Definition of Harmonics and Their Origin

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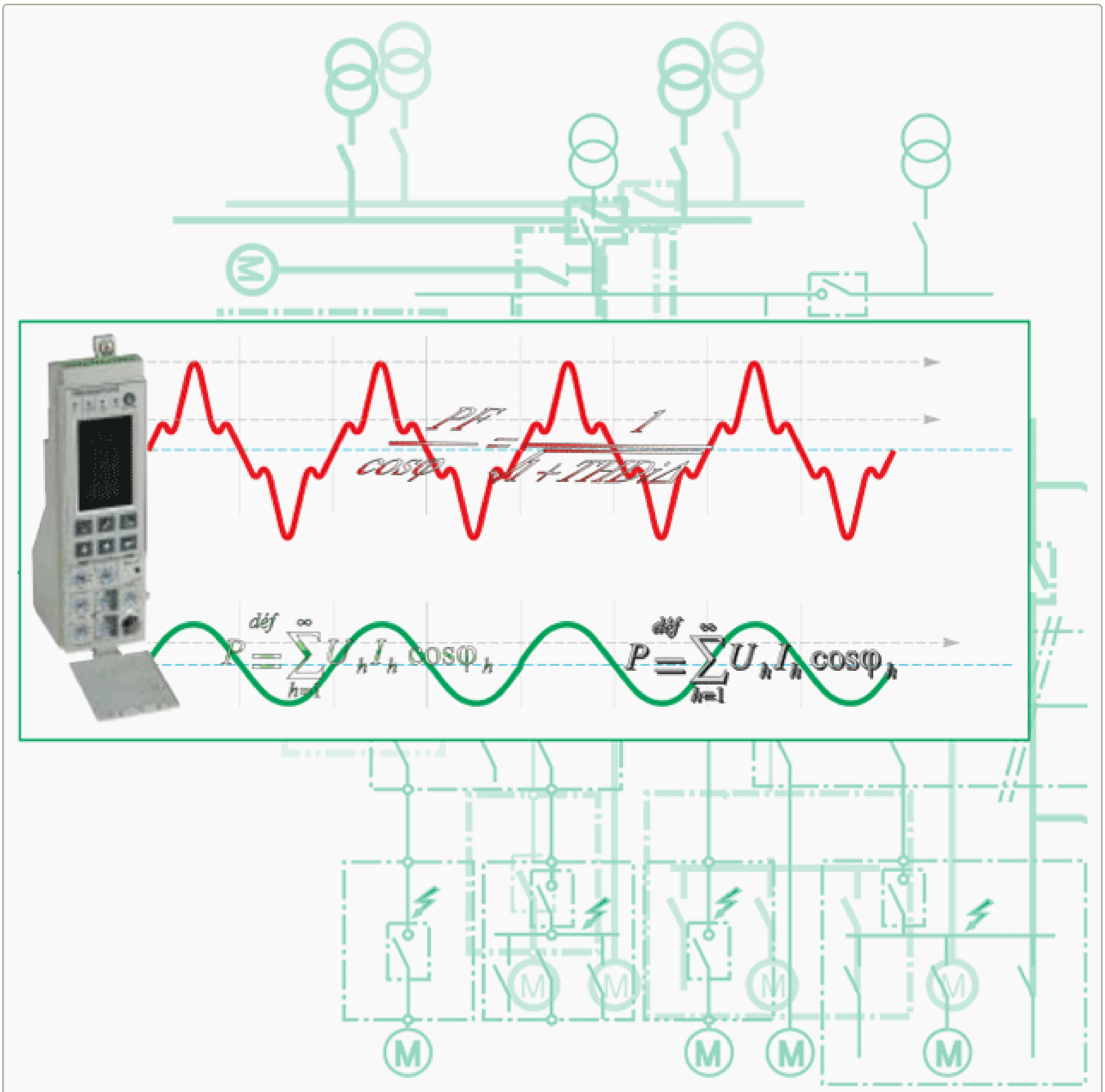


Definition of harmonics and their origin

Distortion of a sinusoidal signal

The ***Fourier theorem*** states that all non-sinusoidal periodic functions can be represented as the sum of terms (*i.e. a series*) made up of:

1. A sinusoidal term at the fundamental frequency,
2. Sinusoidal terms (harmonics) whose frequencies are whole multiples of the fundamental frequency,
3. A DC component, where applicable.

The nth order harmonic (*commonly referred to as simply the nth harmonic*) in a signal is the sinusoidal component with a frequency that is n times the fundamental frequency.

The equation for the harmonic expansion of a periodic function is presented below:

where:

$$y(t) = Yo + \sum_{n=1}^{n=\infty} Y_n \sqrt{2} \sin(n\omega t - \varphi_n)$$

Yo - value of the DC component, generally zero and considered as such hereinafter,
Yn - rms value of the nth harmonic,
ω – angular frequency of the fundamental frequency,
□**n** – displacement of the harmonic component at t = 0.

Example of signals (current and voltage waves) on the French electrical distribution system:

- The value of the fundamental frequency (or first order harmonic) is 50 Hertz (Hz),
- The second (order) harmonic has a frequency of 100 Hz,
- The third harmonic has a frequency of 150 Hz,
- The fourth harmonic has a frequency of 200 Hz, etc.

A distorted signal is the sum of a number of superimposed harmonics. ***Figure 1*** shows an example of a current wave affected by harmonic distortion.

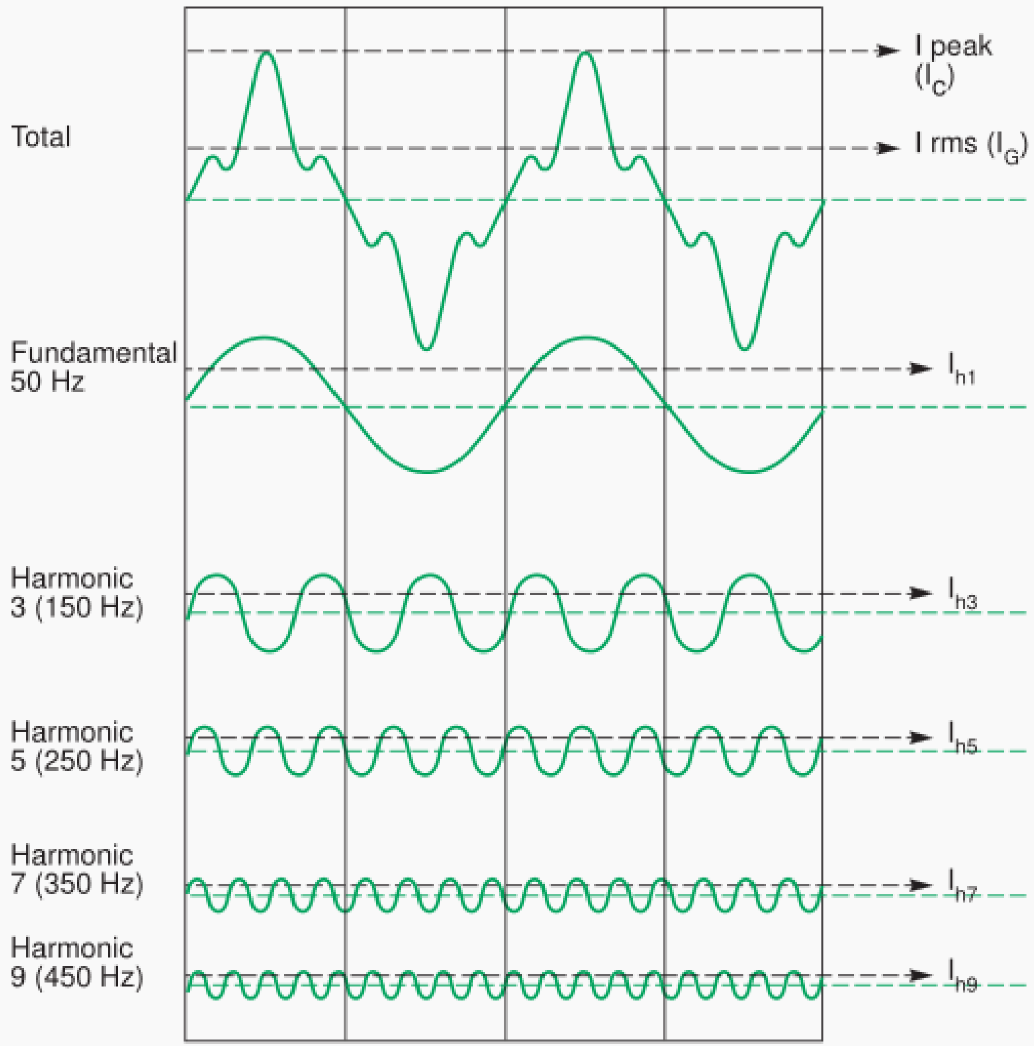


Figure 1 - example of a current containing harmonics and expansion of the overall current into its harmonic orders 1 (fundamental), 3, 5, 7 and 9

Representation of harmonics: the frequency spectrum

The frequency spectrum is a practical graphical means of representing the harmonics contained in a ***periodic signal***.

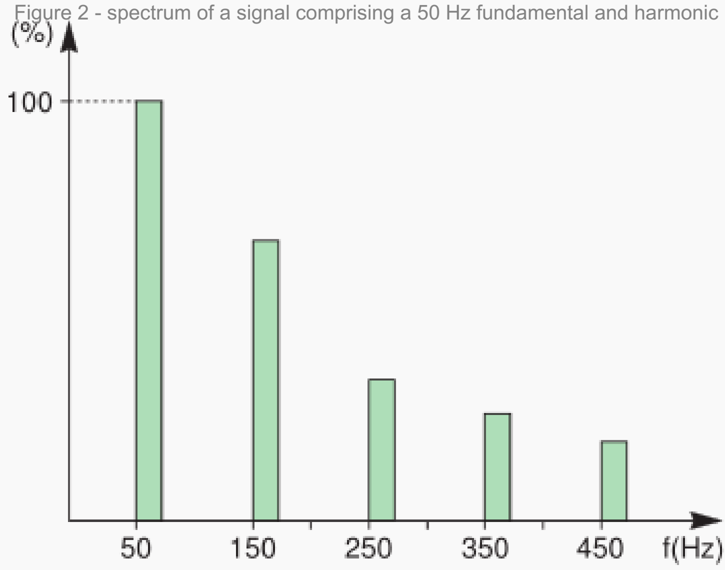
The graph indicates the amplitude of each harmonic order. This type of representation is also referred to as spectral analysis. The frequency spectrum indicates which harmonics are present and their relative importance.

Figure 2 shows the frequency spectrum of the signal presented in ***figure 1***.

Origin of harmonics

Devices causing harmonics are present in all industrial, commercial and residential installations. Harmonics are caused by ***non-linear loads***.

Figure 2 - spectrum of a signal comprising a 50 Hz fundamental and harmonic



orders 3 (150 Hz), 5 (250 Hz), 7 (350 Hz) and 9 (450 Hz)

Definition of non-linear loads

A load is said to be non-linear when the current it draws does not have the same wave form as the supply voltage.

Examples of non-linear loads

Devices comprising power electronics circuits are ***typical non-linear loads***. Such loads are increasingly frequent and their percentage in overall electrical consumption is growing steadily.

Examples include:

- Industrial equipment (welding machines, arc furnaces, induction furnaces, rectifiers),
- Variable-speed drives for asynchronous and DC motors,
- Office equipment (PCs, photocopy machines, fax machines, etc.),
- Household appliances (television sets, microwave ovens, fluorescent lighting, etc.),
- UPSs.

Saturation of equipment (*essentially transformers*) may also cause non-linear currents.

Disturbances caused by non-linear loads, i.e. current and voltage harmonics

The supply of power to non-linear loads causes the ***flow of harmonic currents*** in the distribution system.

Voltage harmonics are caused by the flow of harmonic currents through the impedances of the supply circuits (e.g. transformer and distribution system a whole in figure 3).

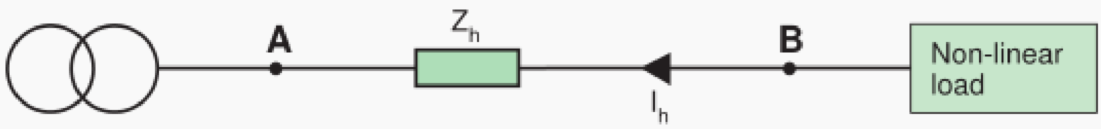


Figure 3 - single-line diagram showing the impedance of the supply circuit for h-order harmonic

Note that the impedance of a conductor increases as a function of the frequency of the current flowing through it. For each ***h-order*** harmonic current, there is therefore an impedance $\mathbf{Z_h}$ in the supply circuit.

The h-order harmonic current creates via impedance $\mathbf{Z_h}$ a harmonic voltage $\mathbf{U_h}$, where $\mathbf{U_h = Z_h \times I_h}$, i.e. a simple application of Ohm’s law. The voltage at **B** is therefore distorted and all devices supplied downstream of point **B** will receive a distorted voltage.

Distortion increases in step with the level of the impedances in the distribution system, for a given harmonic current.

Flow of harmonics in distribution systems

To better understand harmonic currents, it may be useful to imagine that the non-linear loads reinject harmonic currents upstream into the distribution system, in the direction of the source.

Figures 4a and ***4b*** show an installation confronted with harmonic disturbances. ***Figure 4a*** shows the flow of the fundamental 50 Hz current, whereas in 4b, the h-order harmonic current is presented.

Supply of this non-linear load causes the flow in the distribution system of current I50Hz (*shown in **figure 4a***) to which is added each of the harmonic currents $\mathbf{I_h}$ (*shown in **figure 4b***) corresponding to each harmonic (*order h*).

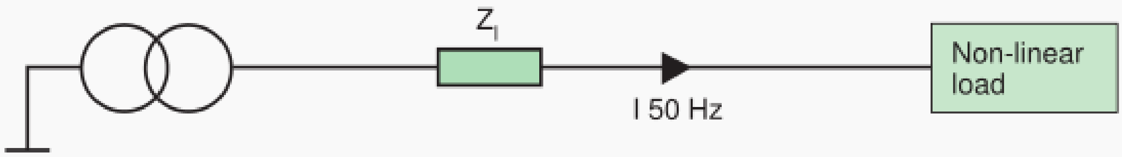


Figure 4a - diagram of an installation supplying a non-linear load, showing only the fundamental 50 Hz current

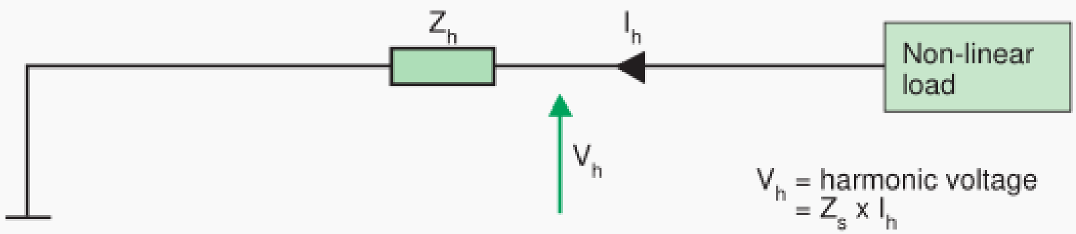


Figure 4b - diagram of the same installation, showing only the phenomena related to the h-order harmonic

Resource: *Harmonic Detection and Filtering – Schneider Electric*

Source: http://electrical-engineering-portal.com/definition-of-harmonics-and-their-origin