Al-Mustaqbal University College
Department of Medical Instrumentation Techniques Engineering
Class: Third
Subject: Power Electronic
Lecturer: Dr. Mayasah Razzaq Al-ghazaly
Lecture: 1

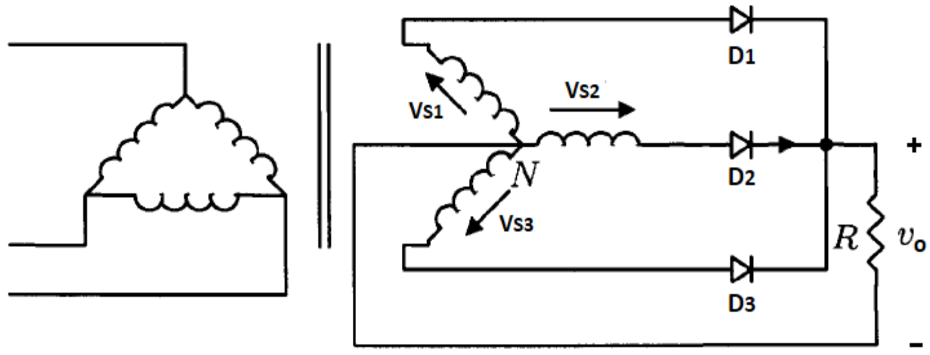

Figure 2.11: A three-phase half-wave uncontrolled rectifier with resistive load.

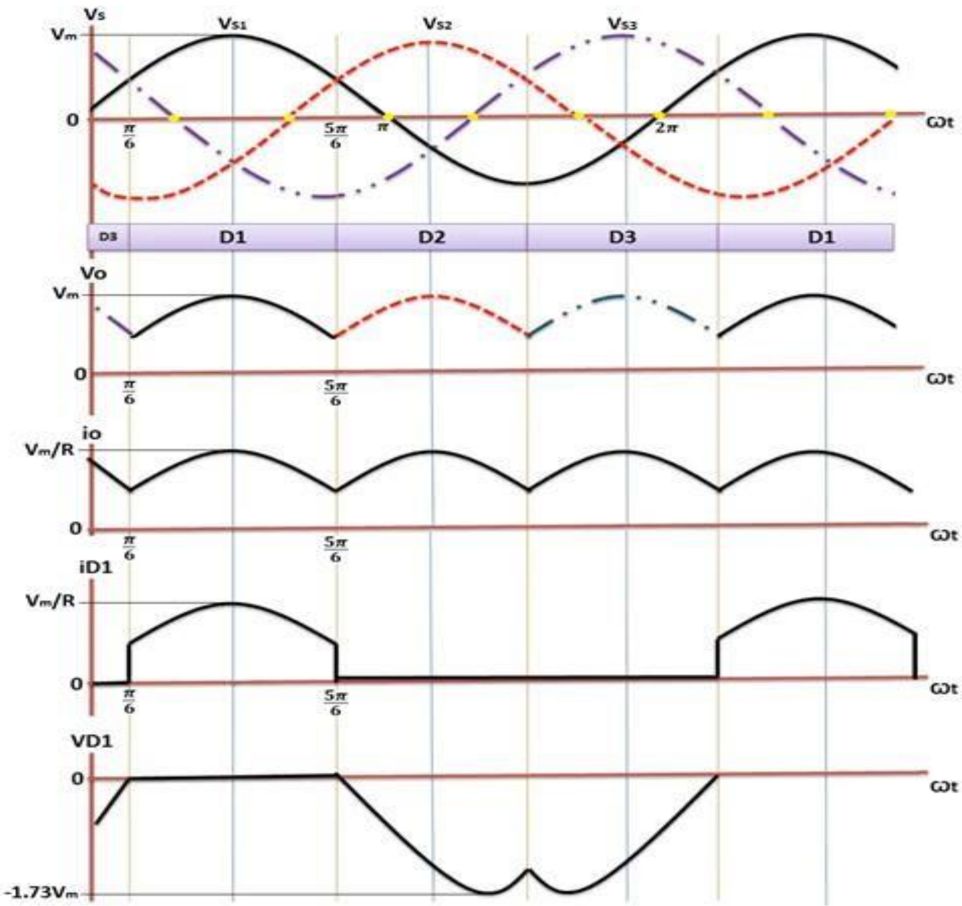

Figure 2.12: The waveforms of the three-phase half-wave uncontrolled rectifier with a resistive load.

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$$V_{line} = \sqrt{3}V_{phase}$$

The average value of the load voltage:

$$V_{DC(Load)} = \frac{3}{2\pi}\int_{\pi/6}^{5\pi/6} v_m sin\omega t d\omega t$$

$$\boxed{V_{DC(Load)} = \frac{3\sqrt{3}v_{m(phase)}}{2\pi}}$$

The average value of the load current:

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

$$\boxed{I_{DC(Load)} = \frac{3\sqrt{3}v_{m(phase)}}{2\pi R}}$$

The rms value of the output voltage and current:

$$V_{RMS(Load)} = \sqrt{\frac{3}{2\pi}\int_{\pi/6}^{5\pi/6} [v_m sin\omega t]^2 d\omega t} = 0.84v_{m(phase)}$$

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

Adding an inductance in series with the load resistance changes the current waveform. <u>If **L** is much higher than **R** (L>>>R),</u> the load time constant L/R is very high and can be considered infinity. Consequently, the load current is assumed constant as shown by the waveforms in Figure 2.13.

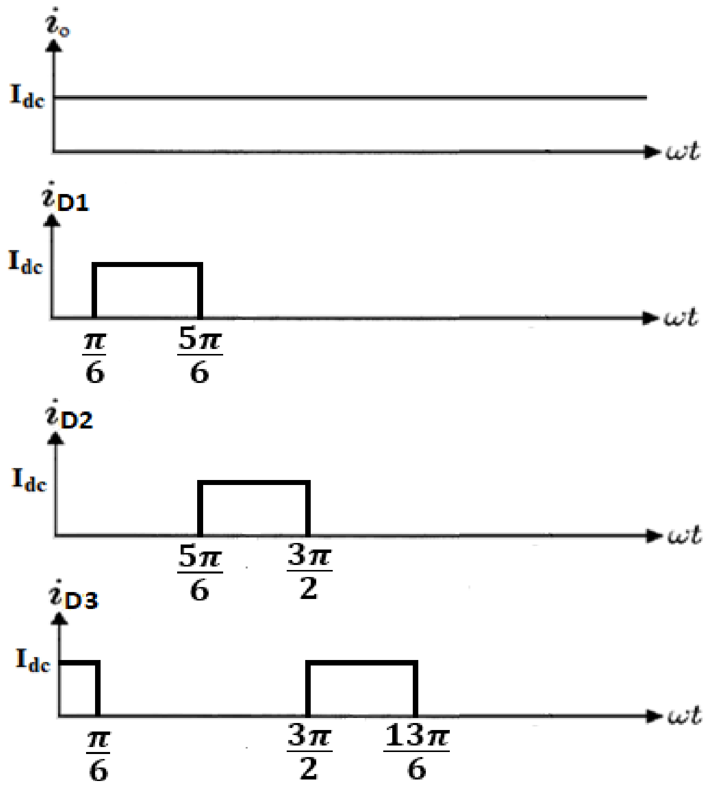


Figure 2.13: The current waveforms of the three-phase half-wave uncontrolled rectifier loaded with highly inductive load.

Example 5: Power is supplied to heavily inductive load from a three-phase supply, using a three-phase half-wave rectifier. If the supply phase voltage is 220 V and the resistance of the load is 100 Ω, determine the DC load voltage and current. Then,

(a) Sketch the output load voltage waveform.

(b) Sketch D1 current waveform.

3 Solution:

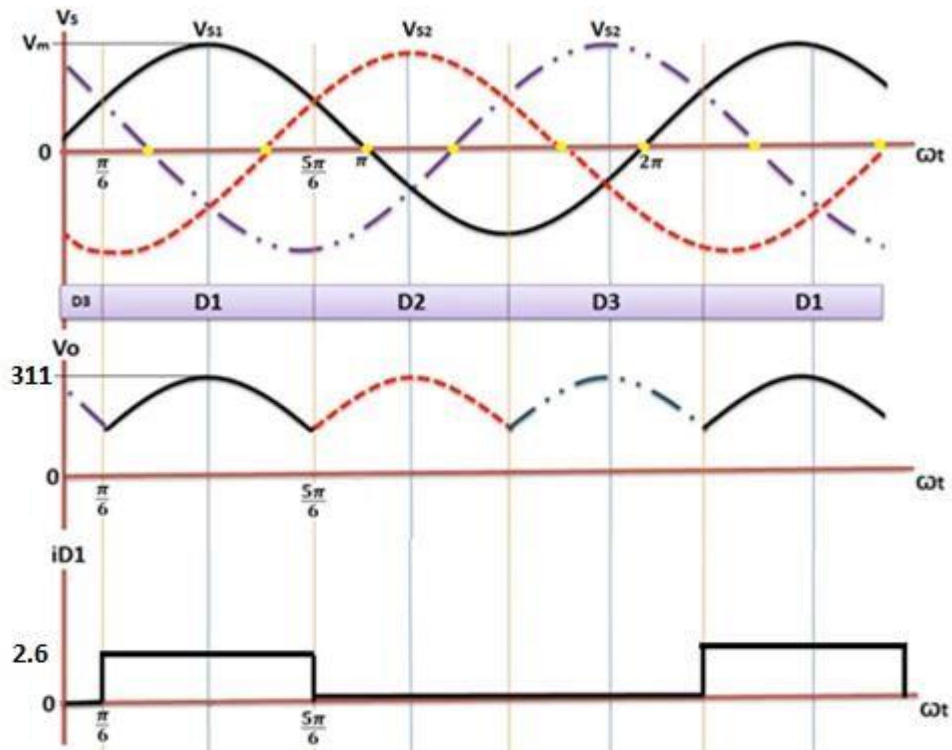
$$V_{s,RMS(Phase)} = 220\ V, \qquad R = 100\ \Omega, \qquad L \gg R$$

$$V_{DC(Load)} = \frac{3\sqrt{3}v_{m(phase)}}{2\pi}, \qquad v_{m(phase)} = 220\sqrt{2}$$

$$V_{DC(Load)} = \frac{(3\sqrt{3})(220\sqrt{2})}{2\pi} = 257.4V$$

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

$$I_{DC(Load)} = \frac{257.4V}{100} = 2.6A$$



3.4 Three-Phase Full-Wave (Bridge) Uncontrolled Rectifier

A basic three-phase Full-wave uncontrolled rectifier circuit is shown in Figure 2.14. The rectifier is fed from an ideal 3-phase supply through delta-star transformer. The principle of operation of this rectifier can be explained as follows:

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- Each three-phase line connects between pair of diodes. One to route power to positive (+) side of load, and other to route power to negative (-) side of load.

- Only one diode in the top half of the bridge may conduct at one time (D1, D3, or D5). The diode that is conducting will have its anode connected to the phase voltage that is highest at that instant.

- Only one diode in the bottom half of the bridge may conduct at one time (D2, D4, or D6). The diode that is conducting will have its cathode connected to the phase voltage that is lowest at that instant.

- There are six combinations of line-to-line voltages (three phases taken two at a time). Considering one period of the source to be 2π, a transition of the highest line-to-line voltage must take place every $2\pi/6 = \pi/3$. Because of the six transitions that occur for each period of the source voltage, the circuit is called a six-pulse rectifier.

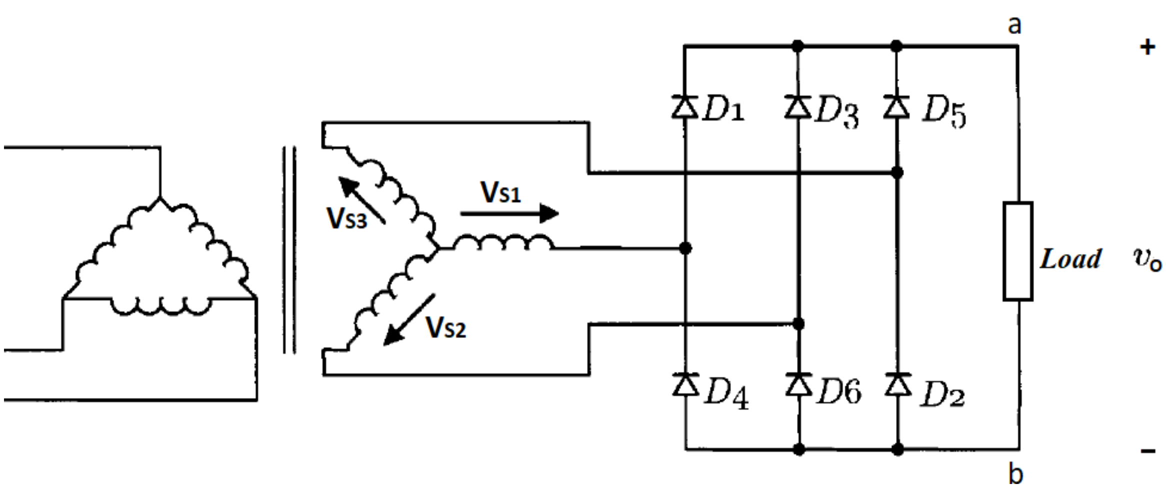

Figure 2.14: A three-phase full-wave uncontrolled rectifier.

Similar to the three-phase rectifier circuit, the conduction angle of each diode is $2\pi/3$. If L is much higher than R (L>>>R), the load time constant L/R is very high and can be considered infinity. Consequently, the load current is assumed constant. The current and voltage waveforms of the three-phase full-wave uncontrolled rectifier loaded with highly inductive load are shown in Figure 2.15.

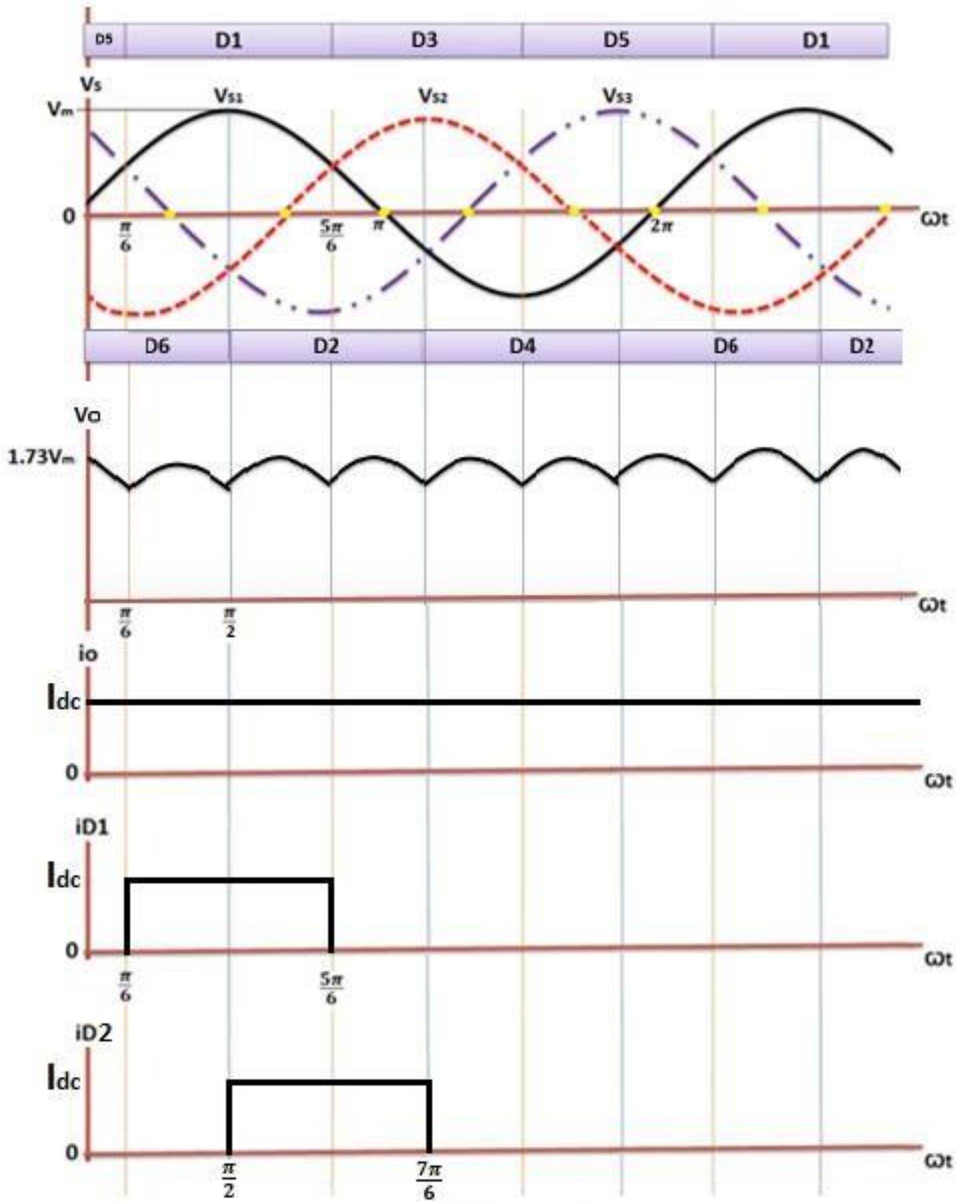

Figure 2.15: The current and voltage waveforms of the three-phase full-wave uncontrolled rectifier loaded with highly inductive load.

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The average value of the load voltage:

$$V_{DC(Load)} = \frac{3}{\pi}\int_{\pi/6}^{\pi/2} \sqrt{3}v_m \sin\left(\omega t + \frac{\pi}{6}\right) d\omega t = \frac{3}{\pi}\int_{\pi/3}^{2\pi/3} \sqrt{3}v_m \sin \omega t d\omega t$$

$$\boxed{V_{DC(Load)} = \frac{3\sqrt{3}v_{m(phase)}}{\pi}}$$

The average value of the load current:

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

$$\boxed{I_{DC(Load)} = \frac{3\sqrt{3}v_{m(phase)}}{\pi R}}$$

The rms value of the output voltage and current:

$$V_{RMS(Load)} = \sqrt{\frac{3}{2\pi}\int_{\pi/6}^{5\pi/6} \left[\sqrt{3}v_m sin\left(\omega t + \frac{\pi}{6}\right)\right]^2 d\omega t} = 1.655v_{m(phase)}$$

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

Example 6: Power is supplied to heavily inductive load from a three-phase supply, using a three-phase bridge rectifier. If the supply phase voltage is 220 V and the resistance of the load is 10 Ω, determine the DC load voltage and current. Then, sketch the output load voltage, the load current, and D4 current waveforms.

$$V_{s,RMS(Phase)} = 220\ V, R = 10\ \Omega, L \gg R$$

$$V_{DC(Load)} = \frac{3\sqrt{3}v_{m(phase)}}{\pi}, \quad v_{m(phase)} = 220\sqrt{2}$$

$$V_{DC(Load)} = \frac{(3\sqrt{3})(220\sqrt{2})}{\pi} = 514.9V$$

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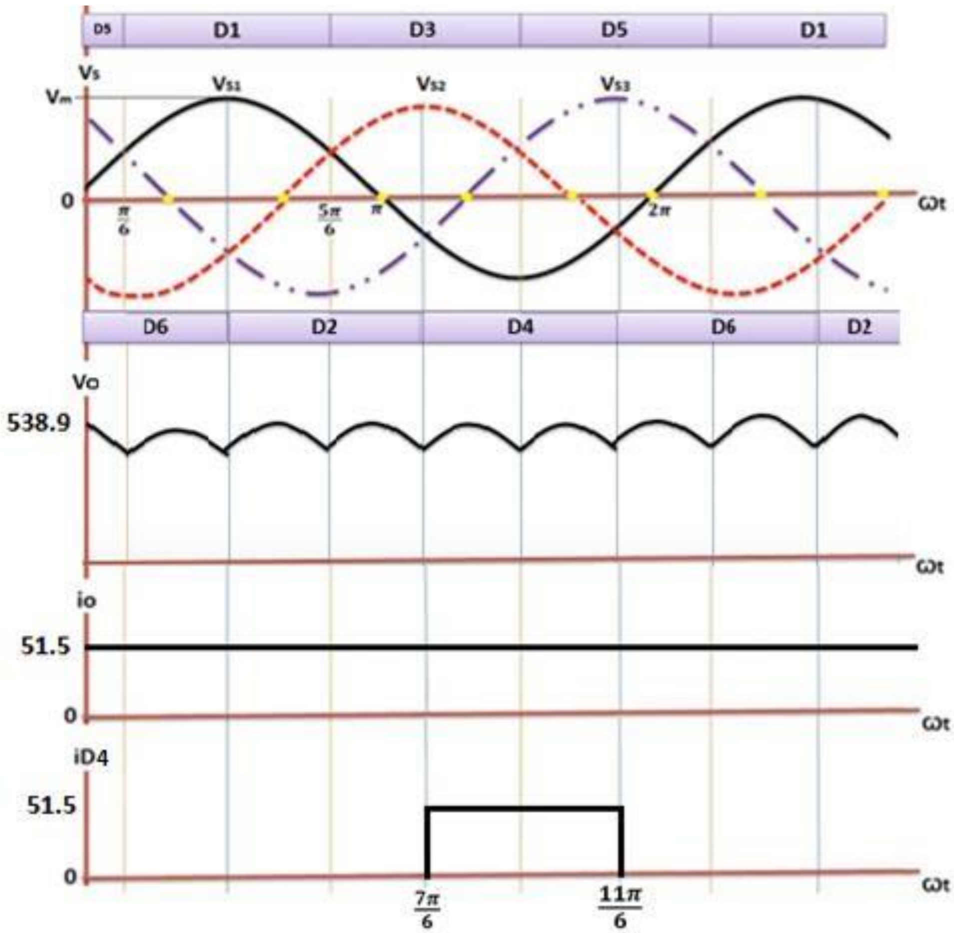
$$I_{DC(Load)} = \frac{V_{DC(Load)}}{R}$$

$$I_{DC(Load)} = \frac{514.9V}{10} = 51.49A$$



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.

3.5 Single-Phase Half-Wave Controlled Rectifier

4 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.

5 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.

6 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 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.