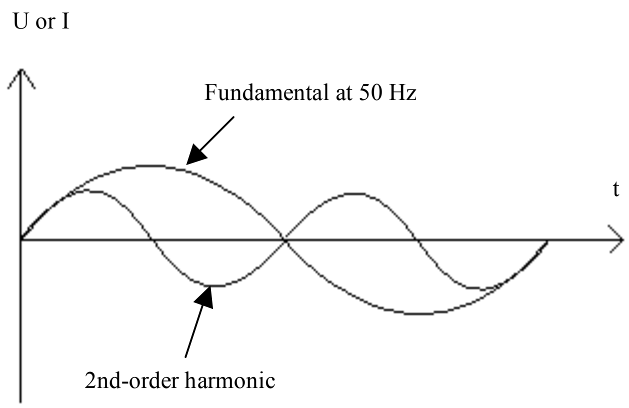
Harmonics

In recent years, there has been a big increase in the number of non-linear loads connected to the electrical network: computers, fax machines, discharge lamps, arc furnaces, battery chargers, uninterruptible power supplies, electronic power supplies, etc.

The growing use of such equipment and the application of electronics to nearly all electrical loads are beginning to have worrying effects on the electricity supply system. A non-linear load draws considerable current from the network, but this current is distorted and can be broken down into harmonics. Harmonic currents have negative effects on almost all the components of the electrical system, by causing new dielectric, thermal and/or mechanical stresses.

What are harmonics?

From the electrical network, a non-linear load draws a distorted current which will modify the shape of the sinusoidal voltage. Non-linear loads generate harmonic currents which flow from the load towards the power supply, following the route with the lowest impedance. Harmonic currents are currents whose frequency is an integer multiple of the fundamental (fundamental of the power supply). Superimposition of the harmonic currents on the fundamental current causes the non-sinusoidal waveforms associated with non-linear loads.

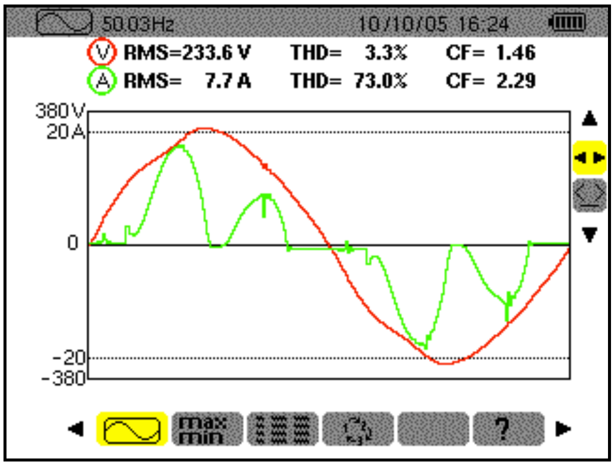


The curve above shows the original signal, with the fundamental at 50 Hz, along with its 2nd-order harmonic at 100 Hz.
The frequency of the 3rd-rank harmonic will thus be 3 times the frequency of the fundamental, i.e. 150 Hz.

Even or odd orders

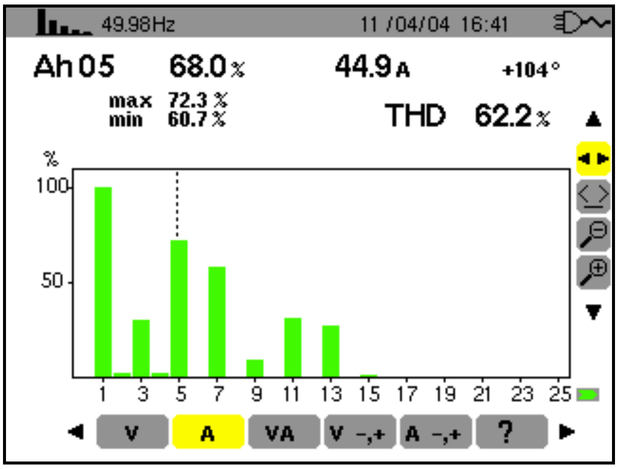
Harmonics are distinguished by their order, which may be even or odd. Even-order harmonics (2, 4, 6, 8…), which are often negligible in industrial environments, cancel one another out due to the symmetry of the signal. They only occur in the presence of a DC component.
Odd-order harmonics (3, 5, 7, 9…), however, are frequently encountered on the electrical network.

Harmonics higher than the 25th order are usually negligible.



On the screenshot above, the green curve corresponds to the sum of the harmonics present. The red curve shows a distorted network voltage signal. It is only clearly visible when the harmonic signal reaches high amplitudes, leading to a voltage drop.

It is possible to obtain a spectral representation of the harmonics by means of Fourier series decomposition.



The harmonic spectrum above shows all the harmonics from the 1st order to the 25th.

Symptoms and consequences of harmonics

The presence of harmonics disturbs the other loads connected to the terminals of the same voltage source, even when they are linear. Indeed, these loads may no longer be supplied in conditions complying with the voltage references required.

Other possible consequences include:

- Heating of the neutral conductor: currents with triplen harmonics (3rd order and multiples of 3) are added together in the neutral conductor, leading to a neutral current which is often 120 to 130 % of the phase currents
- Untimely main circuit-breaker tripping due to overcurrents
- Untimely tripping of RCDs due to the frequencies of the harmonics, linked to the network's stray capacitances.
- Higher RMS current values than those required for the load's energy needs.
- Overheating of installations (transformers, cables, etc.) due to the skin effect
- Voltage resonance on a system composed of capacitors designed to raise the displacement power factor.

Are harmonics present or not?

The harmonic currents flowing through the impedances in the electrical system cause harmonic voltage drops, observed as harmonic distortion of the voltage. One of the solutions for detecting the presence of harmonics is calculation of the THD (total harmonic distortion). There are 2 sorts of THD: voltage THD (occurs at the source) and current THD (due to the loads). When the THD is equal to zero, it can be concluded that there are no harmonics on the network.

This THD value corresponds to the ratio between the true root-mean-square value of a signal's harmonics (U or I) and its root-mean-square value at the fundamental frequency (I_{rms1} in the example that follows).

For example, for an Nth-order harmonic, the **individual current distortion rate** per harmonic can be calculated as follows:

$$\tau_N = \frac{I_{rmsN}}{I_{rms1}}$$

To find out the total distortion of this signal, you must take into account all the harmonics present. There are 2 measurement methods: THD_f (total harmonic distortion in relation to the fundamental) and THD_r (total harmonic distortion in relation to the TRMS value of the signal).

The following equations are used to define these two THD values:

$$THD_F = \frac{\sqrt{\left(I_2^{\,2} + I_3^{\,2} + \ldots + I_n^{\,2}\right)}}{I_1}$$

$$THD_R = \frac{\sqrt{\left(I_0^{\,2} + I_2^{\,2} + \ldots + I_n^{\,2}\right)}}{\sqrt{\left(I_0^{\,2} + I_1^{\,2} + \ldots + I_n^{\,2}\right)}}$$

The 2 formulae can be used interchangeably. The only constraint is that the same formula must be used for the whole duration of a different measurement campaign.

One of the characteristics for identifying a distorted signal is its crest factor (Fc). For an undistorted sinusoidal signal, this corresponds to:

$$Fc = \frac{I_{max}}{I_{rms}} = \sqrt{2} = 1.414$$

When the current is distorted, the crest factor is higher than this value.

Conclusion

Current harmonics cannot be eliminated: they are generated by the load!

They must therefore be confined to an area as close to the polluting loads as possible in order to prevent them from reaching the overall network. The main methods used involve installing a filtering or isolating system (transformers).

These methods will limit the deterioration of energy quality (dequalification of the source voltage) and other harmful effects.

Once the harmonics are "under control", the associated power losses disappear. All the power supplied by the network is then available for the other loads.

The power supplied by the network will therefore be optimized, thus reducing energy costs.

> The IEC 61000-4-7 standard defines the methods for measuring harmonics.
> The EN 50160 standard defines all the parameters to be tested in order to define electrical network distribution quality, particularly in terms of electrical disturbances.

CHAUVIN ARNOUX INSTRUMENTS WHICH MEASURE HARMONICS

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