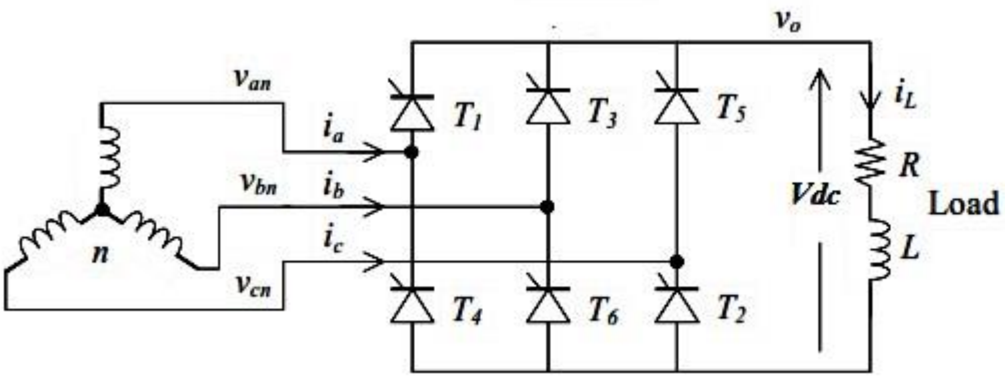
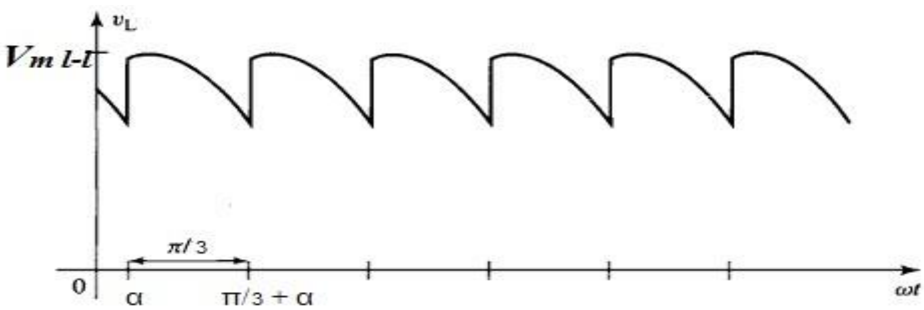
3.2 Three-phase Controlled Rectifier

3.2.2. Three- phase full – wave fully - controlled rectifier

The circuit configuration of the three- phase full – wave controlled rectifier is shown in Fig.. In this circuit, the thyristor which has the most positive voltage at its anode conducts when triggered, and the thyristor with the most negative voltage at its cathode returns the load current, if triggered. The waveforms are shown in Fig.

- Commutation of the load current from one thyristor to the next occurs at the firing instant, when the incoming thyristor reverse biases the previously conducting thyristor.
- The output dc voltage waveform is determined by the difference of potentials of the positive and negative rails.





elaf.hussein.hadi@uomus.edu.iq

- **The three thyristors (T_1,T_3 andT_5) will not work together at the same time or two of them also will not work together at the same time.**
- **The three thyristors (T_2,T_4 andT_6) will not work together at the same time or two of them also will not work together at the same time.**
- **(T_1 and T_4), (T_3 and T_6) or (T_5 and T_2) will not work together at the same time.**
- **Each thyristor is triggered at an interval of $2\pi/3$.**
- **Each thyristors pair ((T_6&T_1), (T_1&T_2), (T_2&T_3), (T_3&T_4), (T_4&T_5), (T_5&T_6)) is triggered at an interval of $\pi/3$.**
- **The frequency of output ripple voltage is $6f_S$**

Assuming continuous conduction, the average dc output voltage can be evaluated from the general p-phase formula:

$$V_{dc} = \frac{V_{ml-l}}{2\pi/P} \int_{-\frac{\pi}{P}+\alpha}^{\frac{\pi}{P}+\alpha} \cos\omega t \, d\omega t = V_{ml-l} \frac{\sin\frac{\pi}{P}}{\frac{\pi}{P}} \cos\alpha$$

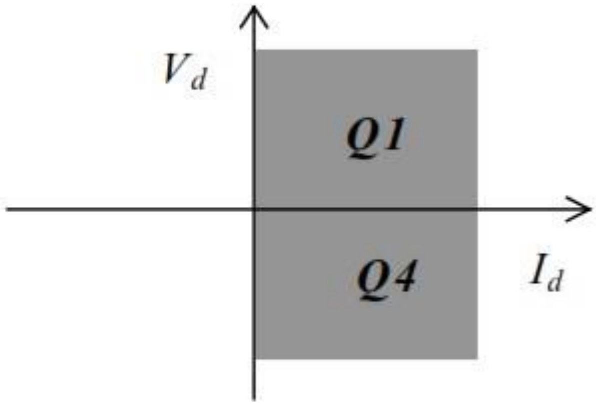
Here p = 6 , $V_{m\,l\text{-}l} = \sqrt{3}V_m$ where $V_{m\,l\text{-}l}$ = maximum line – to –line voltage,

V_m = maximum line –to-neutral voltage. Hence

$$V_{dc} = \sqrt{3}\frac{V_m}{2\pi/6} \int_{-\frac{\pi}{6}+\alpha}^{\frac{\pi}{6}+\alpha} \cos\omega t \, d\omega t = \sqrt{3}V_m \frac{\sin\frac{\pi}{6}}{\frac{\pi}{6}} \cos\alpha$$

$$V_{dc} = \frac{3\sqrt{3}}{\pi} V_m \cos\alpha$$

This converter operates in quadrants 1 and 4, developing both positive and negative polarity dc output voltage. For firing angles, $0^o \le \alpha \le 90^o$ the converter operates in quadrant 1 (giving positive output power, i.e., rectifier operation) and for $90^o \le \alpha \le 180^o$, the operation is in quadrant 4 (giving negative output power, i.e., inverter operation). Operation in quadrant 4 is of course possible only when the load includes an active dc source, able to source power into the ac supply circuit.



3. Three- phase full – wave , Half -controlled rectifier

This converter is shown in Fig.7.8. It consists of three thyristors and three diodes with freewheeling diode across the load. It gives positive voltage and positive current only (not regenerative converter) i.e, it operates in the first quadrant only (Fig.7.9).

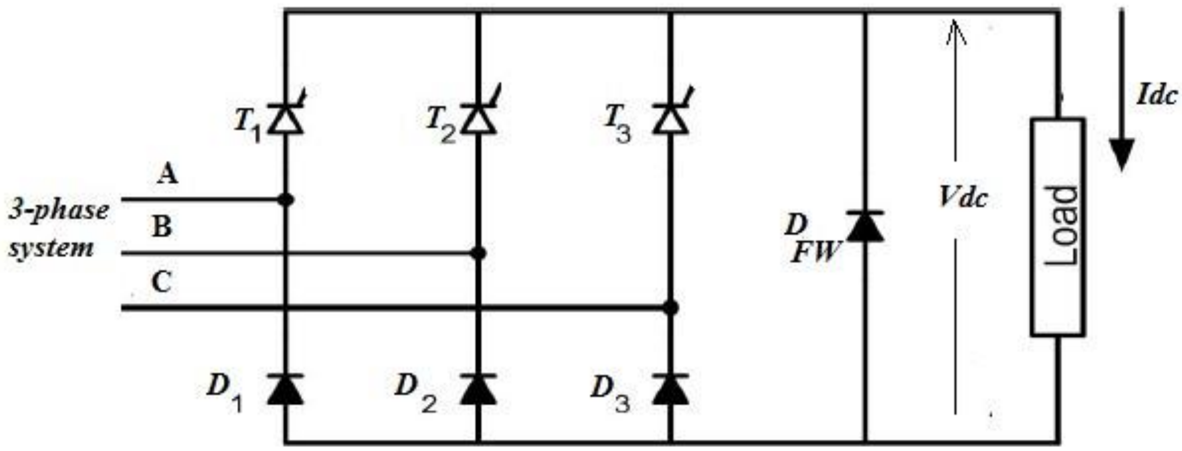
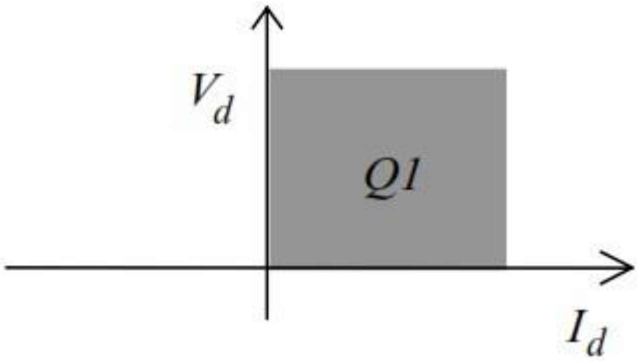


Fig.7.8

The output voltage is given by:

$$V_{dc} = \frac{3\sqrt{3}}{2\pi} V_m (1 + \cos\alpha)$$



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Example 1: A 3-phase Full-wave Fully controlled rectifier supply a highly inductive load with $R = 10\,\Omega$. The supply is a 3-phase Y-connected with 208 r.m.s. Calculate:

(a) The load current when the firing angle $\alpha = 40°$.
(b) The power drawn from the supply.
(c) If the current value kept at (a) and α changed to $135°$, calculate the power returned to the supply.

Solution

(a) For $\alpha = 40°$

$$V_m = \frac{\sqrt{2} \times 208}{\sqrt{3}} = 169.83\ V \qquad \text{(per phase)}$$

$$V_{dc} = \frac{3\sqrt{3}\,V_m}{\pi}\cos\alpha = \frac{3 \times \sqrt{3} \times 169.83}{\pi}\cos 40° = 215.18\ V$$

$$I_{dc} = \frac{V_{dc}}{R} = \frac{215.18}{10} = 21.518\ A.$$

(b) The power drawn from the source = the power dissipated at the resistance of the load

$$P_s = P_{load} = V_{dc}\,I_{dc} = 215.18 \times 21.518 = 4630.25\ W$$

(c) For $\alpha = 135°$, $i_o = I_{dc} = 21.518\ A$

$$V'_{dc} = \frac{3\sqrt{3}\,V_m}{\pi}\cos 135° = \frac{3\sqrt{3} \times 169.83}{\pi}\cos(135)$$

$$= -198.625.$$

∴ power return to the source:

$$P_s = V'_{dc}\,I_{dc} = -198.625 \times 21.518$$

$$= -3945.189\ W.$$

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Example 2 : If the converter in example 1 is replaced by Full-wave half-controlled converter, Calculate :

(a) V_{dc} when $\alpha = 45^\circ$
(b) V_{dc} when $\alpha = 75^\circ$
(c) V_{dc} when $\alpha = 135^\circ$
(d) Maximum value of V_{dc}.
(e) The value of α to obtain $I_{dc} = 6A$.

Solution :

(a)

$$V_{dc} = \frac{3\sqrt{3}V_m}{2\pi}(1+\cos\alpha)$$

For $\alpha = 45^\circ$

$$V_{dc} = \frac{3\sqrt{3} \times 169.83}{2\pi}(1+\cos 45^\circ) = 239.76\,V.$$

(b) For $\alpha = 75^\circ$

$$V_{dc} = \frac{3\sqrt{3} \times 169.83}{2\pi}(1+\cos 75^\circ) = 176.8\,V.$$

(c) For $\alpha = 135^\circ$

$$V_{dc} = \frac{3\sqrt{3} \times 169.83}{2\pi}(1+\cos 135^\circ) = 41.36\,V.$$

(d) Max. Voltage output is when $\alpha = 0^\circ$:

$$V_{dc} = \frac{3\sqrt{3} \times 169.83}{2\pi}(1+\cos 0^\circ) = 280.8\,V.$$

(e) $I_{dc} = \frac{V_{dc}}{R} = 6A$ or $V_{dc} = 6R = 6 \times 10 = 60V.$

$$60 = \frac{3\sqrt{3} \times 169.83}{2\pi}(1+\cos\alpha)$$

From which $\alpha = \underline{\underline{52.9^\circ}}$.