Unit 5: Converters

Module 18: Cycloconverter

Introduction:

Cycloconverter:

A Cyclo-converter is a device (frequency changer) that convert AC Power from one (Fixed) frequency to AC Power at another frequency (Variable), without using any intermediate DC link.

Besides the Frequency Control, Cyclo-converter output voltage can be varied / controlled by applying phase control technique.

The circuit for conversion mainly consists of switches such as thyristors, IGBTs and controlling mechanism of it.

Types of Cyclo-converters:

Based on the output frequency: The Cyclo-converters can be classified as below:

i. Step-Up Cyclo-converters

ii. Step-Down Cyclo-converters

Step-Up Cycloconverters: Step-up Cyclo-converters are those Cyclo- converters that provide output signal having frequency greater than that of input frequency. But it is not widely used since it does not have enough applications. Most applications will require a frequency less than 50Hz. Also, Step-Up Cyclo-Converter will require forced commutation which increases the complexity of the circuit.

Step-Down Cyclo-converters: Step-Down Cyclo-converters are those Cycloconverters that provide output signal having frequency which lesser then the input frequency.

These are most commonly used and work with help of Natural Commutation hence comparatively easy to build and operate.

The Step-Down is further classified into three types:

a) Single-Phase to Single-Phase Cyclo-converter

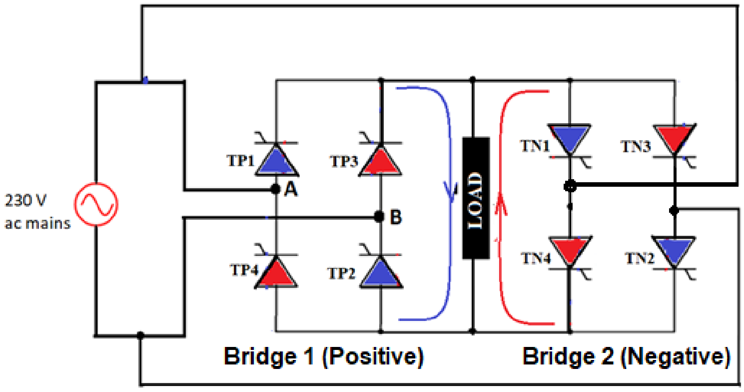
b) Three-Phase to Single-Phase Cyclo-converter

c) Three-Phase to Three-Phase Cyclo-converter

Single Phase to Single Phase Cyclo-converters is further classified into 2 types:

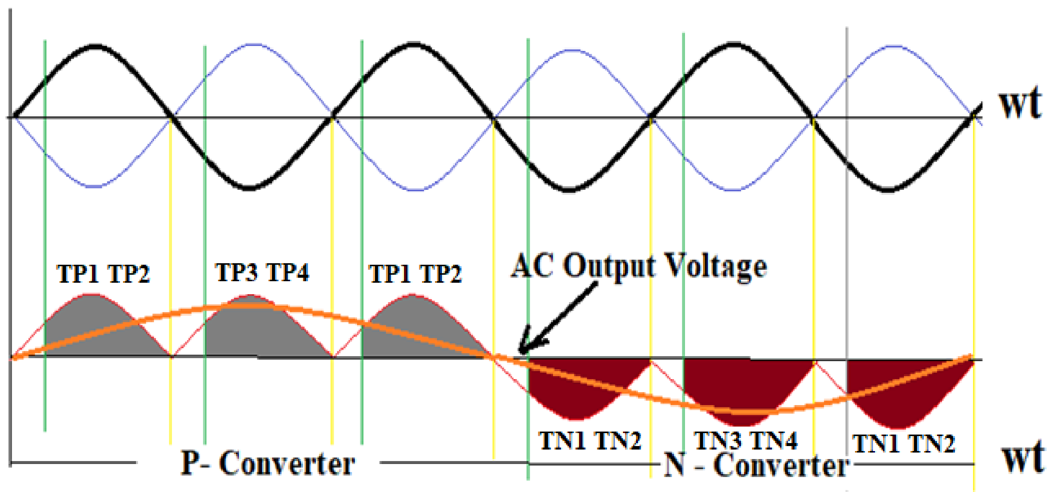
a) Single Phase to Single Phase Cycloconverter: Bridge Configuration
b) Single Phase to Single Phase Cycloconverter: Centre Tapped Transformer Configuration

Single Phase to Single Phase Cycloconverter (Step down): Bridge Configuration



It consists of Two Full-Wave, Fully Controlled Bridge thyristors, where each Bridge has 4 thyristors, and each bridge is connected in opposite direction (back to back) such that both Positive and Negative Voltages can be obtained as shown in figure below. Both these bridges are excited by single phase, 50 Hz AC supply.

During Positive half cycle of the input voltage, Positive converter (Bridge-1) is turned ON and it supplies the load current. During Negative half cycle of the input, Negative converter (Bridge-2) is turned ON and it supplies load current. Both converters should not conduct together that cause short circuit at the input. To avoid short circuit, triggering to thyristors of bridge-2 is prevented /intercepted during positive half cycle of load current, while triggering is applied to the thyristors of bridge-1 at their gates. During negative half cycle of load current, triggering to positive bridge is prevented / intercepted, while applying triggering to negative bridge. By controlling the switching period of thyristors, time periods of both positive and negative half cycles are changed and hence the frequency. This frequency of output voltage can be easily reduced in steps, i.e., 1/2, 1/3, 1/4 and so on.



The above figure shows output waveforms of a cyclo-converter that produces one-third of the input frequency. Here, for the first three cycles, the positive converter operates and supplies current to the load. And during next three cycles, the Negative converter operates and supplies load current. Here one converter is disabled if another one operates, so there is no circulating current between two converters.

Single Phase Cycloconverter: Mid Point Configuration- Step down

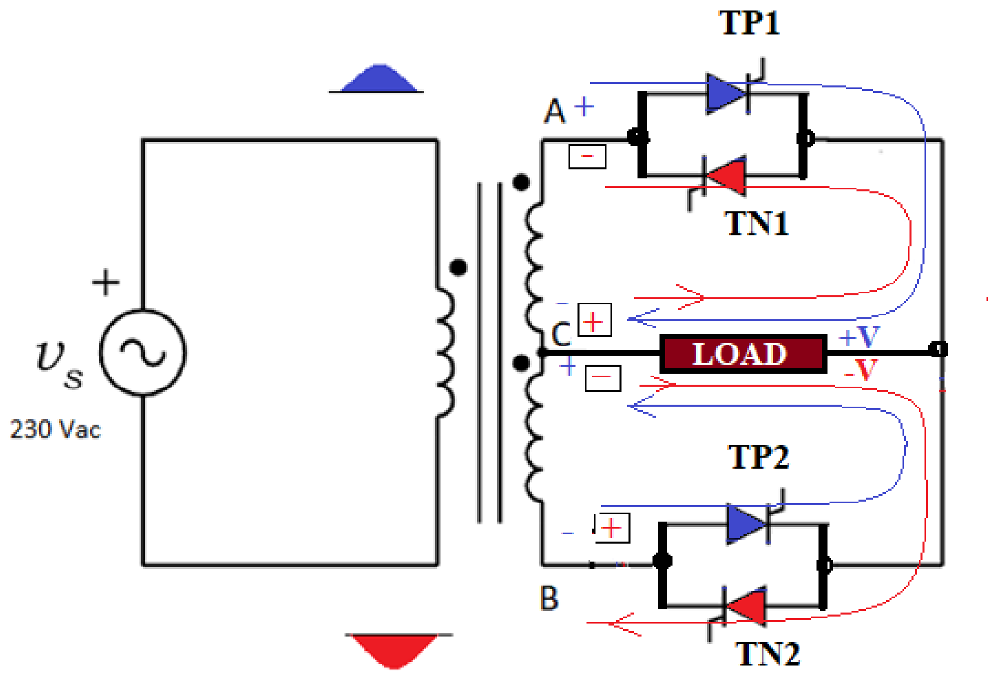


Fig: Single Phase Cycloconverter: Mid-Point Configuration- Step down

Above figure shows the power circuit of a single-phase-to-single-phase cycloconverter employing a centre-tapped transformer. There are four thyristors, namely, TP1, TN1, TP2, and TN2. Out of the four SCRs, SCRs TP1 and TP2 are responsible for generating positive halves forming the positive group. The other two SCRs TN1 and TN2 are responsible for producing the negative halves forming the negative group. This configuration is meant for generating 1/3 of the input frequency, i.e., this circuits generates a frequency of 1623Hz at its output.

Depending upon the polarities of the points A and B of the transformer, SCRs are gated. During the first positive half cycle, when point A is positive and B is negative, SCR TP1 being in conducting mode is gated. The current flows through positive point A, SCR TP1, load and the negative point C. In the negative half cycle, when point B is positive and point A is negative, SCR TP1 is automatically turned-off and SCR TP2 is triggered simultaneously. Path for the current flow in this condition will be from positive Q, SCR TP2, load and the negative point C. Direction of flow of current through the load remains the same as in the positive half cycle. In next cycle, again point A becomes positive and B becomes negative, thus, SCR TP2 is automatically line commutated. SCR TP1 is gated simultaneously. The current path again becomes as in the previous case when SCR TP1 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 combine half cycle as output.

Similarly, in the next negative half cycle of the ac. input, when point B is again positive and point A is negative, SCR TP1 is automatically switched OFF. Now, instead of SCR TP2, SCR TN1 is gated. The path for the current flow will be from point B, load, SCR TN1 and back to negative point A. Thus, the direction of flow of current through the load is reversed.

In the next positive half cycle, point A is positive and point B is negative. SCR TN1 is automatically turned off. SCR TN2 which is in the conducting mode is simultaneously turned-on. The path for the current flow becomes from positive point A, load, SCR TN2 to negative point B. Thus, the direction of flow of current through the load remains the same. For the next negative half cycle of the ac. input when point B is positive and point A is negative, SCR TN2 is automatically switched off and SCR TN1 is gated. The current flow through the load again remains in the same direction. We can thus analyse it as producing one negative half cycle at the output by combining three negative halves of the input.

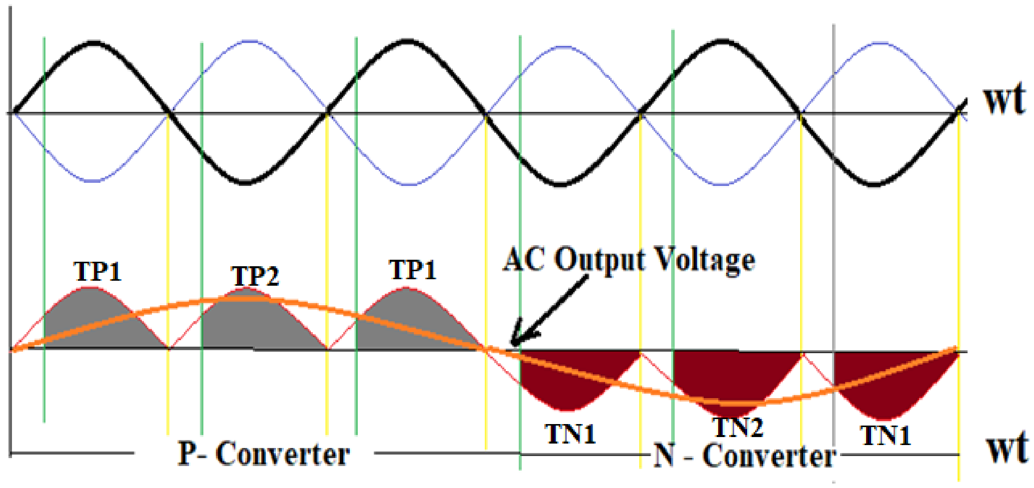


Fig: Output Waveforms of SPSP Cycloconverter (Stepdown)– Midpoint Configuration

In other words, it can be said that, three cycles of the input ac. have been combined to produce one cycle at the output, i.e., three positive half cycles at the output by the SCRs TP1 and TP2 whereas, three negative half-cycle of the input ac. are combined to produce one negative half cycle at the output by SCRs TN1 and TN2. This clearly indicates that the input frequency 50 Hz is reduced to 1/3rd (16.2/3Hz) at the output across the load. The input and output waves are shown in Figure. The output voltage magnitude can be changed by varying the firing angle of the SCRs.

Improved SPSP Cycloconverter – Midpoint Configuration

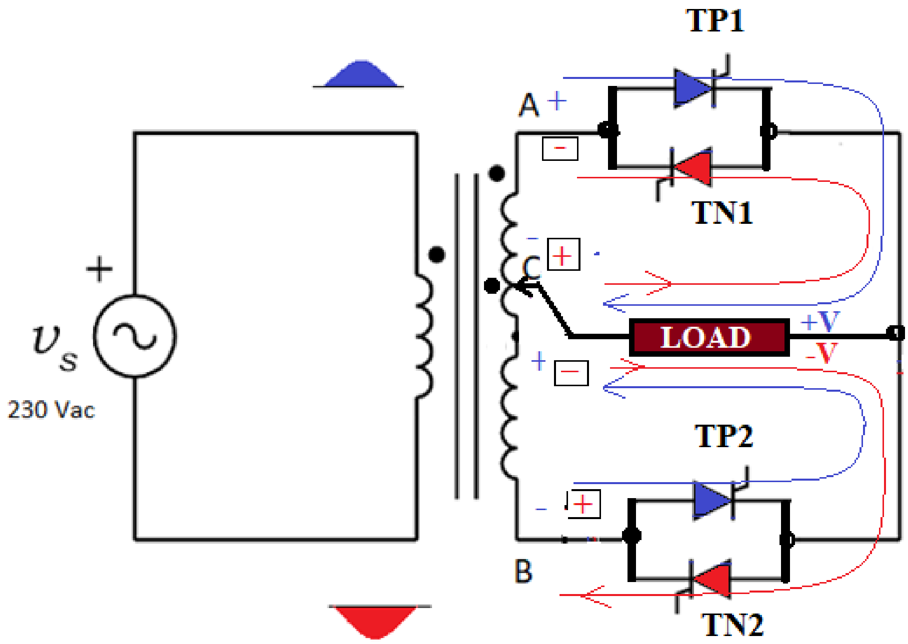


Fig: Improved SPSP Cycloconverter – Midpoint Configuration

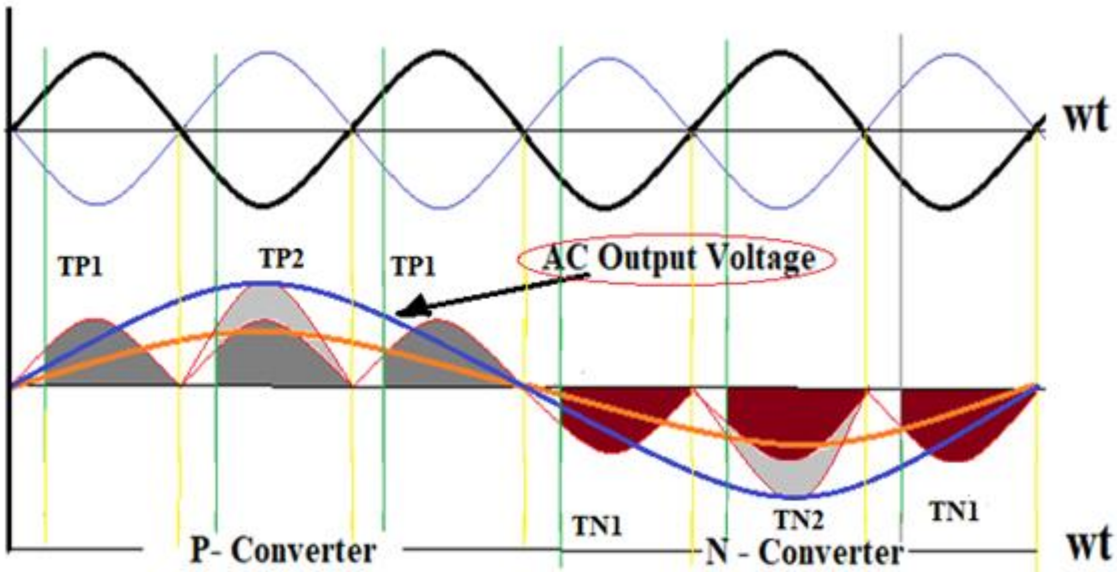


Fig: Output waveforms of Improved version of Cycloconverter(MidPoint Configuration)

Advantages of Cyclo-Converter :

- Efficiency is very high compared to other converters
- Four quadrant operation is possible because cyclo-converter is capable of power transfer in both the directions
- AC power at one frequency is directly converted to a lower frequency in a single conversion
- If one of the SCR fails, the cyclo-converter operates with a distorted output
- In this converter, power transfer is possible from supply load and vice versa at any power factor
- Dynamic response is good
- Smooth low-speed operation

Disadvantages of Cyclo-Converter

- Control circuit of Cyclo-Converter becomes complex because there are large numbers of SCRs.
- Power factor is poor at large values of Firing Angle (α).
- Cyclo-Converter output is distorted at low frequencies.

Applications of Cyclo-converters

Cycloconverters are extensively used for driving large motors like the one used in:

- Grinding Mills
- Heavy Washing Machines
- Aircraft Power supply
- Ship Propulsion system
- Cement kilns
- Rolling mills