CYCLOCONVERTER

In industrial applications, two forms of electrical energy are used: direct current (DC) and alternating current (AC). Usually constant voltage constant frequency single-phase or three-phase AC is readily available. However, for different applications, different forms, magnitudes and/or Frequencies are required. There are four different conversions between DC and AC power sources. These conversions are done by circuits called power converters. The converters are classified as:

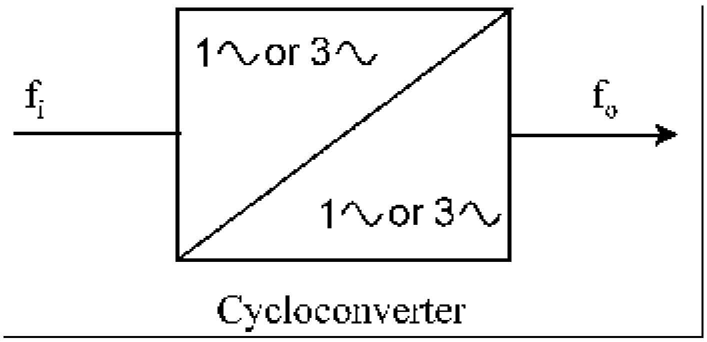
1. Rectifiers : from single-phase or three-phase AC to variable voltage DC.

2. Choppers : from DC to variable voltage DC.

3. Inverters: from DC to variable magnitude and variable frequency, single-phase or three phases AC.

4. Cycloconverters : From single-phase or three-phase AC to variable magnitude and variable frequency. A cycloconverter or a cycloinverter converts an AC waveform, such as the mains supply, to another AC waveform of a lower or higher frequency. They are most commonly used in three phase applications - while single phase cycloconverters are possible, they are so impractical that they are never used in real systems. The amplitude and the frequency of input voltage to a cycloconverter tend to be fixed values, whereas both the amplitude and the frequency of output voltage of a cycloconverter tend to be variable. A circuit that converts an AC voltage to another AC voltage at the same frequency is known as an AC/AC chopper. A typical application of a cycloconverter is for use in controlling the speed of an AC traction motor and starting of synchronous motor. Most of these cycloconverters have a high power output – in the order a few megawatts - and silicon controlled rectifier (SCRs) are used in these circuits. By contrast, low cost, low-power cycloconverters for low-power AC motors are also in use, and many such circuits tend to use TRIACs in place of SCRs. Unlike an SCR which conducts in only one direction, a TRIAC is capable of conducting in either direction, but it is also a three terminal device. It may be noted that the use of a cycloconverter is not as common as that of an inverter and a cycloinverter is rarely used. However, it is common in very high power applications.

Traditionally, AC-AC conversion using semiconductor switches is done in two different ways: 1- in two stages (AC-DC and then DC-AC) as in DC link converters or 2- in one stage (AC-AC) cycloconverters (figure 1). Cycloconverters are used in high power applications driving induction and synchronous motors. They are usually phase-controlled and they traditionally use thyristors due to their ease of phase commutation.



Block diagram of a Cycloconverter

There are other newer forms of cycloconversion such as AC-AC matrix converters and high Frequency AC-AC (HF AC-AC) converters and these use self-controlled switches. These converters, however, are not popular yet.

Some applications of cycloconverters are:

- Cement mill drives
- Ship propulsion drives
- Rolling mill drives
- Scherbius drives
- Ore grinding mills
- Mine winders

Operation Principles:

The following sections will describe the operation principles of the cycloconverter starting from the simplest one, single-phase to single-phase (1ϕ-1ϕ) cycloconverter.

2. Single-phase to Single-phase (1ϕ-1ϕ) Cycloconverter:

To understand the operation principles of cycloconverter shows the power circuit of a singlephase to single-phase Cycloconverter employing a center tapped transformer. There are four thyristors namely, P1, N1, P2 and N2. Out of the four SCRs, SCRs P1 and P2 are responsible for generating the positive halves forming the positive group. The other two SCRs, N1 and N2, are responsible for producing the negative halves forming the negative group. This configuration meant for generating 1/3 of the input frequency, i.e. this circuit generates a frequency of 16 ⅔ Hz at its output.

Depending upon the polarities of the points P and Q of the transformer, SCRs are gated. Natural commutation process is used for turning off the SCRs. This circuit configuration can be analyses for purely resistive load and R-L load.

3. With resistive load:

Let us analyses the configuration of figure 2 for a purely resistive load. During the positive half cycle, when point 7 is positive and point 11 is negative, SCR P1 being in conducting mode is gated. The current flows through positive point 7, load and the negative point 11. In the negative half cycle, when point 11 is positive and point 7 is negative, SCR P1 is automatically turned-off and SCR P2 is triggered simultaneously. Path for the current flow in this condition will be from positive point 11, SCR P2, load and the negative point 9. Direction of flow of current through the load remains the same as in the positive half cycle. Next moment, again point 7 becomes positive and point 11 becomes negative, thus, SCR P2 is automatically line commutated. SCR P1 is gated simultaneously. The current path again becomes as in the previous case when SCR P1 was conducting. Thus, it is seen that the direction of flow of current through the load remains same in all the three half cycle, or, in other words, the three positive half – cycles are being obtained across the load to produce one combined positive half-cycles as output.

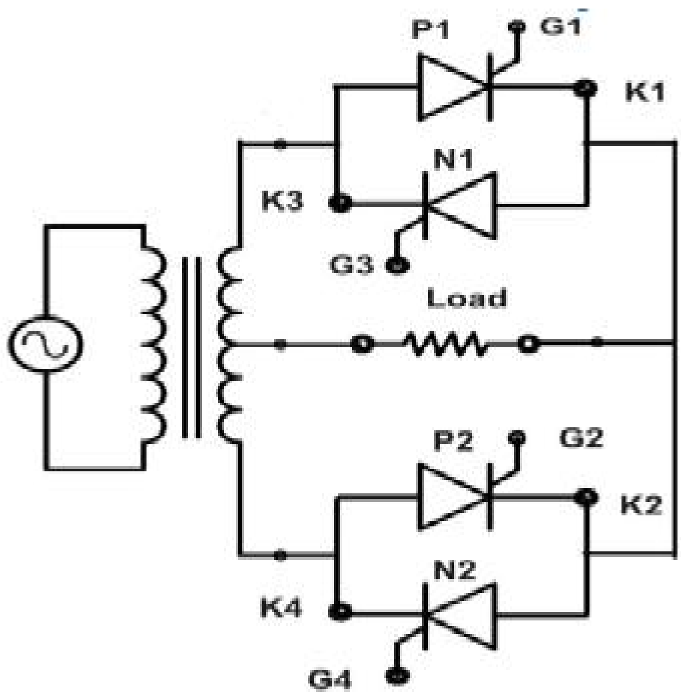
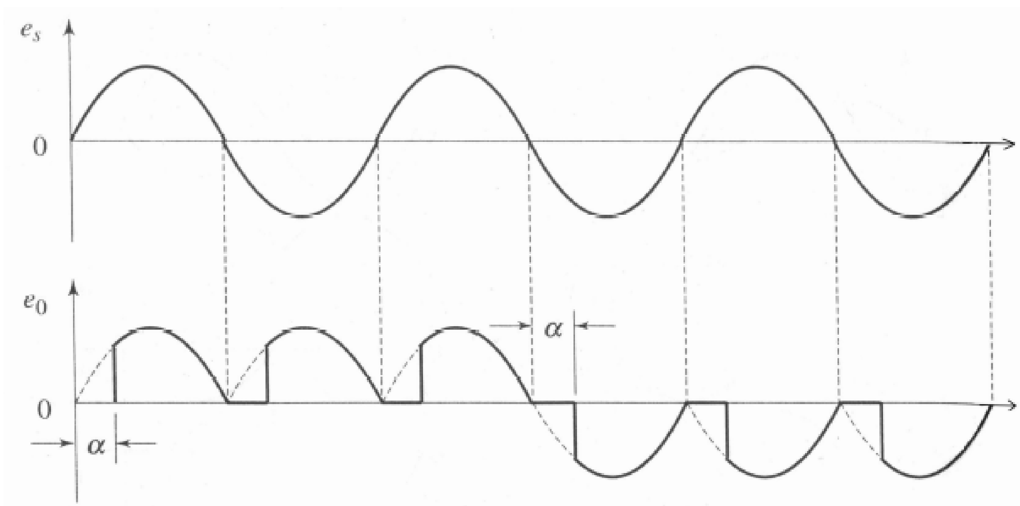


Fig. Single Phase Cycloconverter With R Load



Input and output waveforms of a $16\frac{2}{3}$ Hz cycloconverter

Figure 2

Similarly, in the next negative half-cycle of the a.c. input, when point 11, is again positive and point 7 is negative, SCR P1 is automatically switched off. Now instead of SCR P2, SCR N1 is gated. The path for the current flow will be from point 11, load, SCR N1 and back to negative point 7. Thus, the direction of flow of current through the load is reversed. In the next positive half cycle, point 7 is positive and point 11 is negative. SCR N1 is automatically turned off. SCR N2 which is in the conducting mode is simultaneously turned on. The path for the current flow becomes from positive point 7, load, SCR N2 to the negative point 11. Thus, the direction of flow of current through the load remains the same. For the next negative half cycle of a.c. input when point 11 positive and point 7 is negative, SCR N2 is automatically switched off and SCR N1 is gated. The current flow through the load again remains in the same direction. We can analyse it as producing one negative half-cycle at the output by combining three negatives halves of the input. In other words, it can be said that, three positive half cycles of the input a.c. have been combined to produce one cycle at the output, i.e. three positive half cycles at the output by the SCRs P1 and P2 whereas, three negative half cycle of the input a.c. are combined to produce one negative half cycle at the output by SCRs N1 and N2. This clearly indicate that the input frequency 50Hz is reduced to 1/3 rd ($16 \frac{2}{3}$ Hz) at the output across the load.

With inductive load :

Let us now analyze the case of an R-L load. When point 7 is positive with respect to point 9 in figure, forward biased SCR P1 is triggered at $\omega t = \alpha$, positive output voltage appears across load and load currents builds up. At $\omega t = \pi$, supply and load voltages are zero. After $\omega t = \pi$, SCR P1 is reverse biased. As load current is continuous, SCR P1 is not turned off at $\omega t = \pi$. When SCR P2 is triggered in sequence at $(\pi + \alpha)$, a reverse voltage appears across SCR P1; it is therefore turned off by natural commutation. When SCR P1 is commutated, load current has built up to some value. With the turning on of SCR P2 at $(\pi + \alpha)$, output voltage is again positive as it was with SCR P1 on. As a consequence, load current builds up further. At $(2\pi + \alpha)$, when SCR P1 is again turned on , SCR P2 is naturally commutated and load current through SCR P1 builds up to beyond . At the end of four positive half – cycles of output voltage. When SCR N2 is now triggered after SCR P2, load is subjected to a negative voltage cycle and load current Io decreases from positive to negative. Now, SCR N2 is commutated and SCR N1 is gated at $(5\pi + \alpha)$. Load current becomes more negative. So with inductive load, SCRs on in reverse biased condition for some time because voltage store in inductor.

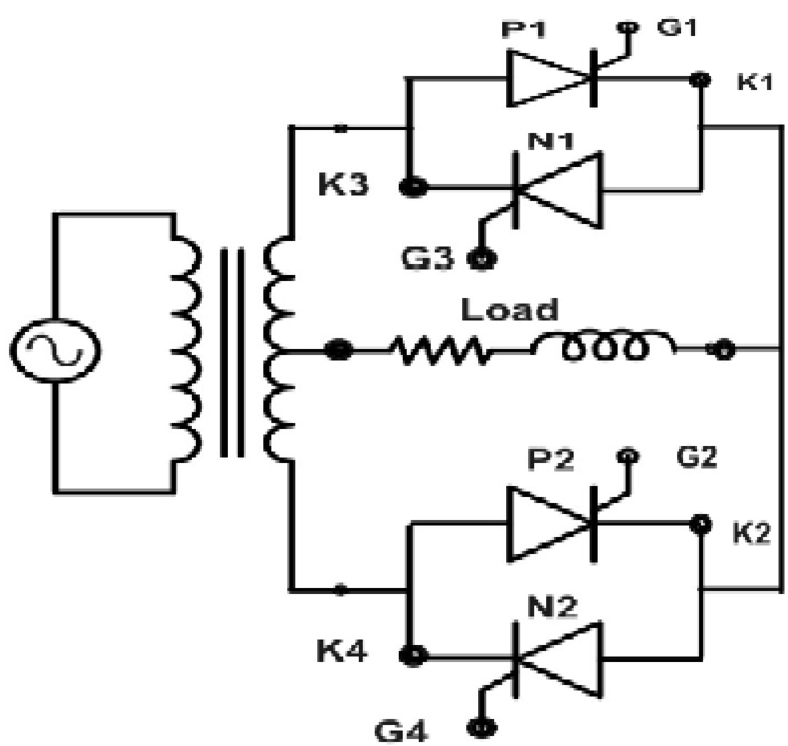


Fig. Single Phase Cycloconverter With RL Load