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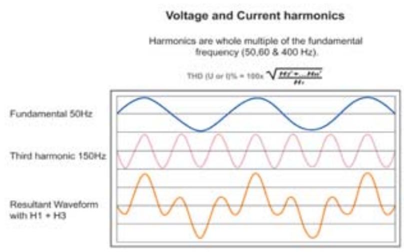
Managing harmonics to protect life and investment

Harmonic pollution is a growing concern as harmonics can cause nuisance tripping of circuit breakers and the increased heat wears components leading to catastrophic failure and additional expense. In this article, Shri Karve looks at the background to the problem, the standards that have been brought into play and what steps can be taken to mitigate the effect of harmonics.

Over the past few years there has been considerable proliferation of non-linear loads caused by the use of PCs, low energy bulbs, TV sets, lighting dimmers, printers, variable speed drives, UPSs etc. It is a well known fact that the public electricity supply does not provide the user with clean electrical power quality or pure Sine wave voltage. The situation has become worse due to the growth of harmonic pollution that is being re-injected into the mains supply in greater and greater quantities.

Harmonics have always been there, however the largest growth of non-linear loads has been in the commercial environment. Even in the domestic environment they have now grown by a huge (>200 %) percentage and this has a serious impact on the power quality expected by the users.

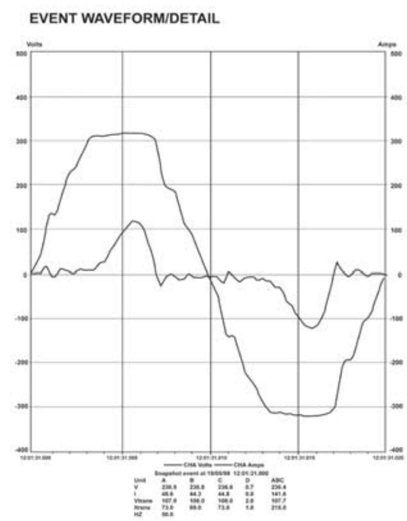
Voltage and Current Harmonics



Harmonics are a multiple of the fundamental frequency of the supply. For example a third harmonic for a fundamental of 50Hz will be 150Hz. However, if one considers the same third harmonic in a Jumbo Jet then it will be 1,200Hz as the aircraft electrical supply has a fundamental frequency of 400Hz. Any distorted waveform is made up of all the harmonics that get superimposed on the fundamental. The higher the proportion of harmonics in any given load the greater the total harmonic distortion generated. Distorted waveforms will have much higher crest factor – ratio of peak of the wave form to its RMS value. This increased crest factor can cause nuisance tripping of circuit breakers due to the increased level of instantaneous current.

Harmonics may cause switchboards to vibrate, motors to overheat, power cables and transformers to overheat. They may also affect the power factor correction banks and failure of standby generating sets or CHP units. The extra heat generated will eventually reduce the life expectancy of all the components within the chain so resulting in a catastrophic failure. Even the motor bearings will fail due to high level of rotor shaft currents.

Event Waveform/Detail



Voltage distortion (THDU) is caused mainly due to the high level of current distortion (THDI) and level of THDU is very much dependent on the source impedance. Higher source impedance means higher THDU and therefore, it is worth keeping an eye on this relationship during the design stage, by making sure that a larger source transformer is selected with adequate K rating (k9 or k13 etc) so that critical loads seem fairly low THDU (4-to-6%) to guarantee peak performance. It is recommended that regular audits are carried out by the FM team at key points within the buildings to make sure that the THDU levels at the point of use meet the requirements of any sensitive equipment connected.

Most PCs and similar equipment utilising Switch Mode Power Supply (SMPS) demand 3rd, 9th and 15th order of harmonic currents – termed as Triplen, which have a return path through the Neutral conductor. However, these Triplen harmonics do not cancel with each other but instead add to each other. This is why most of the so-called intelligent buildings need to have double rated neutral. Hence, it may be worth using a five core cable instead of the standard four core. Cables may overheat if during design stage adequate attention is not given to take account of the skin effect since higher order harmonics need greater conductor surface area rather than larger cross sectional area. High frequency currents do not penetrate up to the core of the conductor. At 160Hz one skin depth (the depth below the surface of the conductor by which the current has decreased to 36.8% of its value at the surface) is about 5mm. In view of this, switchboards often use laminated busbars rather than solid copper busbars when dealing with harmonic-rich loads.

UK regulations were changed some three years ago to cover for the higher neutral currents: if the neutral current is equal to or higher than phase current then the neutral shall be treated as live conductor. This may require use of breakers that have double rated fourth pole or a larger breaker. Depending on the amount of neutral current one can expect a high level of neutral to earth potential.

Power Factor

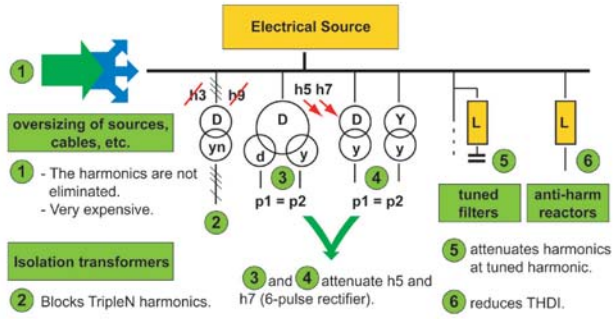
It is essential that true RMS reading instruments are utilised for all power quality related measurements as an average reading meter will not take account of any harmonics and hence will not depict a true picture. Most of the RMS reading instruments will display two types of power factors: True Power Factor (TPF) that covers all the harmonics, and the Displacement Power Factor (DPF) that looks at only 50Hz current. Hence, it is very important not to mix up the two readings. If the two readings of power factors are wide apart then it can be assumed that one is looking at a highly non-linear load eg. desktop PC and printer can have 0.99 as DPF and 0.58 as TPF.

Crest Factor (CF)

Switch Mode Power Supply (SMPS) units draw current in small pulses and are normally pulsed at the peak of the voltage waveform. Crest factor is the ratio of peak current to its RMS value. Crest factor for pure sine wave is 1.414, however, it is common to see CF at a level of 2.5 to 1 in large data centers. Most of the modern UPSs can handle CF level of 3.5 to 1 without any voltage distortion for the load.

International & UK Standards

The relevant standards pertaining to harmonic pollution control are: IEEE 519-2 for USA, EN61000-3-2, EN61000-3-4 & G5/4 for UK issued almost four years ago and extends up to 50th Harmonic measurement.



Electrical Source

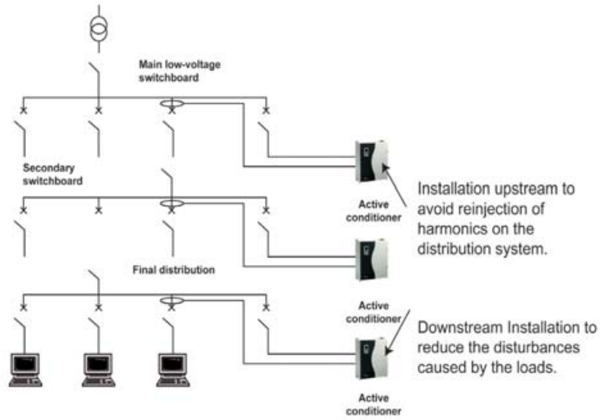
Harmonic Mitigation Methods

Since power quality is very much dependent on harmonic management and containment, we need to use suitable means to mitigate the harmonics in most effective way with focus on value engineering. It is worth reminding ourselves that high voltage distortion (THDU) is the effect of high level of current distortion (THDI).

Passive solutions:

- Over sizing of input source - This is an expensive option and it does not eliminate harmonics.
- Over sizing of cables - Again it increases the cost of the installation but does not eliminate harmonics.
- Isolation Transformers - This option does block all the TripleN (3rd 9th and 15th) harmonics however it has no effect in the remainder of harmonics and needs to be K rated with zero phase shift. It can also be utilised to provide the required galvanic isolation.
- Interconnected Star Transformer - Good solution to mitigate 3rd harmonic and sized just for the harmonic current and not the entire load.
- Inline Choke (inductor) - Fairly simple and common with Variable Speed Drive type application and reduces THDI to some degree and harmonic reduction is very much dependent on level of load current.
- Tuned LC filter - Only attenuates harmonics at tuned frequency. Cost effective solution provided that the harmonic spectrum and the load current remain at planned level. There is a risk of possible resonance by using this solution.
- Phase shifting - Typical example is a 12 pulse rectifier which utilises two phase shifted (30º) six pulse bridges, thus reducing the 5th and 7th harmonics.

Active Harmonic Filter installation options



Active Harmonic Filter Installation options

Active solution

Active harmonic filters/conditioners are suitable for almost all types of application and can be preset to eliminate all the dominant harmonics from 2nd to 50th. There is built-in flexibility to cover for any future change in the load harmonic spectrum. However, one must select only the shunt type active harmonic filters rather than the series connected ones to prevent risk due to overload or internal malfunction. There is no risk of resonance with this type of unit. In the long run this is a very cost effective method which is easy to adopt and it is the solution which meets all of the global stringent standards designed to contain harmonics.

Conclusion

It is interesting to note that over US$24 billion worth of power semiconductors are installed each year globally and 30 % of all power flows through these today. This present level of harmonic is expected to grow to 70%! If we do not monitor and manage harmonics then a number of critical applications will fail without any warning and can be a source of fire risk. In view of this, some of the American insurance companies factor their premium charge for intelligent buildings based on the Neutral size utilised (calculated on the population of PCs and Servers)

In Europe the cost of poor Power Quality is estimated to be around 10 billion euros per annum. Prevention can be achieved by spending just 5% of that amount.

About the Author

Before joining MGE in 1992, Shri held sales management positions with a number of dynamic and static UPS manufacturers including Holec and Anton Pillar. With a BSc in Electrical Engineering, his career path developed from design engineering, where he spent eight years designing rotating machines, motors and alternators. Considered today as one of the leading authorities on UPS and active harmonic conditioners, Shri is frequently asked to speak at international conferences and symposiums, and has published many papers that include power quality problems and the use of active power conditioners for total harmonic management.