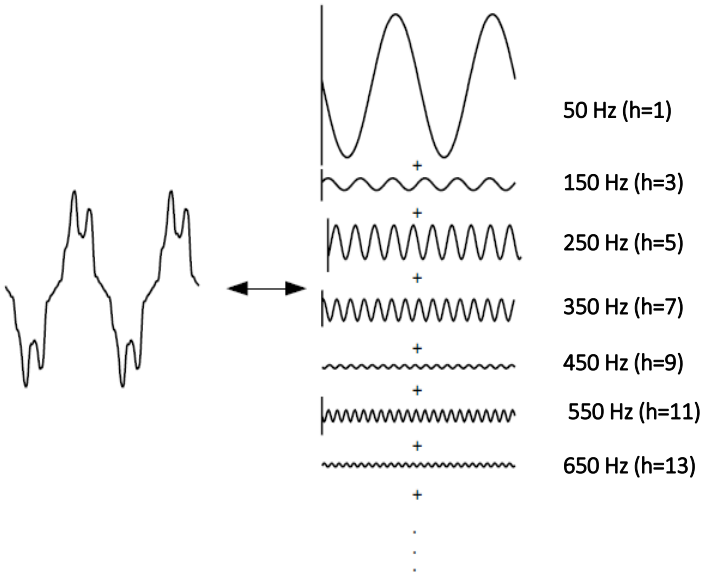
Harmonics

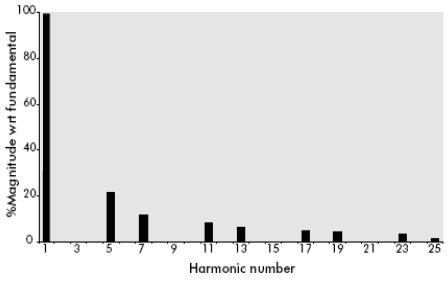
Introduction

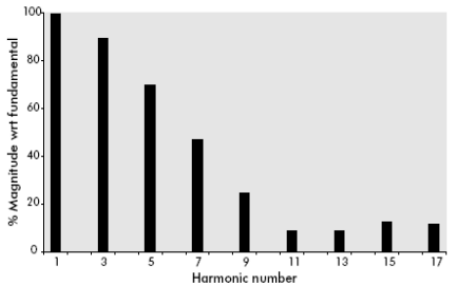
Harmonics are defined as the component of periodic wave (or a signal) whose frequency is integral multiple of the fundamental frequency. Non-linear loads such as rectifiers, inverters, variable speed drives, furnaces etc. create harmonics. These currents consist of a fundamental frequency component rated at 50 Hz, plus a series of overlapping currents, with frequencies that are multiples of the fundamental frequency. The result is the deformation of the current (and as a consequence, voltage) that has a series of secondary effects. The diagram below gives an illustration of how the harmonic waveforms of higher frequency give a net effect of a distorted sine wave.



Causes

Increasing use of modern power electronic apparatus produces non-linear current and thus influences and loads the network with harmonics. All devices that are “energy efficient” work on the principle of saving power by means of chopping the sine wave. As soon as the sine wave is chopped i.e. distorted, harmonics are induced in the system. This means that whenever sinusoidal current passes through a non-linear device, the output waves would be distorted. Major loads that are responsible for inducing harmonics in the system are:

Type of Load	Harmonic Spectrum I-THD
• 6 pulse and 12 pulse drives* (VFD & UPS) • Three phase/Single phase rectifiers • Arc/Induction Furnace	

• Discharge lamps • Single phase converters • Computers/IT loads • SMPS • TVs	

*Higher the number of pulses, lesser is the harmonic distortion

Ill effects of harmonics

Current harmonics increase the rms current flowing in the circuit and thereby increase the power losses. Current harmonics affect the entire distribution all the way down to the loads. They may cause increased eddy currents and hysteresis loses in motor and transformer resulting in overheating, overloading in neutral conductors, nuisance tripping of circuit breakers, over stressing of power factor correction capacitors, interference with communication etc. They can also lead to overheating and saturation of detuned reactors.

Voltage harmonics do not originate directly from non-linear loads. The current harmonics flow through the system impedance (source and line impedance) and cause harmonic voltage drops across the impedances. This will distort the supply voltage waveform. Thus voltage harmonics are generated. Hence even if the current harmonics are low, if the source impedance is high - like in case of Diesel Generators - it can lead to higher levels of voltage harmonics. Voltage harmonics affect the entire system irrespective of the type of load. They affect sensitive instrument throughout the facility like those that work on zero voltage crossing as they introduce voltage distortions.

Presence of high harmonics can also lead to phenomenon like harmonic amplification by the power factor capacitors and harmonic amplification where certain orders of harmonic current shoot up to dangerous levels. Both these phenomena will be discussed in detail in the upcoming articles in the blog.

Other major ill effects of harmonics are listed as follows:

Type of equipment	Effects of harmonics
Rotating machines	Increased power losses, over heating due to skin effect as higher frequency current flows on the cable periphery increasing cable resistance, pulsating torque due to negative phase sequence harmonics
Power Capacitors	High currents and failure due to overload
Transformer, Switchgear, Power cables	Power losses, Over-heating, Increased power consumption, neutral overloading due to triple-n harmonics
Protective Relays	Mal-operation, nuisance tripping
Power Electronics	Mal-operation, failure

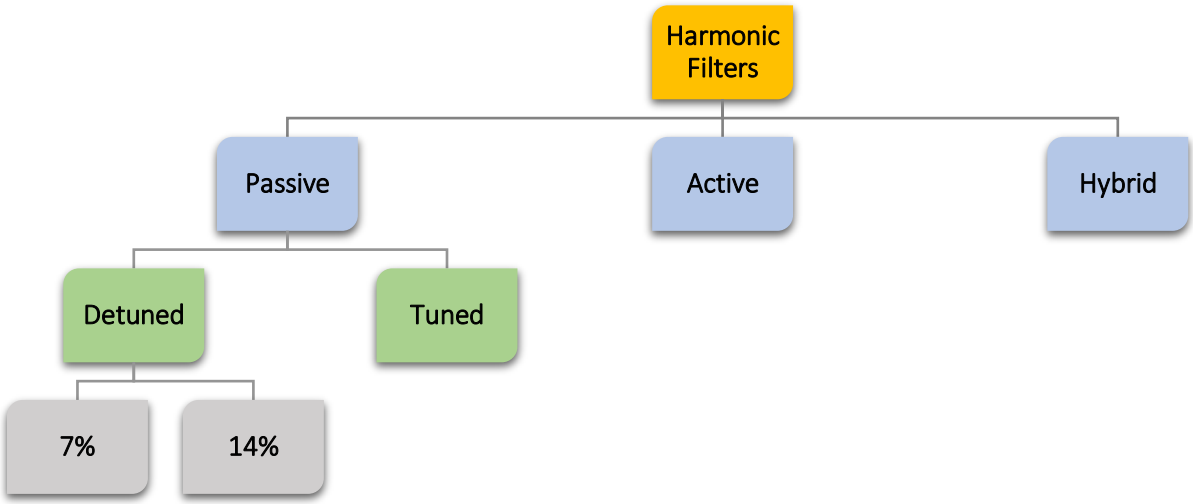
Malfunctions caused by harmonics are not always felt immediately after the system is installed, but the effects may be felt in the long term and are difficult to distinguish from the natural ageing of equipment. Hence it is important to have some basic knowledge about harmonics and find timely solutions for the same.

Benefits of harmonic mitigation

1) Reduction in operating expenses:
   Harmonic mitigation contributes to reduced power losses in transformers, cable and switchgear. Harmonic mitigation helps in reducing the energy losses.
2) Reduction in capital expenditure:
   Harmonic mitigation reduces the rms value of the current and it eliminates the need to oversize transformer and hence switchgear, cables and busbars.
3) Improved business performance:
   Harmonics are responsible for increased line currents, resulting in additional power losses and increased temperature in transformers, cables, motors, capacitors. The consequence maybe the unwanted tripping of circuit breakers or protection relays. This might cause significant financial losses linked to a process interruption.

Solutions for harmonic mitigation

The different solutions employed for harmonic mitigation and elimination are as follows –



✓ <u>Harmonic mitigation:</u>

1) <u>Detuned filter:</u> Series LC combination helps in avoiding harmonic resonance and amplification
   Merits: Simple and economical
   Demerits: Marginal reduction of %THD
   High V-THD will affect performance**
2) <u>Tuned filter:</u> Mitigates harmonics by acting as a harmonic sink
   Merits: Reduces % THD

Demerits: Tuning efficiency is susceptible to system frequency and load variations leading to overheating and failure of filter.
Extensive harmonic audit is mandatory before installation.

✓ Harmonic elimination:

1) Active filter: IGBT based power converter that reduces harmonic distortion by generating waveform exact opposite to that of the harmonic waveform
2) Hybrid filter: Combination of passive and active filters
   Merits: Reduces VTHD within IEEE limits
   Dynamic correction of THD is possible
   Improves distortion pf
   Load balancing and displacement pf improvement possible
   Modular in nature so can be easily expanded along with the load

Conclusion

In today's era of power electronics domination where we can achieve high energy efficiencies, harmonics are a necessary concomitant. In order to prevent the ill effects of their presence, we need to understand harmonics well and employ suitable mitigation techniques. This article discusses the basic concepts of harmonics. But there are many other aspects to this topic which need to be looked upon separately in detail.

Watch out this space for more details and concepts regarding harmonics, harmonic mitigation and harmonic elimination.

**In case of high V-THD, contact L&T for customized solutions