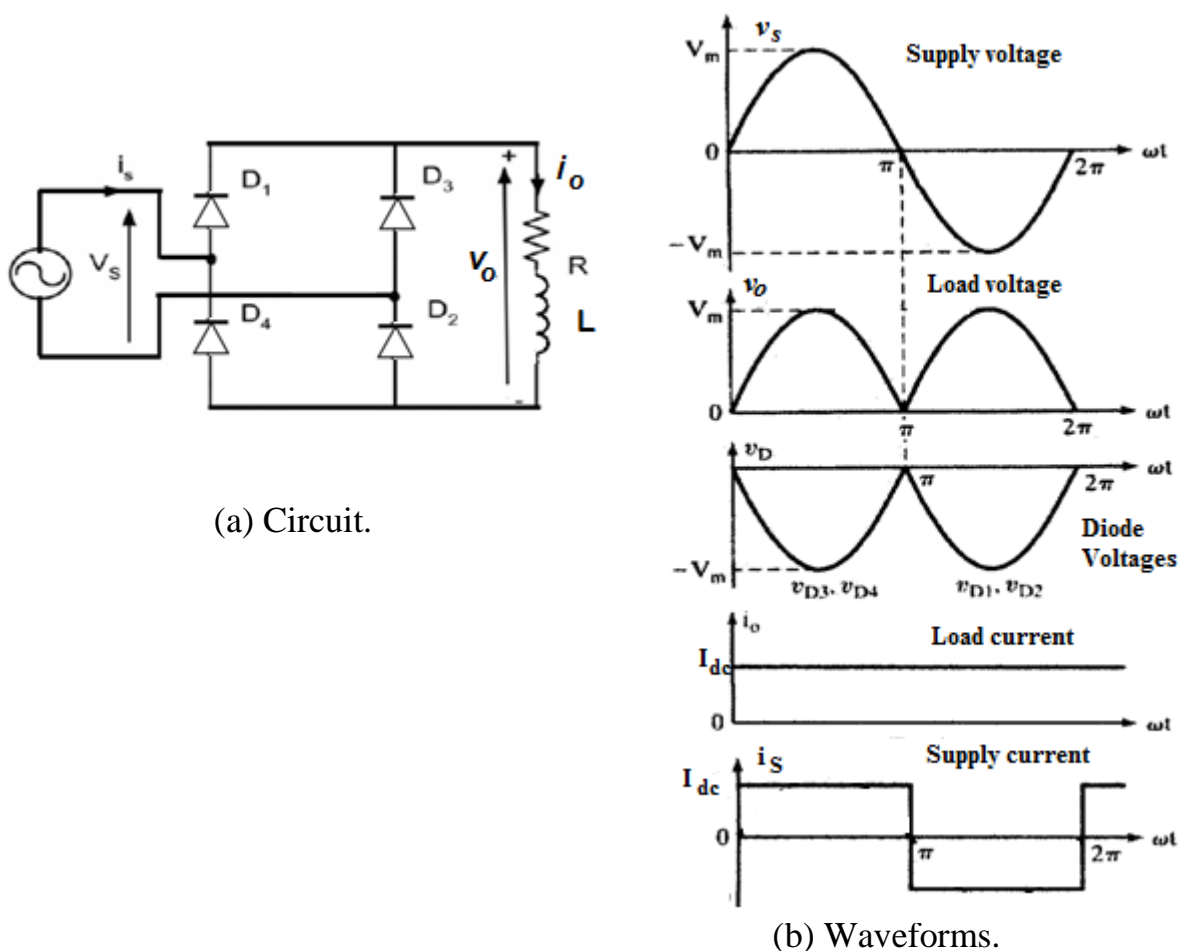

(a) Circuit.

(b) Waveforms.

Fig.4.4 Single -phase full-wave rectifier loaded with highly inductive load.

Since the load is a highly inductive load. Then, the load current is considered constant (ripple free current) and its average value is

$$I_{dc} = \frac{V_{dc}}{R} = \frac{2V_m}{\pi R} \tag{4.10}$$

and the d.c. power is

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$$P_{dc} = V_{dc}I_{dc} = \frac{V_{dc}^2}{R} \tag{4.11}$$

The rms value of the load voltage V_{rms} can be calculated as follows:

$$V_{orms} = \sqrt{\frac{1}{\pi}\int_0^\pi (V_m sin\omega t)^2\, d\omega t}$$

$$= \sqrt{\frac{(V_m)^2}{\pi}\int_0^\pi \frac{1}{2}(1 - cos2\omega t)d\omega t} = \frac{V_m}{\sqrt{2}} \tag{4.12}$$

Therefore the rms value of the load current I_{orms} is

$$I_{orms} = \frac{V_{rms}}{R} = \frac{V_m}{\sqrt{2}R} \tag{4.13}$$

Since the load current is constant over the studied period, therefore the rms value of the load current I_{orms} is

$$I_{orms} = I_{dc} = I_a \tag{4.14}$$

The output AC power is given by:

$$P_{ac} = V_{orms}I_{orms} = \frac{V_{orms}^2}{R} = \frac{(0.707V_m)^2}{R} \tag{4.15}$$

Problem 4.1
A single-phase full-wave uncontrolled bridge rectifier is supplying a highly inductive load (L/R   ratio is very large), the load current is assumed to be smooth and ripple –free. If the supply voltage is 220V, 50Hz, and the inductor load resistance R=22 Ω, Calculate:
(a)The average output voltage V_{dc} and current I_{dc}.
(b) The rms value of the output voltage V_{orms} and current I_{orms} .
(c) The rms value of the diode current I_{Drms} and the PRV of each diode.

Problem 2.2   Repeat problem (4.1) with Bi-phase rectifier type and compare your results.