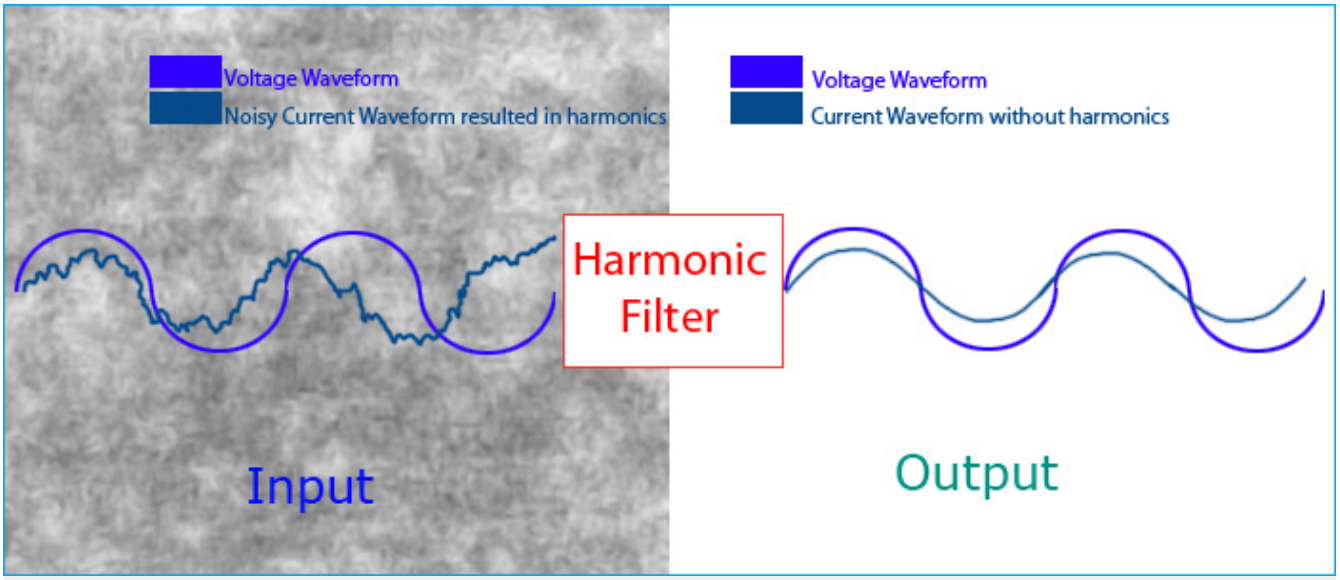
Harmonic Filter Circuit: How to remove Harmonics using Active and Passive Harmonic Filters

By Sourav Gupta Feb 08, 2019 0



Harmonic Filter Circuit: How to remove Harmonics using Active and Passive Harmonic Filters

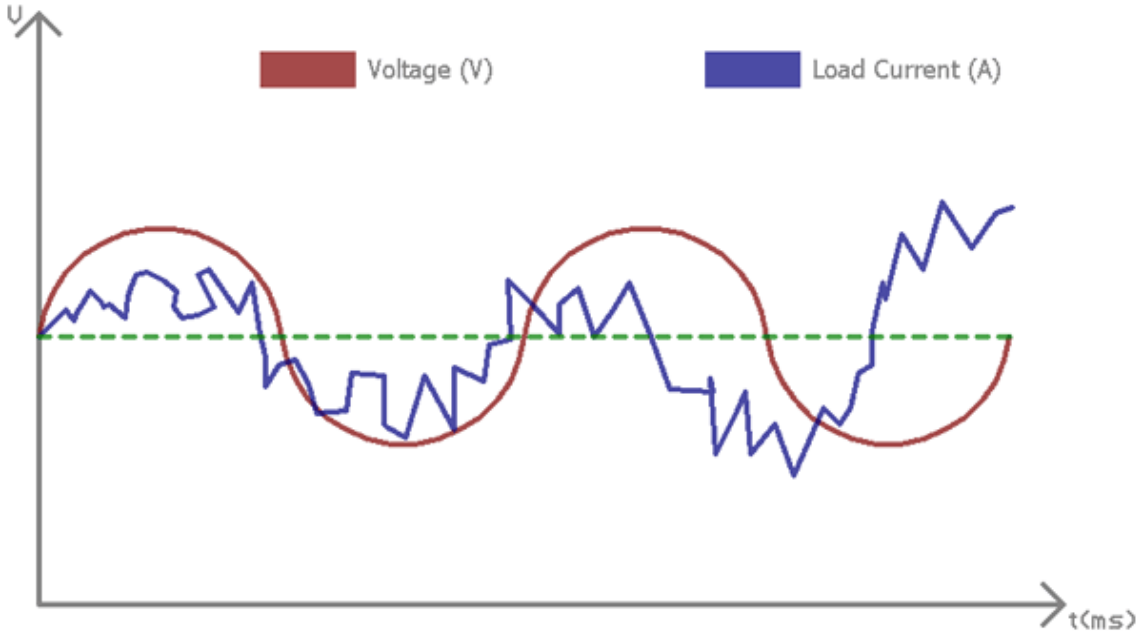
What is Harmonics in Electrical System?

In power systems, harmonics are defined as positive integer multiples of the fundamental frequency. Harmonic is a voltage or current occurs at a multiple of the fundamental frequency. **It is often regarded as noise in the power line**.

The harmonics in the power system can be classified into two types: **current harmonics and voltage harmonics.**

The **current harmonics** induced by the non-linear load such as VSDs (variable speed drives). The nonlinear loads draw current from the power line that is not in a perfect sinusoidal waveform. The nonsinusoidal current waveform can be a complex series of simple sinusoidal which can oscillate at an integer, multiple of the power line fundamental frequency.

In most cases, the **voltage harmonics** are caused by the current harmonics. The Voltage harmonic occurs because of the distorted voltage produced by the effect of current harmonics with the source impedance.



Harmonics

The above image shows the distressed current waveform across the non-linear load. Here the distorted current waveform is not following the sinusoidal wave. This shows the current harmonics in the power system.

Why it is necessary to eliminate Harmonics in the Power System?

Current and the voltage harmonics are directly proportional to the noisy power transfer to the Load. Various household and office equipment are responsible for the harmonics in the power system. The power system harmonics often increase the load current. Various instruments, like Fluorescent lights in the factories or in the house or office, are affected by harmonics and suffer from various malfunctions. Motors are hugely affected by the power system harmonics.

Sometimes the harmonics in the power systems can be very dangerous and increase power delivered to the instruments which leads to a temperature rise in the Load and can shorten the instrument life.

To **overcome this power system harmonics**, one need to reconstruct the power connection to drive nonlinear loads and to **introduce harmonics filters in the power system**.

Type of Harmonics Filters

Harmonics filters very effective to protect costly electrical equipment from distorted power outputs due to harmonics. There are different types of harmonics filters available in the electrical and electronics market depending on the rated power, applied voltage, single phase or three phases and other load-dependent parameters.

However, there are two main **types of harmonics filters** available which are **Passive Harmonic Filters and Active Harmonic Filter.**

The main difference between these two types of harmonic filters is the components used for the filter design. **Passive harmonic filters use simple passive components** mainly resistors, inductors, and capacitors. Whereas **active harmonic filters use active components** such as different types of BJTs, IGBTs, MOSFETs and integrated circuits.

As the harmonics filters are the electrical line safety equipment they must confirm the international safety standards like IEEE, EN, AS, BS and the underwriter's laboratories UL mark.

Also, the harmonics filters can be designed in different orders. Like a third order harmonic filters can filter out the frequency which is the third multiple of the fundamental frequency.

Passive Harmonic Filters

Passive harmonic filters are the most common and the easily available harmonic filter. It is affordable filter to suppress the harmonic disturbance in the power line.

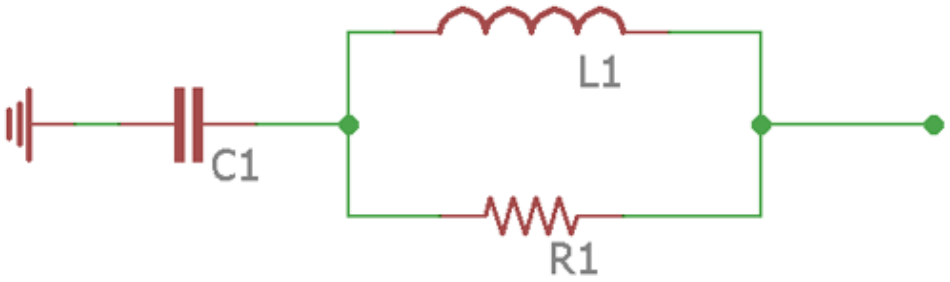
As discussed before, passive harmonic filters use standard passive components such as resistors inductors and capacitors. Those **passive components are used to form a tank circuit**. The tank circuit is designed in a special way so that it can be operated at the same resonance frequency in respect to the unwanted harmonics. The passive harmonic filters block the unwanted harmonics to pass. **The passive harmonic filter converts the harmonic current into the heat and protects the end device or load**. The filter can be tuned to a certain frequency that needs to be eliminated as harmonics.

There are mainly **four types of passive harmonic filters** are used:

1. High pass filter
2. Bandpass filter
3. C type filter and
4. Series filter.

High pass filter

High pass passive harmonic filters are used to eliminate higher order harmonics and to have flexible control over the wide range of frequencies. The basic high pass harmonic filter design use three passive components, resistor, capacitor, and inductor.

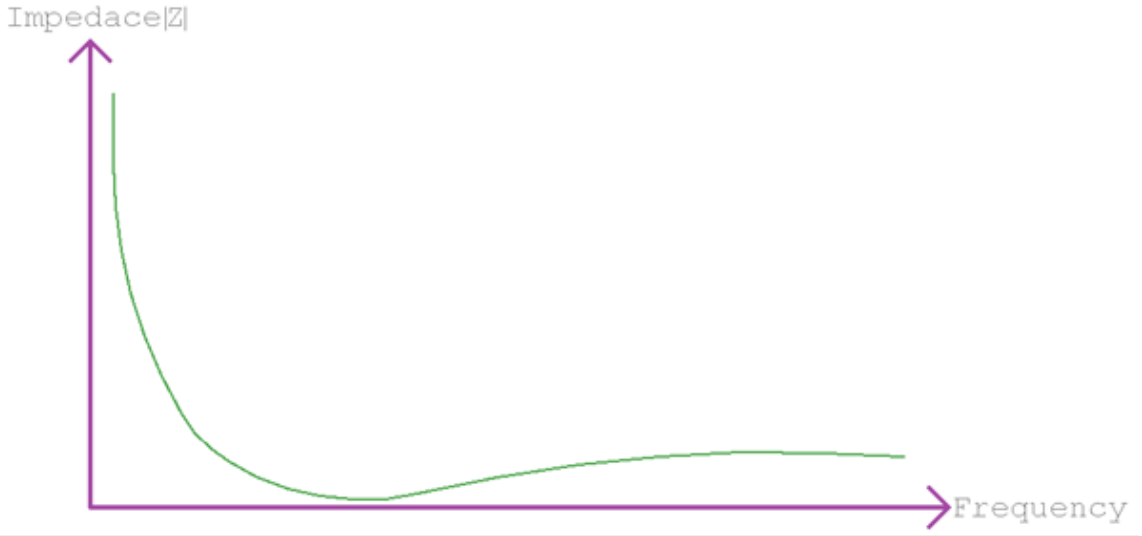


High Pass Filter

In the above image, we can see the basic construction of a passive high pass harmonic filter. The construction shows the resistor and the inductor is in parallel connection a capacitor in series. The filter produces flat impedance characteristics in the high-frequency range. The high frequency decreases the power loss.

This type of filters is mainly used for filtering 5^{th}/ 6th or higher order current. Often different filters are combined with high pass harmonic filters to eliminate power loss when used in low order or low-frequency applications.

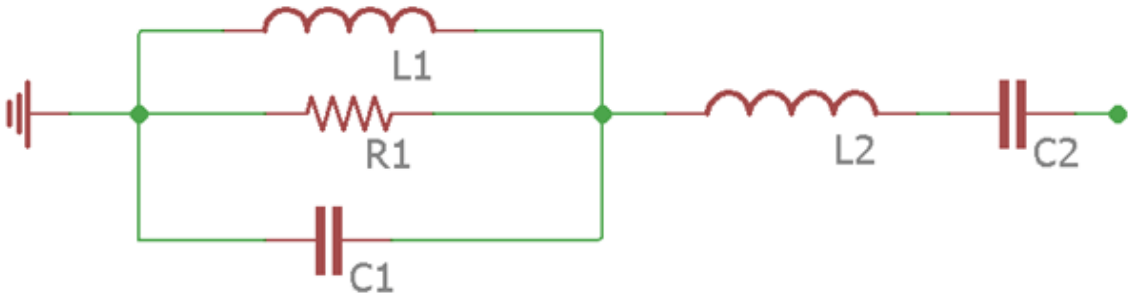
The impedance curve with the frequency can be shown in the below image.



Impedance Curve - High Pass Filter

Bandpass filter

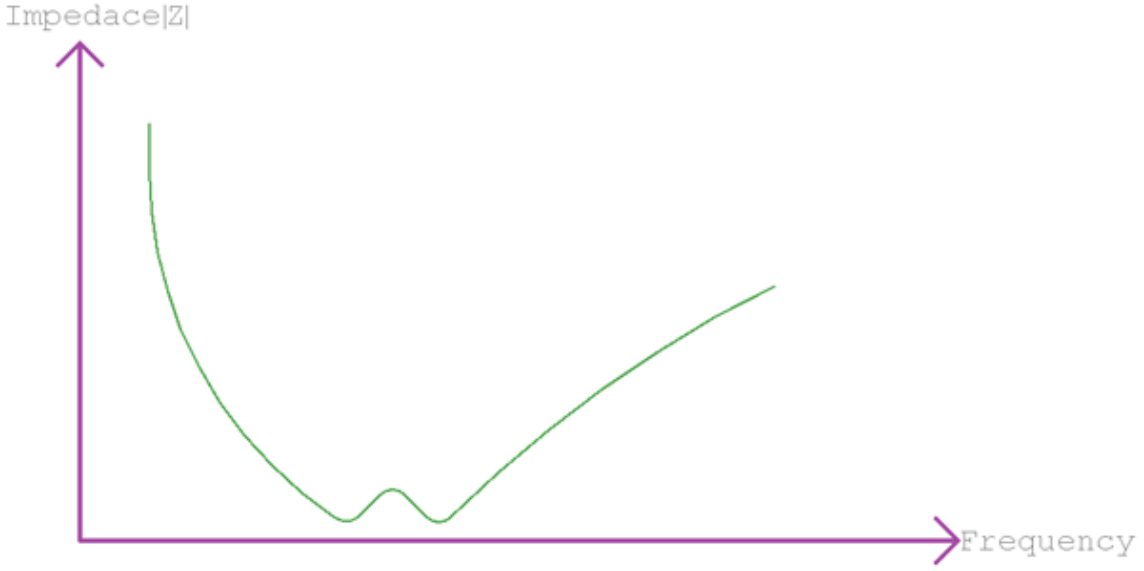
Bandpass harmonic filter is a double tuned filter. The **bandpass harmonic filter consists of two capacitors, two inductors, and a single resistor**. It is also used for high order harmonic filtration purposes. This filter works with the combining parallel resonance of the standard bandpass filter along with series resonance of inductor and capacitor combined.



Double Tuned Band Pass Filter

In the above image, basic bandpass filter schematic is shown. The **filter circuit has two parts**, in the **first part** a capacitor C2 and inductor L2 is connected in series whereas in **second part** a resistor, an inductor, and a capacitor are connected in parallel. The first part and the second part are also connected in series.

The impedance characteristics with the frequency can be shown in the below graph.

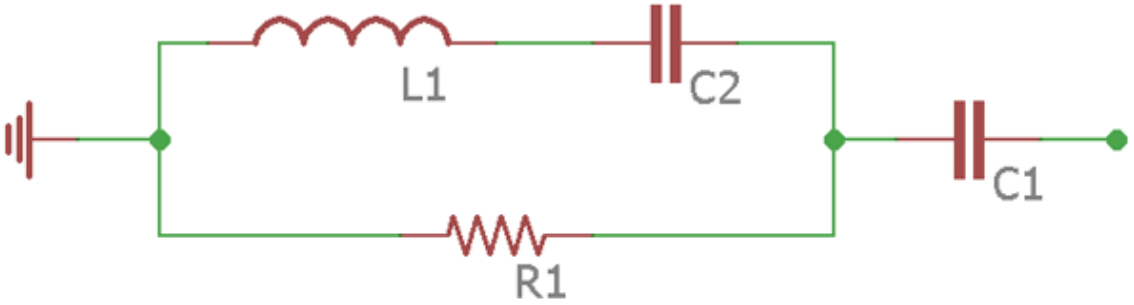


Impedance Curve - Double Tuned Band Pass Filter

C type filter

C type filter is used for the low order such as second or third order harmonic filtration purposes. C type filters have lower loss than the equivalent bandpass or the series filter.

C type filters consist 4 passive components - **two capacitors, an inductor, and a single resistor.**

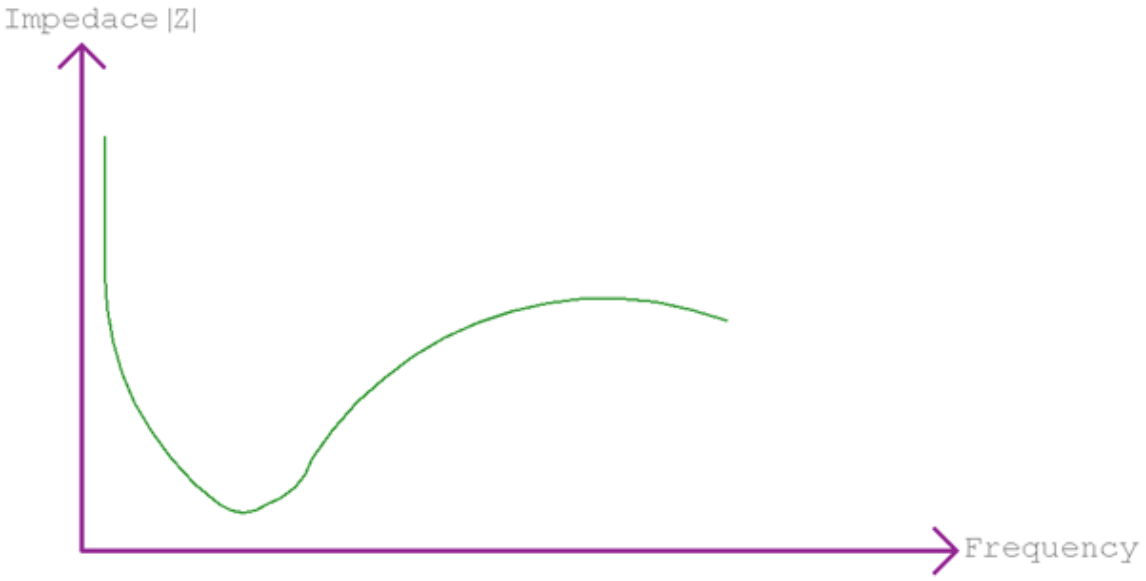


C Type Filter

In the above image, the basic construction of c type filter is shown. A capacitor is connected in series of an inductor which is again connected in parallel with the resistor. The three component parallel connection is again connected in series with a second capacitor.

The resistor suppresses the fundamental current created by the oscillated inductor and capacitor.

The Impedance curve is shown in the below image-



Impedance Curve - C Type Filter

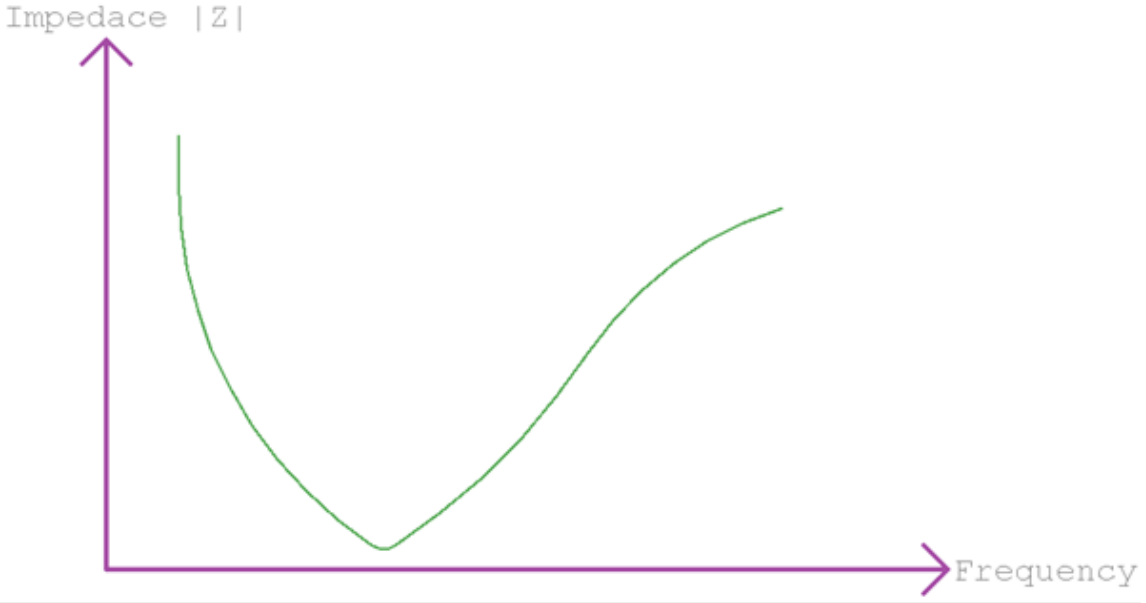
Series filter

The series filter is called as **single tuned harmonic suppressor passive filter**. This filter has the most simple construction properties. Only three passive components – **a single capacitor, inductor, and resistor are used in series.** This filter eliminates single frequency.

The construction of this filter can be shown in the below image where 3 passive components are connected in series to form the single tuned series harmonic filter.

Single Tuned Series Filter

The Impedance characteristic is shown in the below image -



Impedance Curve - Single Tuned Series Filter

Active Harmonic Filters

As discussed previously, passive harmonics filters are good to eliminate harmonics associated in the power line. However, the passive harmonic filter design is really complex and the designer must design the passive harmonic filters in accordance with the reactive power requirements of the load. In such a case, the passive filter design is very difficult and it leads to a poor power factor operation for certain load conditions.

In this matter, **active filters are better to handle the power line harmonics without the reactive power dependencies of the fundamental frequency**.

Active harmonic filters use an excellent method where the filter use self-produced harmonic components and injects this to the power line which cancels the unwanted harmonics.

There are **different types of active filters available** which use different topologies to eliminate the harmonics in the power line.

The most common active harmonic filters design uses the following basic things like

1.Voltage source inverter using various power switches

2.Sampling and control reference from the power line

3.PWM system which injects PWM firing pulse into the system as harmonics.

The Active Harmonic filter uses a different kind of semiconductor switches which requires power to operate.

How to select Harmonic Filters

Determining the perfect harmonic filter is quite tricky. One needs to **identify the harmonic frequency** at which the filters need to be tuned. In a few cases, the filter operation is failed to serve the purpose just because of wrong tuning at a certain fundamental frequency where no harmonics are present.

The **first important step is to identify the harmonics order** and depending on the harmonic order the filter need to be chosen. To eliminate single frequency harmonic distortion series harmonic filters are efficient but in few cases double tuned harmonics filters need to be employed.

The **losses across the filters** also need to be compensated which are highly dependent on the choice of filter. Sometimes for a high level of nonlinear loads, active and passive both types of harmonic filters are required.