Getting to grips with Harmonic Filters

An overview of the requirement, application and theory of harmonic filters and how they improve power quality.

Harmonic filters improve the quality of your power supply. They help eliminate nuisance circuit breaker tripping, reduce stresses on electrical plant and minimize downtime caused by electrical power outages. In other words, they save time and money for any industrial business that depends on electricity to power its operations.

What are Harmonics?

Harmonics are a distortion of a wave form; in this case, the electrical AC (alternating current) supply. They are made up of a division of the electrical wave into multiple smaller 'sub-waves'. These "sub-waves' are multiples of the fundamental frequency.

An easy to understand example of harmonics is found in music. A pure, clean note viewed on an oscilloscope or similar device would produce a sinewave. However, the reason musical instruments sound different to each other is because of the proportions of harmonics in their sound – it's why musicians will spend thousands of pounds to find an individual instrument that sounds exactly the way they like.

This is most obvious with an over-driven electric guitar (say, in a heavy metal band), where a very large part of what you hear is made up of harmonics producing a 'distorted' sound. On the other hand, a clean sound would be made up of notes with a lower 'harmonic content', so the same instrument can produce a range of sounds by varying the harmonic content of the signal sent through the amplifier to the speaker.

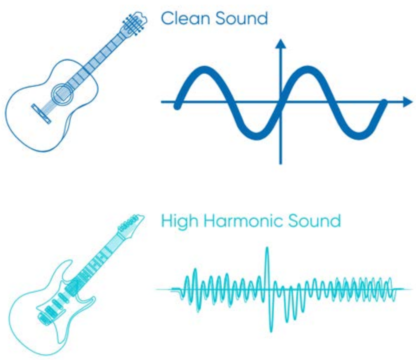

Figure 1 - Musical Example of Harmonics

In electrical power systems, harmonics are typically generated by non-linear power electronic devices such as variable frequency drive (VFD) speed controllers and inverters. These are commonly found in industrial and power generation applications.

Due to the way they interrupt the current flow, by changing the AC frequency sent to the motor they control, VFDs can introduce harmonic distortion to the electrical supply wave form. While a guitarist creates harmonic distortion by increasing the input to the amplifier, as a VFD reduces the speed of the motor, it increases the harmonic distortion caused in its power supply.

Why do Harmonics Matter?

Excessive harmonic distortion is problematic. It can cause equipment malfunctions and in severe cases may lead to damage and grid connection issues.

Returning to our electric guitar example, players who use a lot of distortion in their sound have to use over-rated speaker systems to avoid damage caused by overheated voice coils (which are essentially electric motors). It therefore stands to reason that a transformer or electric motor receiving a badly distorted electrical current (with a high harmonic content) would also be prone to overheating.

Another problem with an industrial electrical system is that it will have many device connections, and therefore many sources of harmonic distortion. Some of these will interfere with each other, sometimes cancelling out each other's effect, sometimes multiplying it. This is known as a 'resonance' and produces an effect known as 'harmonic amplification'. Amplification is a frequent cause of repeated circuit breaker tripping.

What can we do about Harmonics?

Harmonic filters are systems designed to attenuate troublesome harmonics within defined parameters or to dampen system resonances to prevent harmonic amplification.

Enspec provides a range of services and products to manage harmonic distortion within your power supplies. These include manufacturing both passive and/or active harmonic filter solutions:

Passive harmonic filters – Employ tuned LC circuits constructed from series connected inductors and capacitors and typically offer a cost-effective solution to single lower order harmonic issues. (The L represents inductors and C capacitors)

Damped filters – A passive technology that incorporates added resistance: a tuned LCR circuit (also known as an RLC circuit, resonant circuit or tuned circuit) provides a damped response across a broader range of harmonic frequencies. Depending on the filter's power rating and tuning frequency, these damped filters may be configured as 2nd Order, 3rd Order or C-Type filters to minimize fundamental frequency losses. (The L represents inductors, C capacitors and R resistors. C-type filters act only as capacitors on the fundamental frequency, thereby reducing losses).

Active harmonic filters – Utilizing power electronics to cancel unwanted harmonic frequencies by injecting anti-phase harmonic currents. These versatile real-time devices are programmable to target specific or multiple harmonic orders and may be used for other power quality issues such as voltage support, power factor correction, flicker compensation and load balancing.

Hybrid filters – A combination of passive and active technologies where the passive section is used to filter low order harmonics, usually 5th and 7th, and the active filter is targeted at higher order harmonics only, minimizing the size and cost of the overall solution.

Figure 2 - Enspec C-type Harmonic Filter

Who do we work for?

Harmonic distortions occur in almost every electrical circuit, so industries drawing large currents are likely to have the biggest issue. However, electrical power generators are also likely to have similar issues - especially wind farms due to multiple turbines and their complex switching requirements.

Enspec has worked on many of the world's biggest wind farms, but also for a world-famous car maker, for water treatment plants, manufacturers and many other organizations needing bespoke and effective solutions to power supply current harmonic distortions.

For example, Enspec was recently retained to carry out extensive site and background network modeling for a UK Wind Farm which was to be connected to the 33kV network. Initial analysis had shown the site may exceed G5/4 (UK grid code compliance standard) limits. Enspec was tasked with accurately modeling the site and network, and then carrying out a harmonic filter design to ensure G5/4 compliance.

Enspec modeled the background network to the 400kV level to ensure that the harmonic, impedance and resonance changes caused by the wind farm were as accurate as possible and closely represented the real-world implementation.

The wind farm developers provided harmonic information from the Point of Common Coupling (PCC). Enspec's simulation showed that once the wind farm was connected the PCC harmonic voltages would indeed exceed the G5/4 limits. Enspec then carried out an iterative process to design a 33kV passive harmonic filter that would mitigate these harmonic levels.

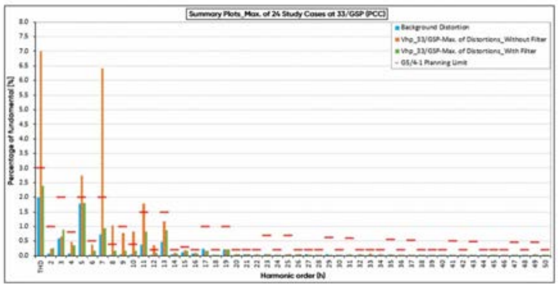

Figure 3 - Harmonic Filter Design, before and after

The final design significantly lowered the voltage harmonics and ensured all harmonic orders were fully compliant with the grid code standard.

How can Enspec help you?

If you have any of the issues we've discussed, or any other electrical power supply problems, please get in touch. We would be very happy to offer advice, develop a full system analysis, produce a solution design, or manufacture and commission your bespoke harmonic filter system.

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