

## Introduction to Harmonic Filters and Harmonics

A harmonic filter is used to eliminate the harmonic distortion caused by appliances. Harmonics are currents and voltages that are continuous multiples of the fundamental frequency of 60 Hz such as 120 Hz (2nd harmonic) and 300 Hz (5th harmonic). Harmonic currents provide power that cannot be used and also takes up electrical system capacity. Large quantities of harmonics can lead to malfunctioning of the system that results in downtime and increase in operating costs. The second harmonic would have a frequency of 120 Hz; the third harmonic would have a frequency of 180 Hz and so on.

### Inside the Harmonic Filter

The harmonic filter is built using an array of capacitors, inductors, and resistors that deflect harmonic currents to the ground. Each harmonic filter could contain many such elements, each of which is used to deflect harmonics of a specific frequency.

### The Cause and the Effect

Harmonic distortion is caused by equipment that are non-linear loads. These loads use current in a pulsing manner and at times feed harmonic currents back into the wiring. In non-linear loads, the current waveform is different from the applied voltage waveform. This causes them to produce the following:

- Voltage distortions
- Excessive currents on neutral wires
- Overheating of motors
- Microprocessor control problems
- Unexplained computer crashes

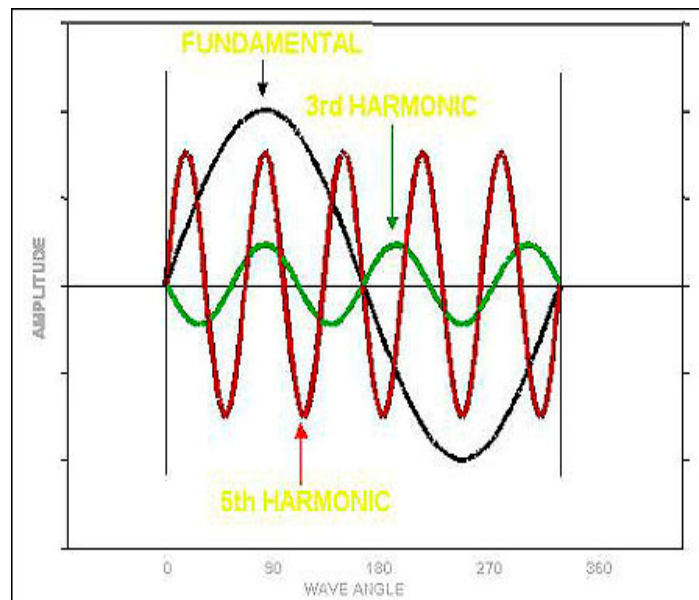
### Examples of non-linear, harmonic-causing loads are:

- Electronic equipment such as personal computers
- Battery chargers
- Lighting dimmer controls
- Fluorescent lights
- Welders
- Electronic ballasts
- Printers
- Photocopiers
- Fax machines

## Harmonic Filter Functions

The various functions that a harmonic filter performs are enumerated as follows:

1. Reduces neutral currents
2. Reduces transformer loading
3. Protects electrical systems
4. Reduces fire hazard
5. Protects the neutral conductor
6. Enhances system protection
7. Minimizes impact on distribution transformers
8. Reduces local neutral to ground voltage
9. Lowers peak phase current/average phase current
10. Increases system capacity
11. Decreases system losses
12. Improves power factor on non-linear loads
13. Reduces total harmonic distortion
14. Improves phase current balance
15. Augments phase voltage balance
16. Reduces three-phase neutral current



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## Types of Harmonic Filters

Harmonic filters can be broadly classified into two basic types: active and passive.



### Active Harmonic Filter

An active harmonic filter is something like a boost regulator. The concept used in an active filter is the introduction of current components using power electronics to remove the harmonic distortions produced by the non-linear load. Active harmonic filters are mostly used for low-voltage networks. There are three types of active harmonic filters based on the way they are connected to the AC distribution network.

- i) The series filter is connected in series with the AC distribution network. It serves to offset harmonic distortions caused by the load as well as that present in the AC system.
- ii) The parallel filter is connected in parallel with the AC distribution network. Parallel filters are also known as shunt filters and offset the harmonic distortions caused by the non-linear load.
- iii) The hybrid filter is a combination of an active and a passive filter and could be of a series or a parallel configuration.

Apart from the above classification, active harmonic filters can be either 3-wire or 4-wire filters.

*3-wire filters:* Are power units that are large and typically used in variable speed drives and other such applications, which have a large number of non-linear loads.

*4-wire filters:* Are those that can filter the neutral conductor of the triple-n harmonics. These filters are used to eliminate harmonics that are generated by switch-mode power supplies and Information Technology equipment, typically commercial applications.

### Passive Harmonic Filter

A passive harmonic filter is built using an array of capacitors, inductors, and resistors. It can take the form of a simple line reactor or may use a series of parallel resonant filters to eliminate harmonics. Passive harmonic filters are also divided based on the way they are connected with the load.

- i) A series filter: Here the filter is placed in series with the load and uses parallel components, i.e., inductors and capacitors are in parallel. This filter is a current rejector.
- ii) A parallel filter: The filter is placed in parallel with the load and its components are built in series. This filter is a current acceptor.

**Based on the components used to build the passive filter, there are the following types:**

*A Band-pass filter* is a common passive filter that is built using a capacitor connected in series with a resistor.

*A High-pass filter* has a resistor connected in parallel with a reactor. This helps in reducing the  $q$  value of the filter, which will in turn help reduce the higher frequencies.

*A High-pass filter when used in combination with a band-pass filter* will provide a solution for medium voltage and sub-transmission voltage networks, which have moderate harmonic distortions.

*A C-type filter* is used for complex loads, cyclo converters and electric arc furnaces and is a special variation of the high pass filter. This filter will provide the load with reactive power and avoid forming parallel resonance circuits with the load.

Other devices that are used to control harmonics are:

*A line reactor*: Is usually just an inductor, which resists the flow of high frequency harmonics and thus causes harmonic currents to decrease when it is applied. Line reactors serve to suppress current spikes and limit peak currents that flow through them, because of their impedance. These are typically used in variable frequency, DC, SCR, and rectifier drives.

*Feedback electronic filter*: Is a complex device that detects the presence of voltage and current harmonics and generates counteracting harmonics to remove harmonic distortions. The electronic filter uses feedback mechanisms, and monitors voltage and current constantly. It thus effectively reduces harmonics and provides voltage regulation.

## **Selection of the Harmonic Filter**

The selection of a harmonic filter must be based on the following:

1. kVA requirements of the load
2. Harmonic profile of the load current
3. Harmonic factor of the neutral current
4. Configuration of the existing or proposed system

## **Manufacture of Harmonic Filters**

They are manufactured with insulating materials that comply with the CSA winding insulation system class 220, which is the highest insulation level that is recognized in the industry.

*Windings*: can be copper or aluminium

*Enclosures*: Drip-proof, weather-proof, and standard types

## Harmonic Filter - Application Areas

Harmonic filters are well suited for three-phase, 4-wire electrical power distribution systems that supply single phase, non-linear loads. There are various application areas for harmonic filters, the most important being:

- Adjustable speed drives
- Welders and battery charges
- Computer equipment
- Consumer electronics

The major end-user industries for harmonic filters include:

*Industrial* - printers, extruders, machining, heavy industries: pulp and paper producers, mining, oil and chemical refineries, iron and steel, rubber and plastics, glass and cement, food processing

*Utilities* - electrical utilities, water treatment plants

*Commercial* - data centres, telephone centres, hospitality services

*Residential* - consumer electronics, personal computers

## Conclusion

High power quality and voltage stability are necessities for the equipment we use today. It is therefore necessary for the power system to be free from harmonics and other electrical disturbances. Hence, harmonic filters play an important role in ensuring a 'clean' power supply.