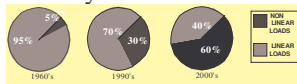


WHY HARMONICS IS A MAJOR TECHNICAL ISSUE TODAY?

The proliferation of non-linear loads in recent years, as shown below (i.e. computers, variable speed drives etc.), can produce significant harmonic current distortion in building wiring systems. These harmonics sometimes create serious and unexpected problems, such as the failure of electrical equipment (e.g. transformers, conductor, motors, etc.) at loads well below their maximum rating and severe overheating of cabling system and termination. This may generate subsequent **cable failure** and **can also lead to a significant internal electrical fire risk from neutral cabling system**. Harmonic distortion in building electrical systems can also create the problem of EMI interference and disturbance to other sensitive equipment nearby, such as communication and computer systems. **Malfunctioning of this equipment because of EMI can pose a serious threat to the safety, security, and reliability of the operation and function of the entire building.**

Problems such as these will become more common in the future as non linear loads continue to grow, particularly since every country in the world is moving into the information superhighway and using more and more electronic systems.



WHAT ARE HARMONICS?

Harmonics are currents or voltages at higher frequencies than the fundamental power frequency ((50Hz). The most significant harmonics in power distribution systems are the low order integral harmonics, typically from the second to the 19th. So the second harmonic is 100Hz, the third harmonic is 150Hz, as so on, as shown in Table

Note that even harmonics are not present, if the waveform is symmetrical, and note also the change in sequence of different harmonic multiples for a three phase system.

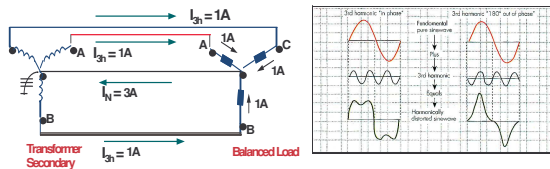
Table : classification of harmonics

Name	F	2nd	3rd	4th	5th
Frequency (Hz)	50	100	150	200	250
Sequence	+	-	0	+	-

Triplen harmonics are all the odd harmonic components that are multiples of the third (ie. 3rd, 9th, 15th, 21st etc). In a 3 phase 4 wire supply system, these harmonics are in phase

with each other (co-phasal), and add numerically in the neutral conductor and typical harmonic distorted waveform as shown below.

Incorrect design/selection of neutral cabling system may lead to potential risk of internal electrical fire due to triplen harmonic current overheating, because no protective device is allowed to be installed for the neutral cabling system.



WHAT CAUSES HARMONICS?

Electronic Switching power converters

- Computers (Typical harmonic current distortion shown – 89.5 % 3rd harmonic & THD_i : 130 %)
- Uninterruptible power supplies (UPS)
- Solid State Rectifiers
- Electronic process control equipment, PLC's,
- Electronic ballasts & dimmer
- Reduced voltage motor controllers

Variable speed / Frequency Drives

Arcing Devices

- Discharge lightings
- Arc furnaces
- Welding equipment
- Electrical traction system

Ferromagnetic Devices

- Transformers operating near saturation level
- Chokes and Magnetic ballasts
- Induction heating equipment
- Motors

Appliances

- TV sets, air conditioners, washing machines, microwave ovens & vacuum cleaners
- Fax machines, photocopiers, printer

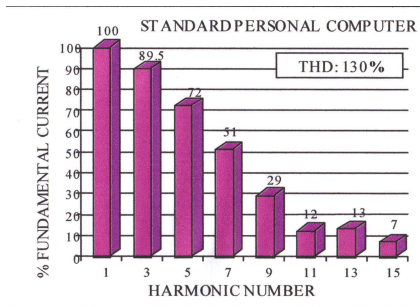
EFFECTS OF HARMONICS

Positive, negative and zero sequence harmonics can cause different effects, as noted in Table. Harmonic voltages and current can also cause the following problems

Sequence	Rotation	Effects
+	Forward	Heating
-	Reverse	Heating & motor problem
0	None	Heating $i_n = \text{sum of all } i_{0h}$

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- ✚ Overheating
- ✚ Interference
- ✚ Resonance
- ✚ Supply distribution system distortion
- ✚ Other effects
 - ❖ Overheating of motors and transformers
 - ❖ Capacitor failure
 - ❖ Burning out small auxiliary equipment
 - ❖ Insulation failures
 - ❖ PLC and computer failures
 - ❖ Frequent tripping of circuit breakers
 - ❖ Frequent fuse blowing
 - ❖ Telephone interference
 - ❖ Misoperation of SCR drives
 - ❖ Malfunctioning of electronic equipment
 - ❖ Severe lamp and computer screen flicker
 - ❖ Machine vibration



HARMONIC MITIGATION TECHNIQUE

BACKGROUND

The usage of non-linear (electronic) loads has been exponentially increased over recent years. This electronic loads, such as computers, UPS, VFD, electronic lighting ballasts, etc generate significant harmonic current and voltage distortions, which can have adverse effects on equipment designed for operation as linear-loads (i.e. Load designed to operate on a sinusoidal waveform of 50Hz). These harmonics can have detrimental effects on electrical equipment, such as transformers, motors, emergency generators, cables & terminations, and other.

When reactive power compensation (in the form of passive power factor improvement capacitors to off-set the low power factor penalty) is installed with the non-linear loads, harmonic resonance can occur. This may result in harmonic current and voltage magnification, thereby causing equipment malfunctioning, failure, and fire hazards in the extreme conditions.

The electrical environment has absorbed most of these problems in the past. However, the problems have now reached a magnitude, where the USA, Europe, Asia Pacific, and other countries have to implement standards, and regulations to limit the level of harmonic distortion in power systems. These standards include IEEE-519, IEC-1000 series, AS/NZS 61000 series, Hong Kong – Code of practice, and other.

In order to meet the requirements of harmonic limits, and also to avoid the potential costly harmonics & power quality problems at a later time, the design engineers must consider to implementing the harmonic mitigation technique at the design stage.

PRINCIPLES AND TECHNOLOGY

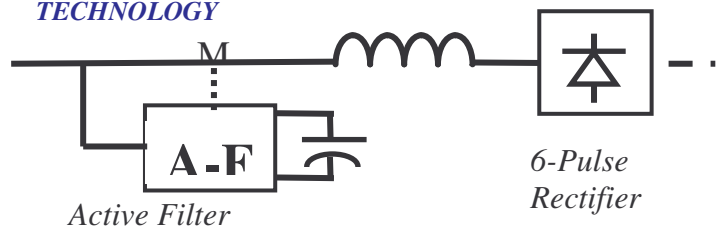
Various mitigation techniques of improving the input current waveform are currently available. The aim of all mitigation techniques is to make the input current more continuous so as to reduce the overall harmonic current distortion.

There are basically two different mitigating techniques – namely the passive and active technology. The performance of passive harmonic mitigating devices is not as good as the active ones, but its cost is many times less.

PASSIVE HARMONIC MITIGATION TECHNOLOGY

Passive harmonic filters consist of passive components – Inductors, capacitors, resistors, and transformers, arranged in a pre-determined fashion either to attenuate the flow of harmonic currents through them or to shunt into them. The passive harmonic filters have been developed and used to mitigate power system harmonics for more than two decades. Currently there are various designs available ranging from a mere reactor to zero sequence, low pass band, mitigating transformer, etc. These mitigating devices can be installed either in series or parallel with the electrical power system. The best way to illustrate the working & performance and benefits of the passive harmonic filters is to look at the basics, principles, and typical application performance. The present cost of these devices varies depending on the design & construction and application. But it is still many times cheaper than the similar size active harmonic filters.

ACTIVE HARMONIC COMPENSATION TECHNOLOGY



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Most passive harmonic mitigation techniques discussed above aim to cure the harmonic problems once they had created by non-linear loads. However, Drive manufacturers are developing drives, which do not generate low order harmonics. These drives use active front ends, instead of using passive diodes as rectifiers, the active front ends VFDs make use of active switches like IGBTs along with parallel diodes. Power flow through a switch becomes bi-directional and can be manipulated to recreate a current waveform, which linearly follows the applied voltage waveform.

Apart from the active front ends, there also exists shunt active harmonic filters used for actively introducing a current waveform into the ac network, which, when combined with the harmonic current generated by non-linear loads, results in an almost perfect sinusoidal waveform. (i.e. Harmonic current cancellation).

Most active harmonic filters topologies are complicated and require switches and control algorithms. These devices are non-standard products, and require an engineered solution for the application. The current cost of this type device is much more expensive than the passive harmonic filter.

EU EMC DIRECTIVE

EMC directive 89/336 had been become mandatory requirements in European Union as from 1-1-1996, other countries around the world, like Australia, Taiwan, and so on had also implemented similar EMC standards and regulations. *The aim of this EMC directive and regulations is to limit the radio frequency interference (RFI) and electromagnetic interference (EMI) arising from harmonics, voltage fluctuations, electrostatic discharges, and fast transients. Harmonics form an integral part of the EMC performance requirements.*

However, a new EMC Directive 2004/108/EC had become mandatory requirements as from 20th July 2007 in EU, and repealing old EMC directive 89/336/EEC. Australia, Taiwan, and other would automatically implement this new regulation.

Since this new EMC directive stipulates “Systems, Installations, and good EMC engineering practices”, then building cabling systems would automatically form an integral part of the entire electrical power distribution system.

Cabling systems are therefore important because they are the longest component of a system and may act as efficient antennas that pick up and /or radiate EMI noise affecting other sensitive equipment and system.

It is therefore absolutely essential and important that considerations of building wiring system performance under the influence of power system harmonics and EMC should be given from day 1 at design stage to minimise the potential risk of prevalent problems whenever the non-linear loads are in operation.

CONCLUSIONS

It is conservatively estimated that the usage of non-linear loads in USA has reached 60 %.

Although the statistics on non-linear load growth for Asia Pacific countries are unknown, it would probably follow the same trend as the USA. Moreover there have been numerous intelligent buildings built over the last decade and the awareness and understanding of this technical issue in these countries leaves a lot more to be desired than in the USA. This would clearly indicate that the problems caused by harmonics in the power system will be more prevalent leading to many power quality problems in coming years. It will be of particular concern for high-rise intelligent buildings because of the multiple tenants with varying load requirements..

The anticipated non-linear load growth will lead to significantly increased harmonics in the power system, which can be expected to produce more power quality problems in coming years. Harmonic distortion can also lead to electromagnetic field /interference (EMF/EMI) problems for sensitive equipment and systems. These issues would definitely pose a new technical challenge to design engineer as well as other in the electrical and electronic industry

Also, the new EMC Standards and regulations, which are becoming mandatory in countries around the world, include specific harmonic limitations. In Hong Kong, the harmonic limits as required by the Code of practice of Energy Efficiency for Electrical Installations has been implemented, and the Electricity Supply Authorities have also specified similar requirements in their supply rules and regulations. It would therefore be essential that in the future, engineers involved in building electrical (cabling) system design will have to ensure that their designs meet and comply with these regulations, and requirements.

It would therefore seem appropriate that considerations must be given to the total system solutions to harmonic and EMF/EMI/EMC from the design stage in order to reduce the risk of possible costly identification and resolution of these potential and prevalent problems.

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The known case histories show that there is no one solution to resolve the harmonic and EMI problems in building cabling (wiring) systems. It requires a solid understanding of the basic principles of harmonic interference, careful measurement to identify the exact cause of the symptoms, and then a creative selection of the available alternative to resolve the problem. In deed, some case studies illustrate that the EMF/EMI effect on computer monitors was caused by the fundamental magnetic field rather than the harmonic distortion; and can only be reduced by correct cable configuration and good cabling (wiring) installation practice. It is therefore important for practicing electrical power engineers that they become familiar with the issues of harmonic and EMF/EMI problems at the design stage, where it is relatively straightforward to modify a building cabling system design without huge additional cost. In contrast, when encounters these potential problems post-commissioning would involve considerable identification and resolution cost. Moreover, the retrofitting or adding additional equipment to eliminate unexpected harmonic and EMI problems may not physically practicable to implement and can be very expensive.

Therefore, system solution approach to design the building cabling system supplying non-linear loads is the most appropriate and cost-effectiveness. It can only be achieved by careful design considerations of additional criteria of harmonics & its mitigation technique, EMF/EMI/EMC, and life-span over above the traditional design / selection criteria of (1) current carrying-capacity, (2) voltage drop, (3) short-circuit current rating, (4) mechanical protection, (5) environmental conditions, and (6) external fire performance.

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