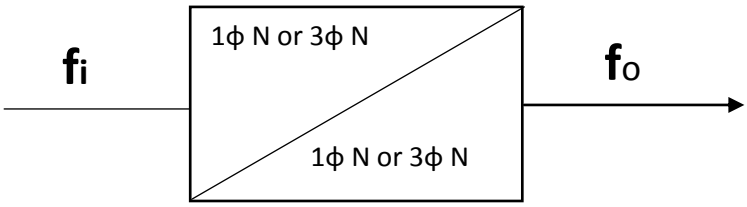
16. Cycloconverters

A cycloconverter is a direct-frequency changer that converts **ac** power at one frequency to **ac** power at another frequency by **ac-ac** conversion.

Cycloconverters are used in high power applications driving synchronous and induction motor. They are usually phase controlled and they use thyristors due to their ease of natural (phase) commutation.



Cycloconverter Fig.1

16.1 single-phase cycloconverter:

To understand the principle of operation of cycloconverter, the single-phase to single-phase cycloconverter (Fig.2) should be studied first. This converter consists of back to ack connection of two full-wave bridge rectifier circuits. Fig.3 shows the operate waveforms of this cycloconverter with resistive load.

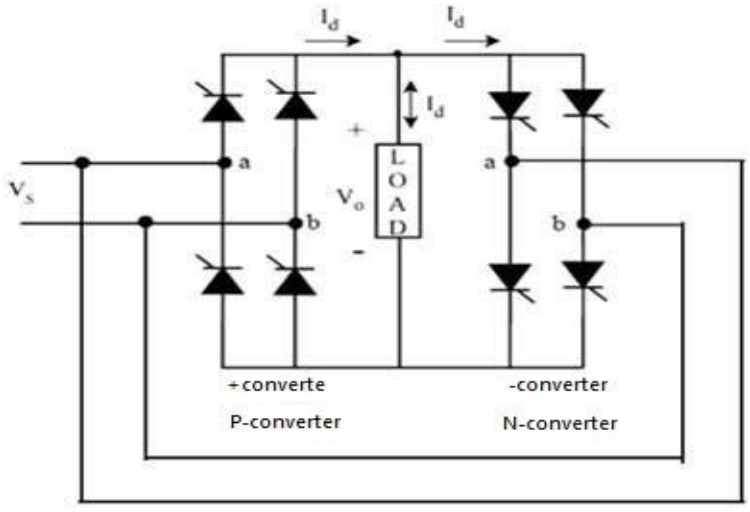


Fig.2 single-phase to single-phase cycloconverter

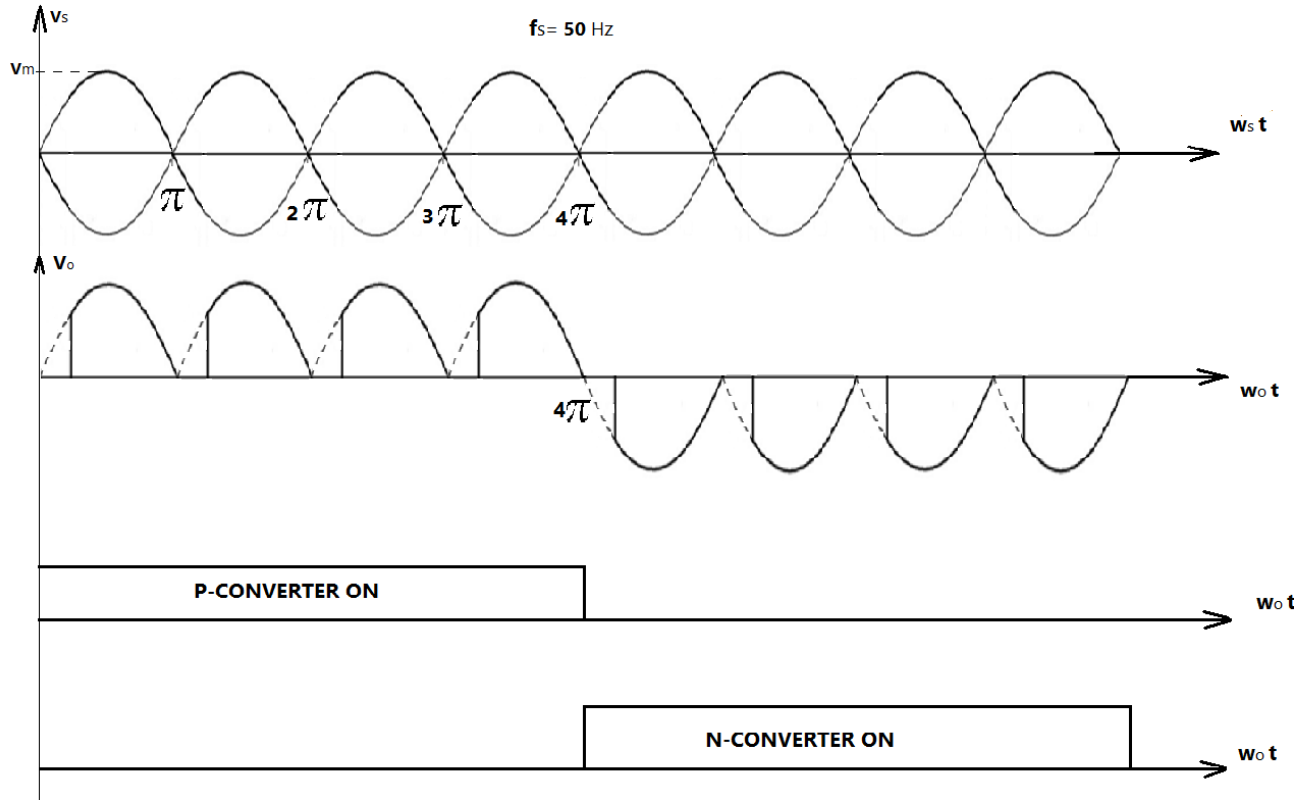


Fig.3 waveforms with resistive load.

If input voltage is

$v_s = V_m \sin w_s t$

The r.m.s output voltage can be found from:

$$V_o = \left\{\frac{8}{8\pi}\int_{\alpha p}^{\pi}\left(\sqrt{2}\,V_s \sin w_s t\right)^2 dwt\right\}^{\frac{1}{2}}$$

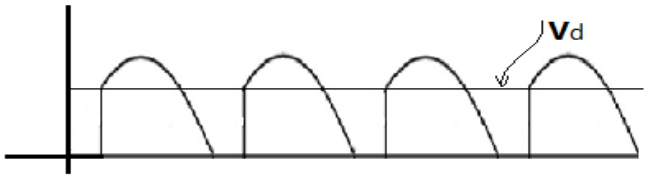
$$= \left\{\frac{16{V_s}^2}{16\pi}\int_{\alpha p}^{\pi}(1-\cos 2w_s t)\,dwt\right\}^{\frac{1}{2}}$$

$$= V_s\left[\frac{1}{\pi}\left(\pi - \alpha p + \frac{\sin 2\alpha p}{2}\right)\right]^{\frac{1}{2}}$$ (Not depend on f_o)

- When p-converter operating alone, the output voltage is positive half-cycles, with average output voltage of

$V_{d1} = \frac{2V_m}{\pi}\cos\alpha$

step down converter



The output frequency $f_o = \frac{1}{T_o} = \frac{1}{4}f_s$. Also, when N-converter operating alone, the output voltage is negative with average value: $V_{d2} = -V_{d1}$

Example: The input voltage to the cycloconverter in Fig.2 is 120 v (r.m.s), 50Hz. The load resister is 5Ω and the inductance is L=40 mH. The frequency of the output voltage is 25Hz. If the converters are operated as semiconverters such that

$0 \le \alpha \le \pi$ the delay angle is $\alpha p = \frac{2\pi}{3}$, determine:

(a) The rms value of the output voltage V_o.
(b) The rms value of the load current I_o.
(c) The input power factor.

Solution:

(a) The rms value of the output voltage:

$$V_o = V_s\left[\frac{1}{\pi}\left(\pi - \alpha p + \frac{\sin 2\alpha p}{2}\right)\right]^{\frac{1}{2}}$$

$$= 120\left[\frac{1}{\pi}\left(\pi - \frac{2\pi}{3} + \frac{\sin\frac{4\pi}{3}}{2}\right)\right]^{\frac{1}{2}}$$

(b) $Z = \sqrt{R^2 + (w_o L)^2} = \sqrt{(5)^2 + (2\pi * 25 * 40 * 10^{-3})^2} = 8.02$

$$\theta = \tan^{-1}\frac{6.28}{5} = 51.4^{\circ}.$$

The r.m.s load current is $I_o = \frac{V_o}{Z} = \frac{53}{8.02} = 6.6\ A$

(c) The input PF:

R.M.S input current $I_s = I_o = 6.6\ A,$

The VA rating is $VA = I_s V_s = 6.6 * 120 = 792\ VA = P_{in}$

The output power $P_o = V_o I_o \cos\theta = 53 * 6.6 * \cos 51.4$

$$= 218.23\ W$$

$$\therefore PF = \frac{P_o(W)}{P_{in}(VA)} = \frac{218.23}{792} = 0.2755\ (lagging).$$

16.2 Three-phase to single-phase cycloconverter:

The 3-phase to single-phase cycloconverter consists of two 3-phase half-wave controlled rectifiers connected as shown in **Fig.4** . One converter is for positive group and the other for the negative group.

- When p-converter operating alone, positive voltage (k) appears across the load, and when N-converter operating alone, negative voltage (L) appears across the load.

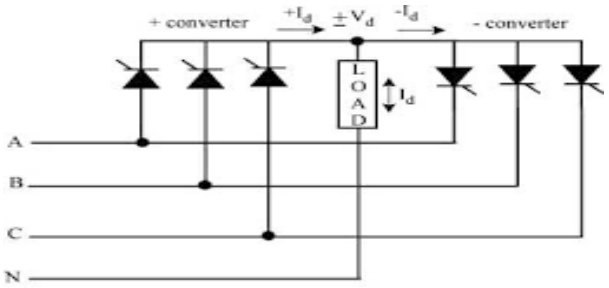


Fig. 4 3ϕ-1ϕ half-wave cycloconverter

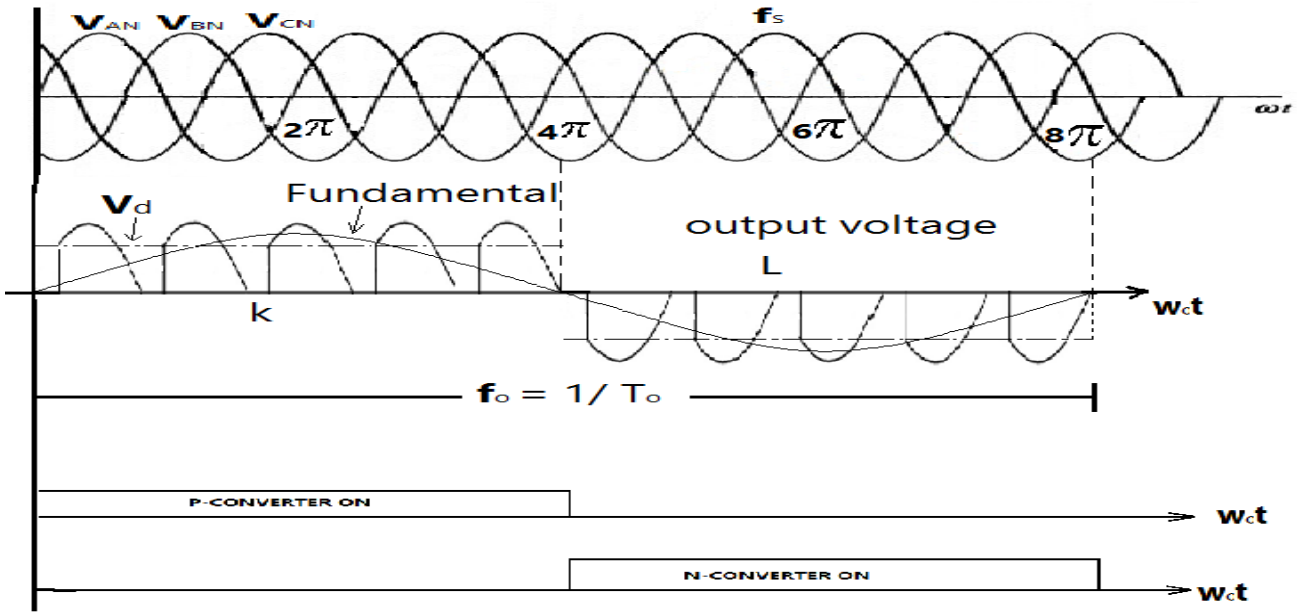


Fig.5 Waveform for resistive load

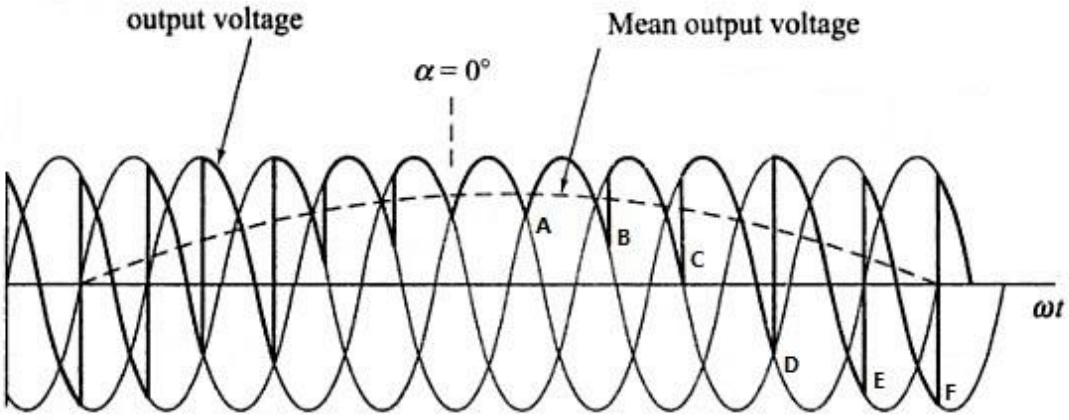
- For $\alpha \neq 0$

  For the positive group converter:

  At point "A" , $\alpha = 0$ $\quad V_d = \frac{3\sqrt{3}}{2\pi} V_m = V_{do}.$

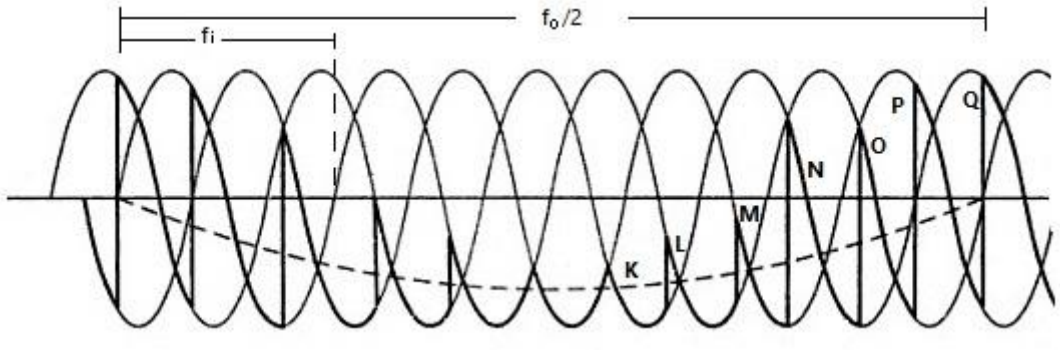
  At point "B" , $\alpha > 0$ $\quad V_d = V_{do} \cos \alpha$

  At point "F" , $\alpha = \frac{\pi}{2}$ $\quad V_d = 0$



Positive group converter operating

Negative group converter is idling



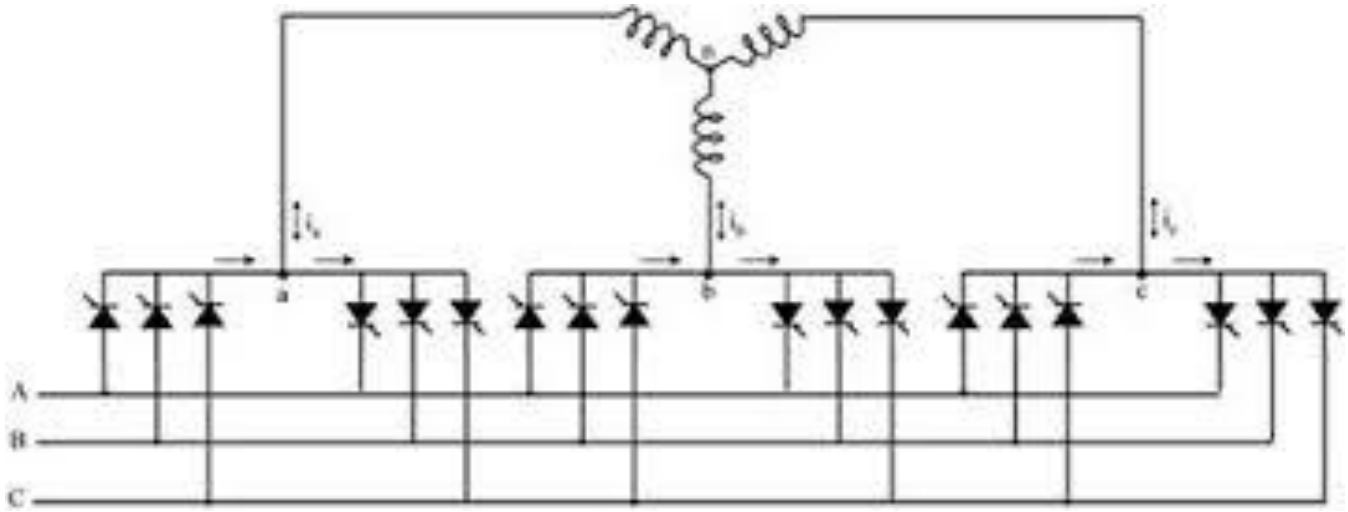
Negative group converter operating
Positive group converter is idling

At point "K" "L" "M" "N" "O" "P" and "Q"
$\alpha > 90°$, V_d is negative [inverting mode]

- Change over from positive group converter to negative group converter should be done at points "F" and "Q" where the output of the two converter are zero to avoid short circuit. Then the condition that $\alpha p + \alpha_N = \pi$ should be met.

16.3 Three-phase to three-phase cycloconverter:

- If the output of 3-phase to single-phase converters of the same kind are connected in $Y\ or\ \Delta$ and if the output voltages are $\frac{2\pi}{3}$ radians phase shifted from each other, the resulting converter is a three-phase to three-phase cycloconverter as shown in Fig.5



- Another type of 3Ø

to 3Ø cycloconverter is obtained by using Full-wave bridge rectifier as shown in Fig.6. This type of frequency changer is using 36 theyristor. The output frequency f_o is less than the input f_i .

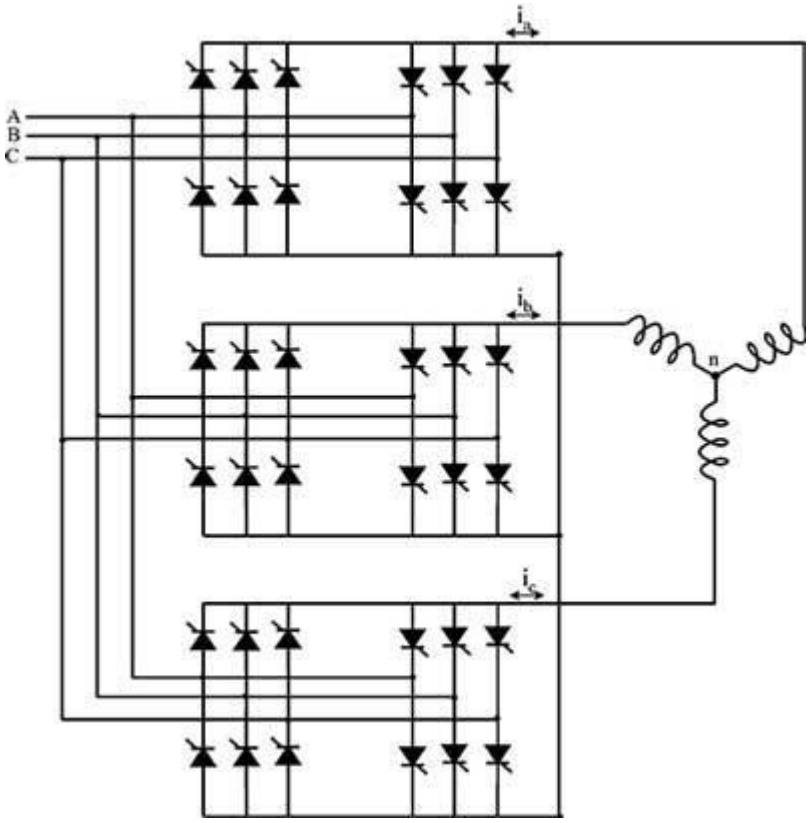


Fig.6 3Ø to 3Ø cycloconverter