PFC SYSTEMS IN PRESENCE OF HARMONIC CURRENTS

In the industrial systems the presence of motors with speed variation, U.P.S., frequency converters is very widespread. These types of electrical machines are powered by AC/DC converters that absorbe a non-linear current: this means that its trend is non-sinusoidal but it is made by ripples. The following pictures in Fig. A show their typical waveforms.

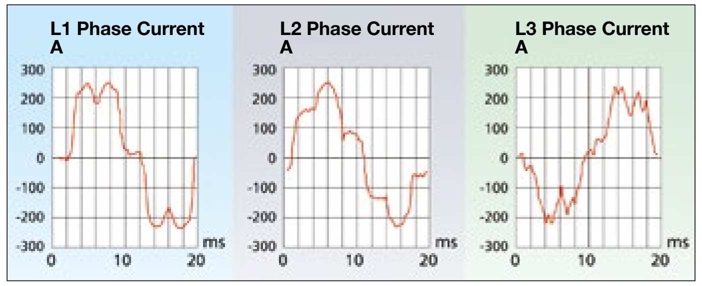

Fig. A

A periodic non-sinusoidal waveform can be decomposed in some frequencies divided into the fundamental one and its multiples: double, triple, etc., that are named second harmonic, third harmonic, etc.

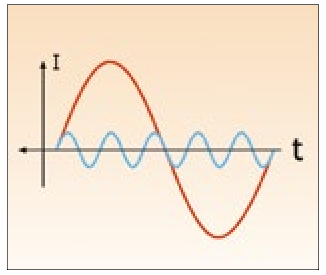

Fig. B

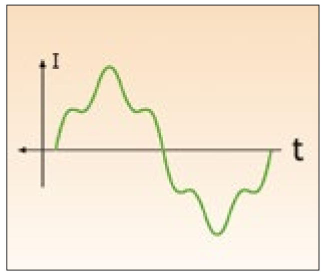

Fig. C

The Fig. B shows the fundamental sinusoidal wave at 50 Hz that is overlapped to a wave at 250 Hz related to the fifth harmonic order wave.
The Fig. C shows the harmonic distorsion created by the overlap between the two above waveforms.

The TOTAL HARMONIC DISTORSION (THD) is defined as the per cent ratio the tota harmonic value and the fundamental one:

$$THD\ \% = \frac{\sqrt{\sum_n I_{an}^2}}{I_f} \times 100 = \frac{I_{aT}}{I_f} \times 100$$

where: n = harmonic order
I_{an} = harmonic current value
I_f = fundamental current value
I_{aT} = total armonic value

In presence of harmonic currents (in general the voltage harmonics are negligible) the installation of capacitors might create some problems that must be carefully evaluated.

The capacitors must withstand currents above their nominal values since they amplify the harmonic currents and that is why some resonance phenomena might occur: this situation is very dangerous both for the capacitors and the electrical system.

The worst condition that might occur is the Parallel Resonance which is a destructive swing between the inductance of the system and the reactance of the capacitors.

For example, let's consider an inverter that could be represented as a harmonic generator and the Power Transformer and the Net could be considered as the total shortcircuit impedance, as shown in Fig. D.

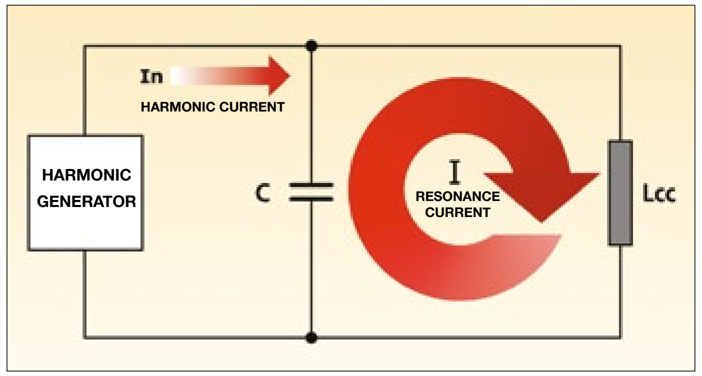

Fig. D

The resonance frequency is given by:

$$f_0 = \frac{1}{2 \cdot \pi \sqrt{L_{cc} \cdot C}}$$

When the resonance occurs the voltages and the currents related to the parallel Lcc-C are amplified; this condition also includes the other harmonics.

When the harmonic current frequency overlaps the frequency of the system Capacitor-Net, the impedance reaches its minimum value while the current gets its maximum, although the voltage keeps remaining a constant.

In order to avoid these inconveniences the capacitors are matched with the inductors, realizing a LC series filter that is tuned on a frequency value than the harmonic orders of the electrical system: thanks to this solution the capacitors are not hit by harmonic currents.

The main purpose of the detuned inductors is to avoid the resonance between the power transformer and the capacitors and their dangerous overload.

The detuned inductor is series-connected with the capacitors supply, as shown in Fig. E. The resonance frequency between the inductors and the capacitors is 189 Hz and the typical frequency response is always figured in Fig. E.

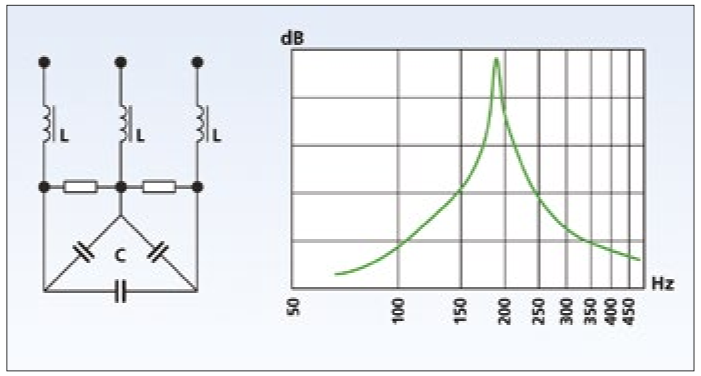

Fig. E

The series chokes make the capacitors voltage increasing and its value increases the higher is the inductor value, reaching an overvoltage of 10% of V_n: hence the capacitors must be properly rated.

SIMULVAR: HOW TO SOLVE PFC PROBLEMS

Trendfin S.r.l. developed SIMULVAR software in order to supply a helpful device for checking the electrical systems and for sizing the PFC equipments. After some complex calculations, SIMULVAR software provides the customer with the correct solution within a few minutes, avoiding any waste of time.

The software gives proper solutions very quickly by only adding the parameters of the electrical system, such as:

- Reactive power required by the electrical system;
- Features of the capacitors;
- Presence of dangerous harmonic currents for the capacitors;
- Any resonance detection;
- PFC equipments provided with antiresonance inductors.

Possible power variations of the electrical systems and expandabilities for the PFC equipments can be easily simulated.

SIMULVAR also automatically provides the user with the correct automatic PFC equipment that is proposed in the **TECNOLOGIC** catalogue.

DESCRIPTION

The program is divided into two parts:

- In the first part the data of the electrical system and the information about the distorting loads must be added; the info about the harmonics may be filled in with four different methods:
  1) The power of the distorting load related to the total load, expressed in %.
  2) The value of each harmonic current that is present in the system.
  3) The Total Harmonic Distorsion (THD) that is expressed in %.
  4) The true RMS value of the THD in current.

- In the second part the user is provided with the following information:

- The required capacitive power.
- The effects produced by the harmonics.
- The PFC equipment choice.
- The simulation of the current overloads.

EXAMPLE

Let's simulate the analysis of the following system:

- Supply voltage: 400V
- Supply frequency: 50 Hz
- Total Power of the load: 557 kW
- Power Factor of the non-compesated load: cos φ 0,75
- Target Power Factor: cos φ 0,95
- Apparent Power of the transformer: 1000KVA
- Nominal Voltage of the capacitors: 400V
- Measured THD% on the general busbar: 20

This simulation leads to:

- The required Reactive Power is 308,2 kvar
- The PFC equipment must be protected by antiresonance inductors due to harmonic currents.

Hence the needed PFC system will be::

RAM 9400 HG - 360 - 400V