

HARMONICS.

CAUSES OF GENERATION,
EFFECTS AND REMEDIAL MEASURES,

With the trend of industrial developments the power consumption is increased. The demand of electricity has increased proportionately. The increased demand aspect with energy conservation created the need of power factor improvement. Since then Capacitor is much favored by industries as the most appropriate choice which is meeting the aspect of energy conservation as well as power factor improvement.

On one side the population of capacitors has increased and on other side the usage of electronic devices such as variable speed drives, SMPS PC's has substantially raised within last decade.

The electronic devices which are used in most of the industries have peculiarity of non linear characteristics. This non linearity reflected in the grid with the disturbance of pure sinusoidal wave which is nothing but harmonics

In this paper we will look the aspects as below.

- 1) What are harmonics
- 2) Causes of generations of harmonics
- 3) Effects of harmonics
- 4) Remedial measures
- 5) Benefits

WHAT ARE HARMONICS ?

Harmonics are nothing but, integral multiple of fundamental supply frequency. These are present either in forms of currents or voltages. The terminologies used are N'th Order harmonic e.g. 3rd Harmonic or 5th Harmonics The magnitude of harmonic is reciprocal of the harmonic order with respect to fundamental. Table indicated below will indicate the frequency and magnitude w.r.t fundamental.

Description	Frequency	Voltage (In PCT 100% as rated voltage)
Fundamental	50 Hz	100%
2 nd	100 Hz	50%
3 rd	150 Hz	33%
4 th	200 Hz	25%
5 th	250 Hz	20%
6 th	300 Hz	16%
7 th	350 Hz	14%

When the harmonics are added together forms a distorted waveforms. Similarly the distorted waveform can be segregated into different order harmonics for analysis and remedial measures. Harmonics are originated as currents. As these harmonic currents flow through the impedances in an AC systems generates harmonic voltages, and these harmonic voltages propagates through grid and installations.

The term "distortion" is used to indicate the deviation from a pure sinusoidal waveform. There are two types of distortion viz.

- 1) Current distortion and
- 2) Voltage distortion.

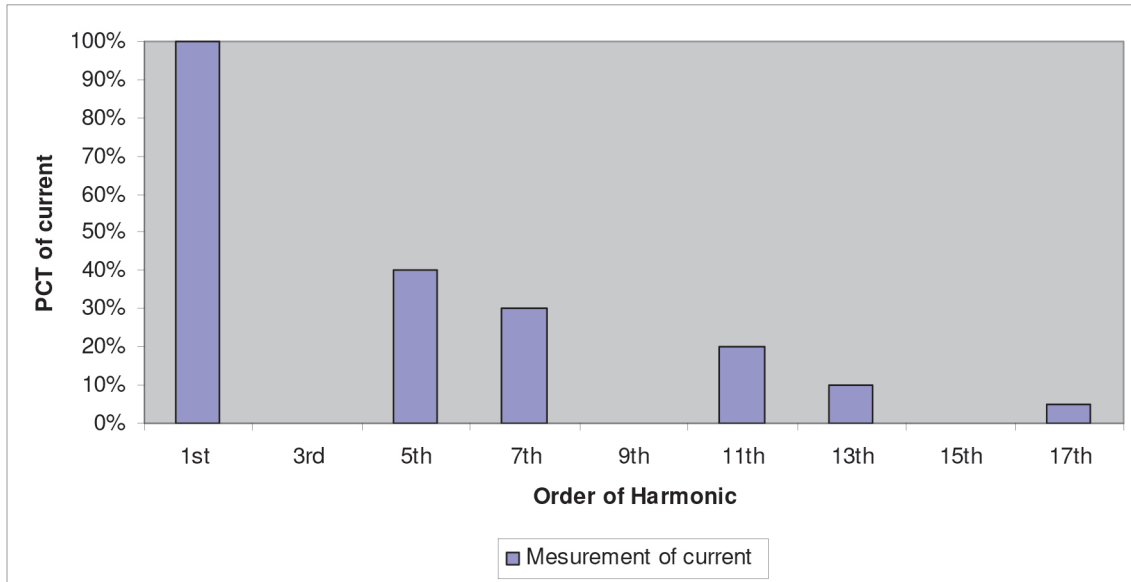
★ CAUSES OF GENERATION HARMONICS

Harmonic load currents are generated by non linear loads which includes

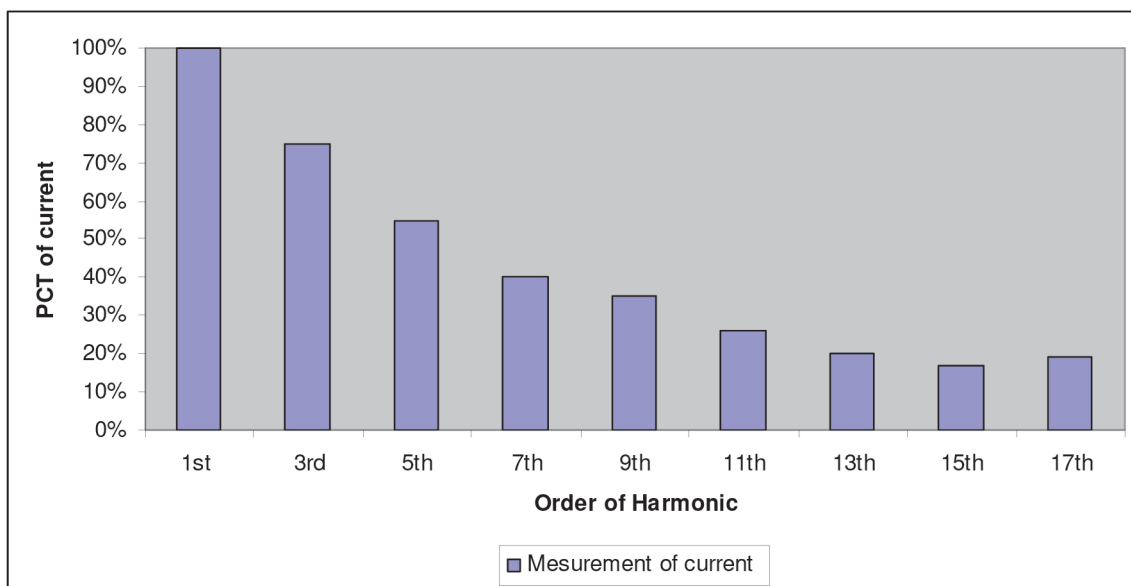
- A) Three Phase Load
 - 1)Variable speed drives
 - 2)Large UPS units
 - 3)Battery charger systems
 - 4)Convertors and invertors
 - 5)Arc furnaces and induction furnaces
 - 6)Steel and Rolling mills
 - 7)Cranes
 - 8)Elevators
 - 9)Plastic extrusion
 - 10)Stamping units.
- B) Single Phase Load
 - 1)Switched Mode power supplies (SMPS)
 - 2)Electronic fluorescent lighting ballasts
 - 3)Welding shops
 - 4)Personal Computers
 - 5)IT industries

It is been observed that almost in all types of industries where most of the processes are controlled by electronic governing systems produces non-linearity and causes harmonics in the systems. In process industries, where variable speed drives are applied consists of electronic chopping devices. These devices convent waveforms from AC to DC, DC to various shapes such as, square , triangular, ramp shaped waveforms . This phenomenon of current chopping produced lot of ripples in the system and in turn produces non-linearity which reflects into the systems as resultant harmonics.

Typically observed harmonic spectrum wave forms for single phase are as below. Generally the effect of even harmonics is considered negligible.



Typically observed harmonic spectrum wave forms for three phase balanced loads phase as below. Generally the effect of even harmonics and triplen harmonics (3,6,9,..) is considered negligible.

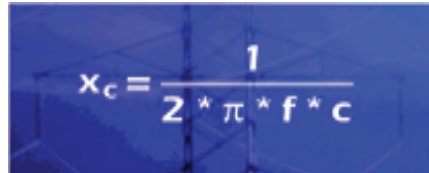


★ EFFECTS OF HARMONICS

We have seen that capacitor is favored because of its improvement of the power factor and offers all the related benefits.

The main disadvantage is that a plain capacitor amplifies the harmonics.

Capacitive reactance is given by formula as



$$X_c = \frac{1}{2 * \pi * f * c}$$

Eq 1:

Switching Operation: $f \rightarrow \infty \rightarrow X_c \rightarrow 0 \rightarrow \hat{i} \rightarrow 200 * I_r$

We can observe from equation that, as the frequency increases the reactance is decreased and the harmonic currents flowing through the capacitor tends to amplify.

The problems caused by harmonics

- 1)Overheating of Transformers and rotating equipments
- 2)Increased eddy and hysteresis losses
- 3)Neutral overloading
- 4)Failure of Capacitor banks
- 5)Nuisance tripping of circuit breakers and fuses
- 6)Unreliable operation of zero crossing equipments
- 7)Nuisance operation of controlling devices.
- 8)Malfunctioning of Generators
- 9)Additional losses due to skin effect
- 10)Increased Maintenance cost of equipments
- 11)Wasted energy due to additional losses
- 12)Higher electricity bills
- 13)Higher downtime of production equipments
- 14)Reduced product quality and output

★ REMEDIAL MEASURES

We have observed the ill effects of harmonics. The filtering solution is available in three different ways.

Depending on the intensity we can adopt to imply these features

- 1)Detuned Harmonic filters
- 2)Tuned Harmonic filters
- 3)Active harmonic filter

1) Detuned Harmonic filters

Most commonly adopted, economical and faster method is, use of detuned harmonic filter reactors. These are connected in series with capacitors. Unlike capacitor, reactor tends to offer higher impedances to the flow of harmonics.

$$X_L = 2 * 11 * f * L$$

Higher the harmonics, higher is the inductive reactance

As we already discussed that, in case of single phase loads the first problem frequency of harmonics is 3rd and that in three phase loads it's 5th.

Generally in case of three phase loads, 7% harmonic filter reactor and 14% in case of single phase loads are applied.

In case of such L-C (reactor capacitor) combination the percentage of reactor, tuning factor and overvoltage factor plays significant role. Hence choices should be made in consultation with experts upon knowing the harmonic spectrum. We are enclosing herewith choice of calculation details for appropriate selection of capacitor for detuned harmonic filter reactor.

2) Tuned Harmonic filters

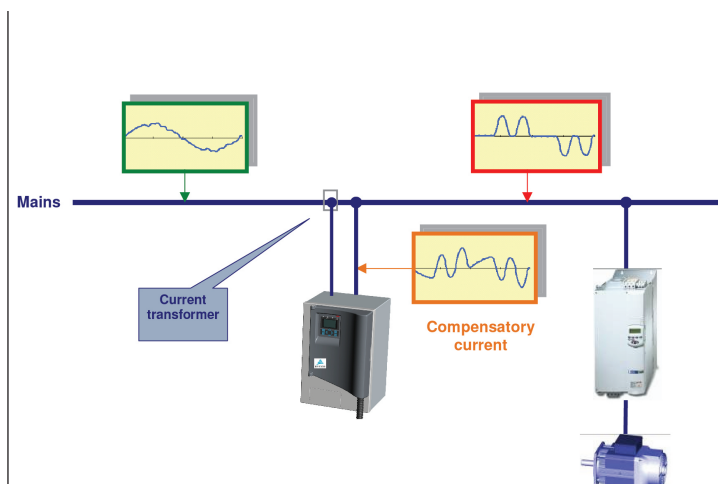
At some sources, a grid may be polluted with single harmonic frequency e.g. 5th or 7th. Hence a tuned filter is installed to filter out this particular harmonic spectrum. The combination of reactor and capacitor is tuned to absorb that particular frequency.

The application is very complex process, which involves lot of study and needs careful selection of components, as well as switchgear

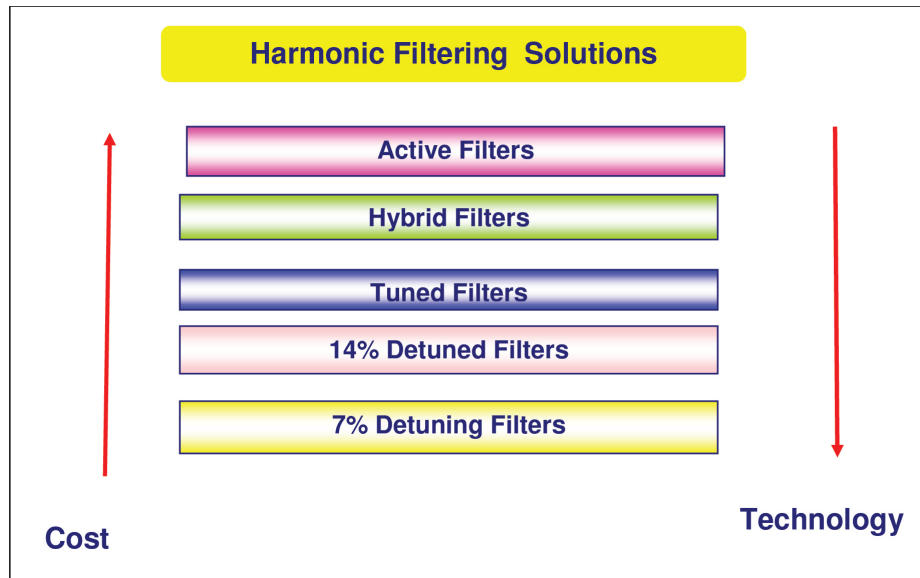
3) Active Harmonic filter

This is a shunt device. CT measures the input distorted current and AHF produces exact replica or compensatory current which is fed to the source. This ensures the elimination of total harmonic distortions and source remains with sinusoidal wave

Pictorial representation is as below



Utility or consumer has to make appropriate choice. It is made depending on the harmonic spectrum . A generalized comparison of cost Vs technology is briefed below



Note — A Global standard IEEE 519 defines the range of allowable limits of harmonic distortion depending on system fault level , load current , voltage level and point of common coupling.

★ BENEFITS OF HARMONIC FILTERING TO UTILITY OR CONSUMERS

- 1)Reduction in losses ,saving in real KW units
- 2)Reduction in current and release of blocked capacity to avoid new investments
- 3)Reduction in demand charges
- 4)Reduction in damages to equipments
- 5)Reduction in maintenance costs and downtime of production equipments
- 6)Improvement in process stability and reliability
- 7)For transformer and rotating equipments , the reduction is in terms of core , copper and stray losses
- 8)Reduction in losses of operational temperature and hence increased life of an equipments.
- 9)Improved voltage stability of the systems

In nutshell, we have reviewed, the causes of producing harmonics, effects on the electrical systems, remedial measures and benefits.

It is now need of the future energy management, where in electricity boards may tighten the regulatory norms and utility / consumers need to face new challenges ahead Let's say NO to harmonics and intent to clean the grid and save our systems