Filtering solutions

for improving energy efficiency

CIRCUTOR

Technology for energy efficiency

What are harmonics?

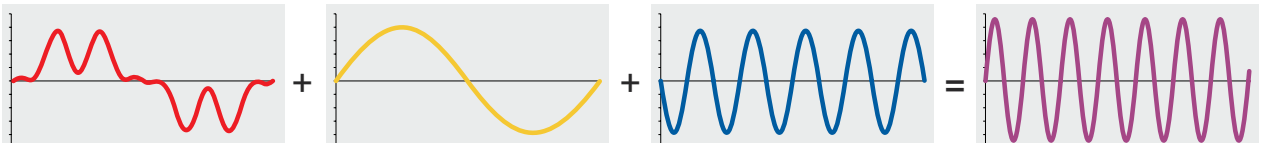
Non linear loads, such as: rectifiers, inverters, speed variators, furnaces, etc. that absorb periodic non-sine wave currents from the network.

Said currents are composed of a fundamental frequency component rated at 50 or 60 Hz, plus a series of overlapping currents, with frequencies that are multiples of the fundamental frequency. This is how we define HARMONICS. The result is a deformation of the current (and consequently, voltage) leading to series of associated secondary effects.

Order	Frequency	Sequence
Fund.	50	↺
2	100	↻
3	150	↑
4	200	↺
5	250	↻
6	300	↑
7	350	↺

Order and behaviour of harmonics

▫ Decomposition o breakdown



Fundamental Wave
50 Hz

Harmonic wave
5th order
250 Hz

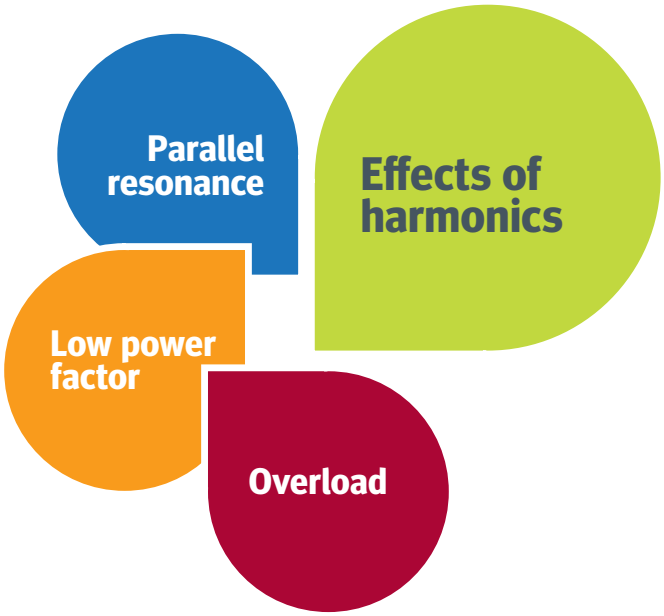
Harmonic wave
7th order
350 Hz

Distorted wave

Effects of harmonics

The main effects of the voltage and current harmonics in a power system can be cited as:

- The possibility of amplification of some harmonics as a result of serial and parallel resonance.
- Reduction in the performance of energy generation, transmision, and usage systems.
- The ageing of the grid isolation components and as a consequence, energy reduction.

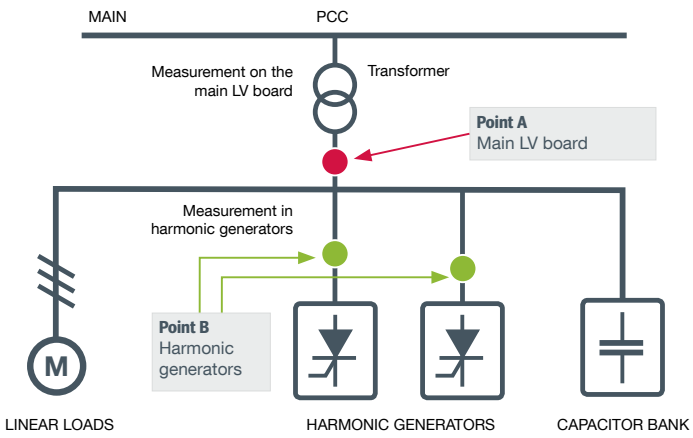


Information required for studying harmonics

Installation information

1 Diagram

The diagram has to show:
- Points where measurements have been taken using the portable **AR5**, **AR6** power analyzer
- Load distribution



2 General information

- Single-line wire diagram of the installation
- Indication of measuring points
- Type of industrial process

Number of power transformers		
S_n (Transformer power)		KV·A
Transformer ratio		V
U_{cc} (Short-circuit voltage)		%

Measurements

3 Main board

- Active and reactive power measurement
- Harmonic measurement

Nbr. of harmonics	1	3	5	7	11	13	ΣTHD
U_k / U_1 (%)							
I_k / I_1 (%)							
$I_{neutral}$ (A)							

- If there is a capacitor bank

With bank connected		Without bank connected	
THD (U)	%	THD (U)	%
THD (I)	%	THD (I)	%
Q (capacitor bank)		kvar	
P (installation)		kW	

4 Loads

- Measurements on power converter loads terminals

Nbr. of harmonics	1	3	5	7	11	13	ΣTHD
U_k / U_1 (%)							
I_k / I_1 (%)							
$I_{neutral}$ (A)							

- Measurements on load terminals of other generators
- Description of type of load:
  - Discharge lighting
  - Welding machinery
  - Computers
  - Others

Nbr. of harmonics	1	3	5	7	11	13	ΣTHD
U_k / U_1 (%)							
I_k / I_1 (%)							
$I_{neutral}$ (A)							

Origin

Faults

- **Interference caused by converters, motor drives, UPS, etc.**
- *Individual protection is recommended*

Supply side:
- Current harmonics (Low frequency)
  - Excessive losses in lines and transformers
  - Wave form distortion
  - Earth-leakage tripping
- **EMI** (High frequency)
  - Earth-leakage tripping
  - Interference to electronic equipment

Load side:
- Excessive ripple at the switching frequency
  - Interference to electronic equipment
- Excessive dU/dt
  - Damage to isolation in motors

- **Non linear loads distributed in the system**
- **Converters, induction ovens, UPS, discharge lamps, etc.**
- *Overall protection of the system is recommended*

- Harmonic resonance:
  - Overload of PF correction equipment
  - Overload and vibration in the transformer
  - Distortion of the voltage wave
- Current harmonics:
  - Excessive losses
  - Distortion of the voltage wave
  - Earth-leakage relays tripping

- **Single-phase, non linear loads between phase and neutral**
- **Electronic equipment, discharge lighting, etc.**
- *Protection per areas is recommended*

- High third harmonic:
  - Waveform distortion
  - Earth-leakage relays tripping
- Overload of neutral in systems of 4 wire (3 phases + neutral)

Solutions

- **LR** reactors
- **LCL** and **LCL-th** filters

- **EMI** filters
- Immunized earth-leakage protecion

- Sinus filters
- *du/dt* filters

- **AFQ** Active filters

- **FR**, **FRE** rejection filters:
  - 7% if 5th, 7th harmonics are dominant
  - 14% if 3rd harmonic is dominant
- Regulated absorption filters:
  - **FAR-Q**, **FARE-Q** (5th and 7th harmonics)
  - **FAR-H** (5th, 7th, 11th, 13th...)
- **AFQ,** ACTIVE filters with or without phase balance

- **FB3** and **FB3T** filters
- **TSA** isolation transformer with harmonics filtering

- **AFQ** Active filters

Active filters

(Global compensation: Power factor, harmonics, imbalance)

AFQ multifunction parallel active filters are the most complete solution to solve those quality problems caused, in either industrial or commercial facilities, not only by harmonics but also for current imbalance, and, even, reactive power consumption (mostly leading PF).

The available functions in all models are the following ones:

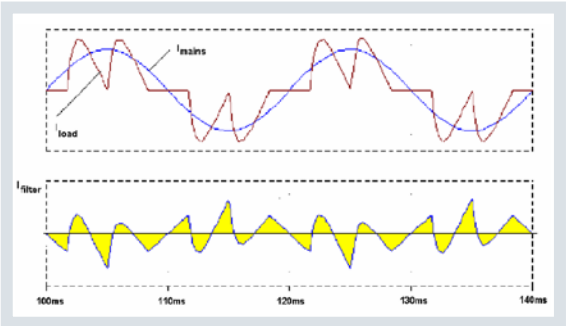
- Reduction of current harmonics up to the 50th order (2500 Hz). Manual selection of harmonic frequencies to be filtered for a higher efficiency.
- Correction of the unbalanced current consumption in each phase of the electric power system.
- Power factor compensation. Both lagging currents (inductive) and leading currents (capacitive).

These filters offer a configurable priority function for an optimal use of the filter's capabilities according to the installation's needs.

AFQ filters are equipped with a user-friendly touch display, which allows to carry out all the required programming actions. Display the status of the main and load sides of the filter's connection point to the mains, for comparison and effectiveness evaluation purposes.

In case of higher filtering requirements, up to a maximum of 8 filters may be connected in parallel (all units must be of the same rating).

The operating principle of active filters for harmonic reduction is based on monitoring the existing harmonic current generated by the loads, and injecting an opposite compensation current in order to cancel each harmonic frequency.



▫ **AFQ** Waveforms

1. Harmonics cancellation

Harmonics current reduction up to the 50th order (2500 Hz). Selectable harmonics frequency for optimizing filtering spectrum efficiency.

2. Phase imbalance correction

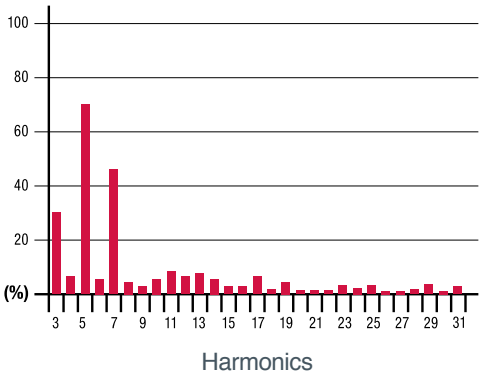
Phase current correction for optimizing imbalance phenomenon in the electric power system.

3. Power Factor compensation

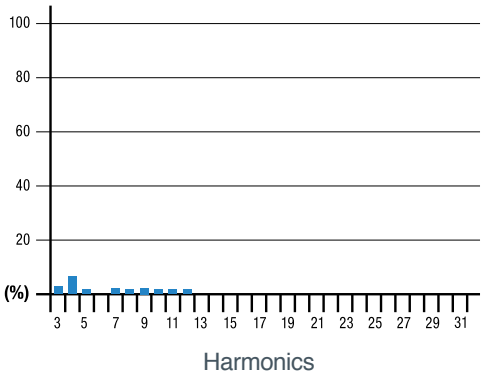
Power Factor compensation for lagging current systems (inductive) or leading currents (capacitive).

What do we get?

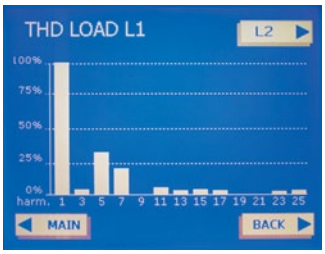
Harmonic level without **AFQ**



Harmonic level with **AFQ**

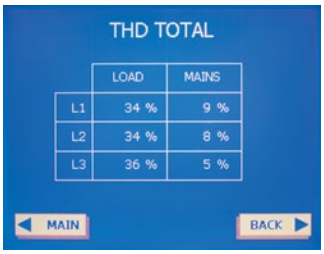


Intuitive touch screen



Harmonics graph

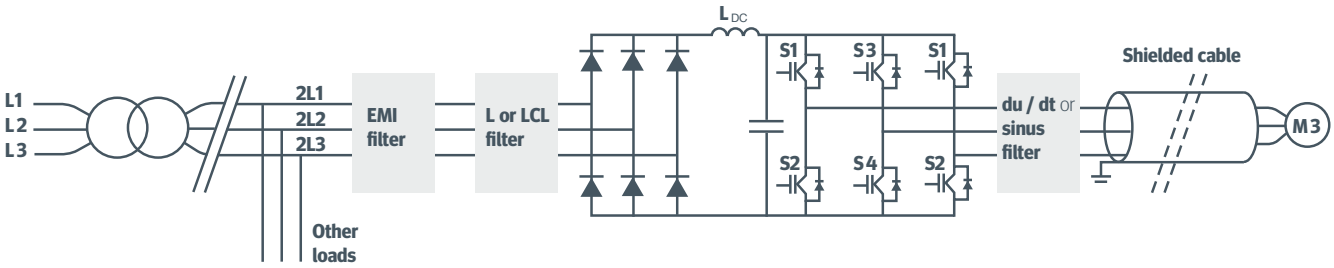
Harmonics selection



Before & After total THD

Filters for power converters
(individual filtering)

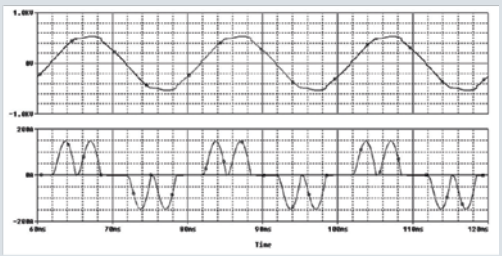
Static converters generate different types of disturbances, both on the main side and on the load side. **CIRCUTOR** has filters to avoid problems caused by these converters and allow installations where they are installed to comply with the EN-61000-3-12, IEEE-519 standards and the 2004/108/CE, 92/31/EEC and 93/68/EEC Compatibility Directives.



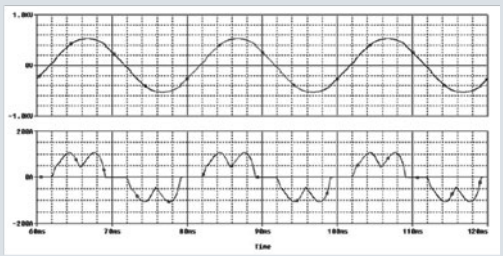
▫ Filtering diagram for three-phase power transducers

LR filters: Reactors

- **LR** filter reactors allow current harmonics to be reduced in any converter from levels of 40% or 50% to values around 20%. They reduce the short circuit current and increase the safety of the converter's semi-conductors.



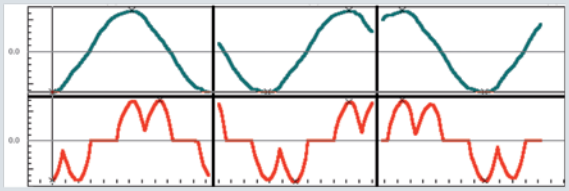
▫ Without reactor: THD=45%



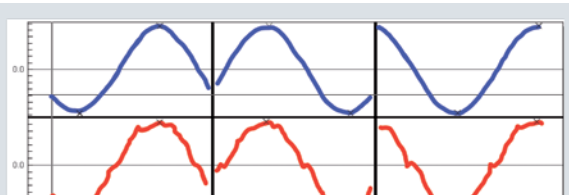
▫ With reactor: THD=20%

LCL and LCL-th filters

- **LCL** Filters are individual filters for converters reducing the level of harmonics produced by converters in the system. Inserting **LCL** Filters allows an installation with converters to comply with the EN-61000-4-3 and IEEE-519 standards. **LCL-th**'s add a disconnection capacity to the filter's parallel branch in the event that the filter operates with no load. Ideal for lifts.



▫ Without filter: THD(I) = 35% ÷ 50%



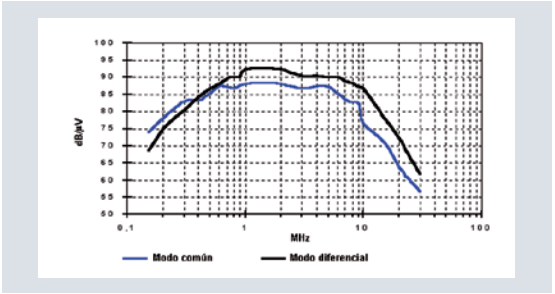
▫ With filter: THD(I) < 5%

EMI filters

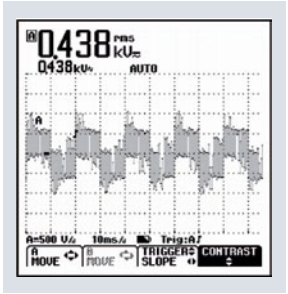
- **EMI** filters are used to remove high frequency disturbances (150kHz-30MHz) and to comply with the 2004/108/CE, 92/31/EEC and 93/68/EEC European Directives on Electromagnetic compatibility.

SINUS and du/dt filters

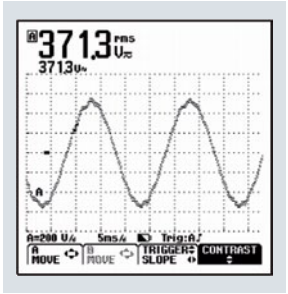
- **SINUS** and **du/dt** filters are used between the converter and motor in inverters with PWM output to improve the waveform and to avoid overvoltages.



▫ EMI filter insertion losses in common mode and differential mode



▫ Without **SINUS** filter



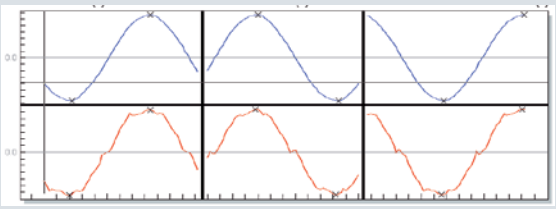
▫ With **SINUS** filter

Power Factor correction in installations with harmonic disturbances

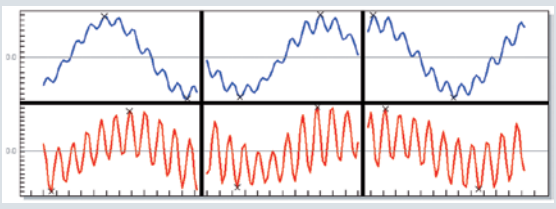
Industrial systems usually require power factor correction. In the event that the system supplies non linear loads which generate harmonics, the design of PF equipment has to take this into account and will have to combine a correction of cos φ with harmonic filtering. **CIRCUTOR** has equipment to prevent harmonics overload and to reduce harmonics effects on the system, in particular preventing the phenomenon of resonance, which may give rise to serious faults in the installation.

FR and FRE filters

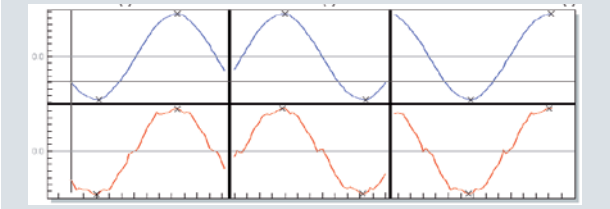
- **FR** and **FRE** filters are power factor correction equipment with built in filters to prevent resonance and overloads in capacitors and transformers due to harmonics. This equipment reduces THD (V) in the system between 1 and 3 percentage points, depending on impedance of the system. In particular, the **FRE** series uses a “real time” static correction system and is specially designed for installations where there are fast load fluctuations.



▫ Without power factor correction THD(V)=5%



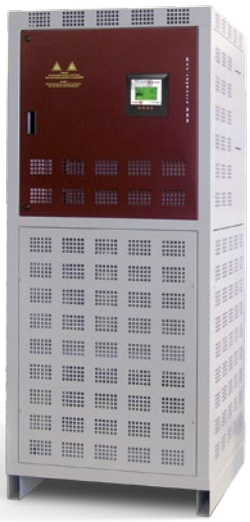
▫ PF correction without filter: resonance THD (V)=12%

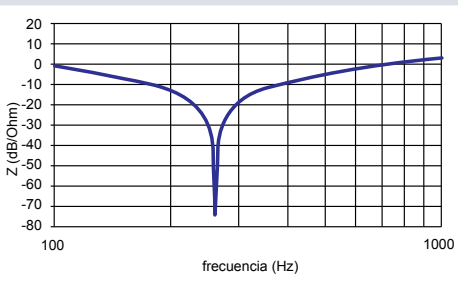


▫ PF correction with filter THD (V)=3.5%

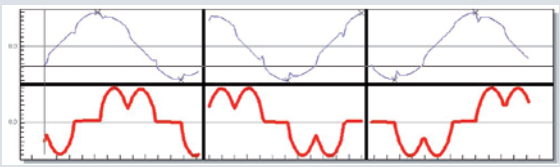
FAR-Q, FARE-Q hybrid filters

- **FAR-Q** and **FARE-Q** filters are power factor correction equipments with built in filters absorbing the 5th and 7th harmonic. This considerably decreases THD (I) in the system. The **FAR-Q** and **FARE-Q**'s absorb 5.3 A of the 5th harmonic + 2.65 A of 7th for every 10 kvar. This decreases THD (V) in the system between 3 and 6 percentage points, depending on the system's impedance. In particular, the **FARE-Q** uses a "real time" static correction system and is specially designed for installations where there are fast load fluctuations.

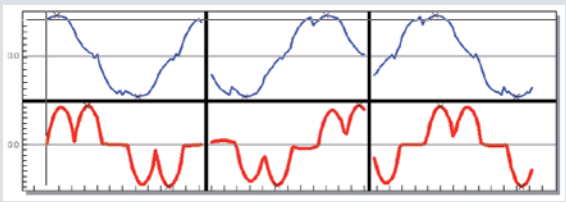




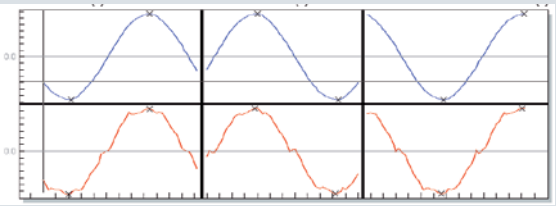
▫ Filter impedance



▫ Without PF correction THD (V)=12%



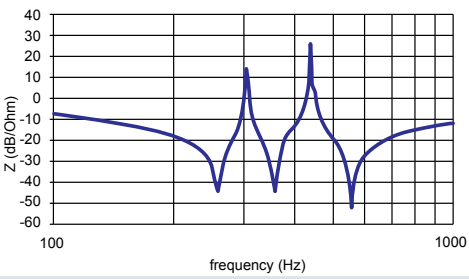
▫ PF correction without filter: Without resonance THD (V)=15%



▫ PF correction with filter THD (V)=3.5%

FAR-H filters

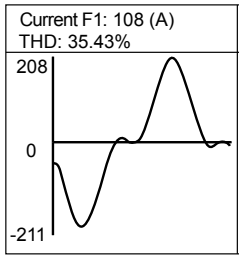
- **FAR-H** filters are harmonic filtering equipment, based on individual filtering. They may be set with branches for the 5th, 7th, 11th, 13th and HF. They are regulated depending on load current THD (I).



▫ Frequency response of a 5th, 7th and 11th harmonic filter

Blocking filters for 3rd harmonic filtering

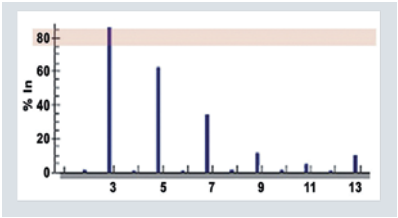
Single-phase loads such as computers, battery chargers, single phase UPS, discharge lamps, etc., generate a large of amount of third harmonics. When these loads are connected between phase and neutral, they generate strong currents in the neutral conductor at the frequency of: 3rd harmonic and its multiples. **CIRCUTOR** has several solutions for this problem.



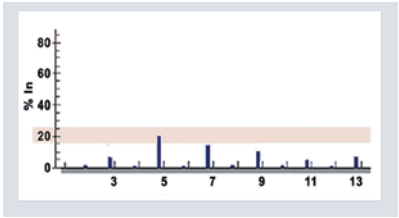
▫ Typical wave form in non linear single-phase loads

FB3 and FB3T filters

- **FB3** filters are harmonic blocking filters, where receivers can be directely plugged. Their main function is to reduce the 3rd harmonic, but they also significantly reduce the 5th and 7th harmonic and others present in domestic and business installations.
- **FB3T** filters are harmonic blocking filters for 3rd harmonic and multiples. The filter must be placed in series with neutral and also provides a significant reduction of the 5th, 7th harmonics and others present in industrial installations.

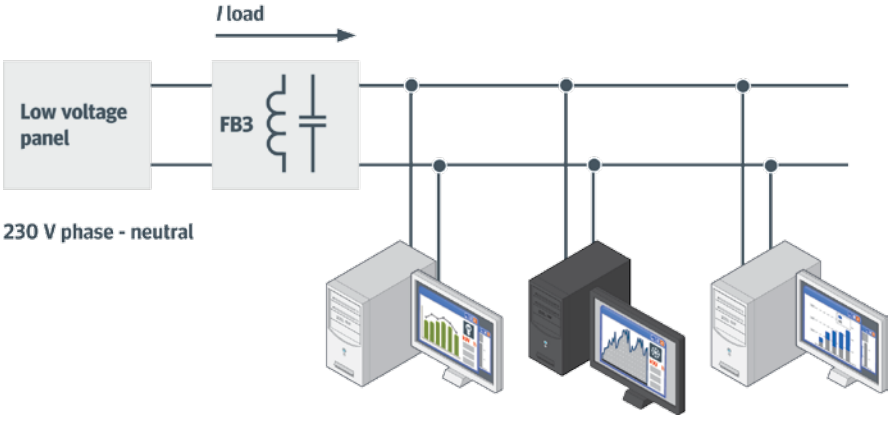


▫ Harmonic spectrum **without** filter

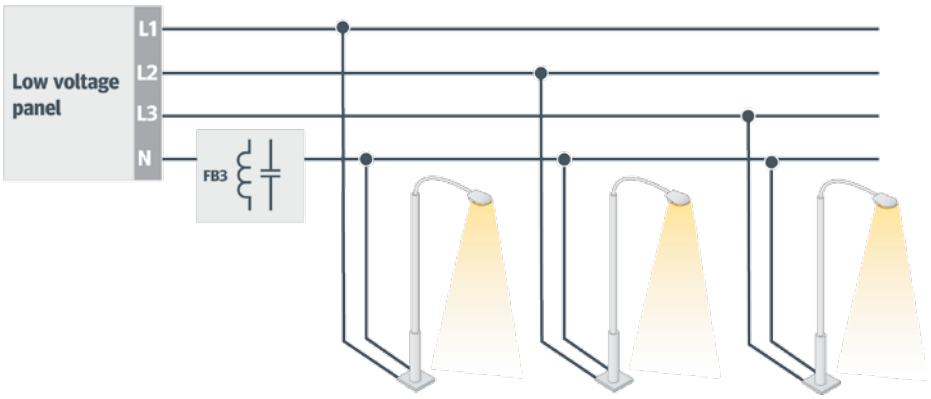


▫ Harmonic spectrum **with** filter

▫ Diagram of **FB3** application



▫ Diagram of **FB3T** application



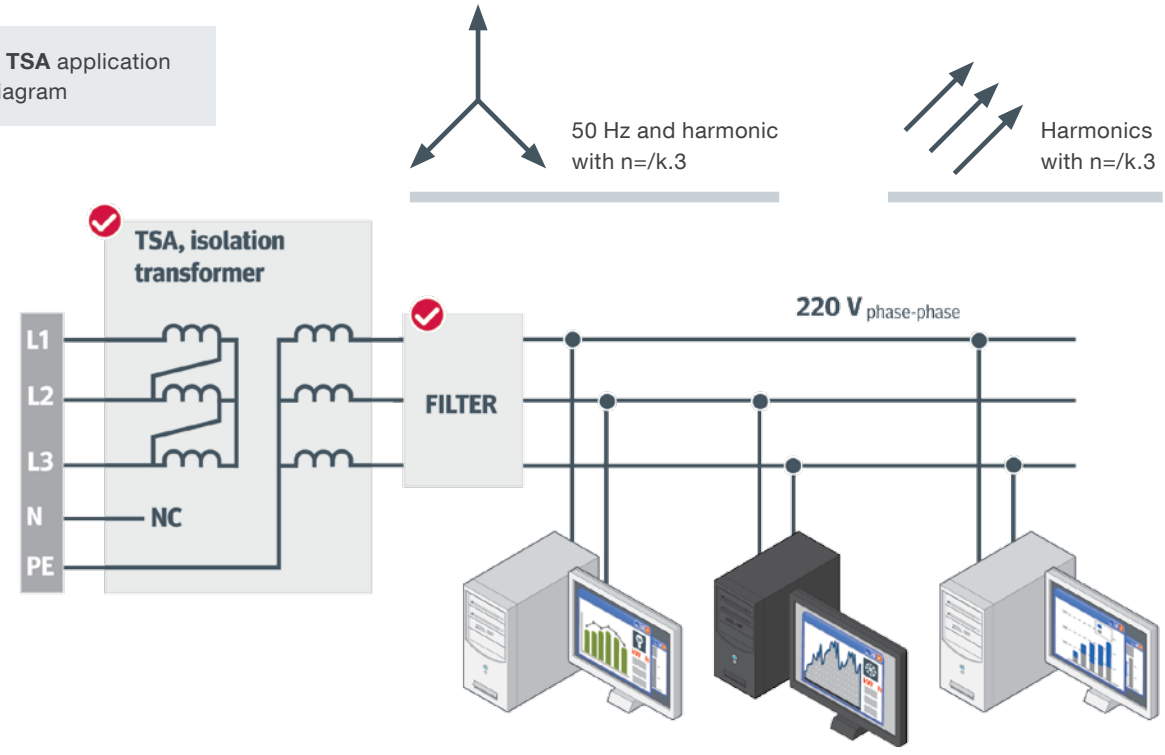
Isolation transformer with filter: TSA

- The **TSA** is an isolation transformer combined with a high frequency absorption filter.
- Elimination of the return possibility of the 3rd harmonic through the neutral conductor.

Features:

- Elimination of 3rd harmonic
- Galvanic isolation of single-phase loads (earth separation)
- Loads balancing

▫ **TSA** application diagram



QNA 500

Modular power quality analyzer

Always know the status of your electrical network at the harmonics and disturbances level and the quality of its supply

We help you to reduce costs of breakdowns and faults and increase your productivity.

QNA 500 is designed to supervise the electric installation and problems relating to electric power quality so as to control production processes and manage incidents.

Main features

- Installation supervision
- Monitoring the level of harmonics and PF
- Preventive and predictive maintenance
- Alarms:
  - Sending e-mails
  - Warnings through relays (for example: Light signals)
- Disturbances/transients log
- Remote monitoring from mobile devices
- On-line connection with mobile devices (android, iO, Blackberry ® OS)
- More than 500 electrical parameters

Over 500 parameters

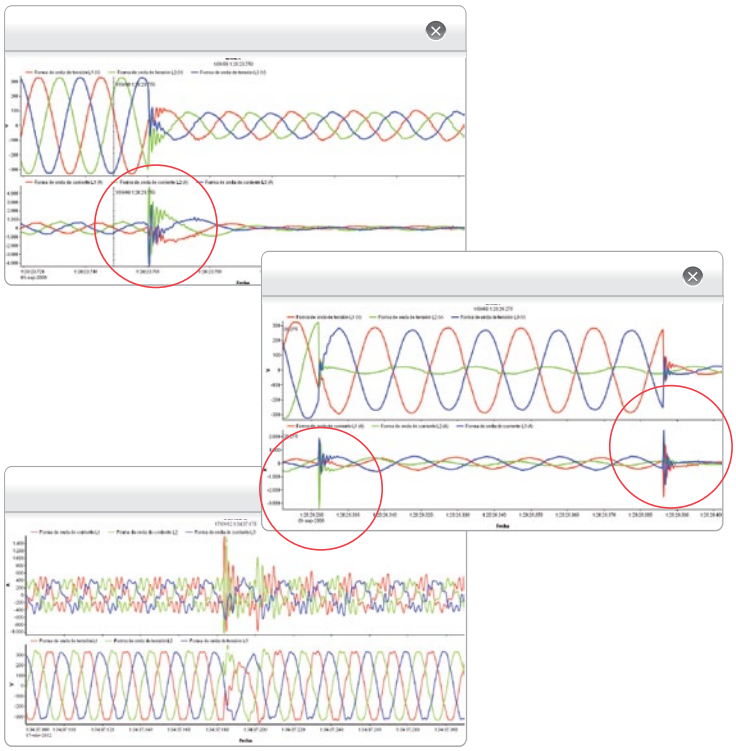
- Voltage and current measurement
- Active and reactive power
- Maximum demand
- Energy (4 quadrants)
- THD and harmonics
- Interharmonics
- Flicker
- Imbalance
- Events and transients

BASE

Base module. Connected modules switch

\+ **QNA 500**
Power quality analyzers

\+ **8iO**
Load and alarm control



Transients capture

- 512 simultaneous samples/cycle per channel
- Voltage and current disturbances log
- Configurable capture conditions, (pre-post trigger)
- Detection of power surges that can affect the installation

Capture of waveforms in voltage and current (screenshot)

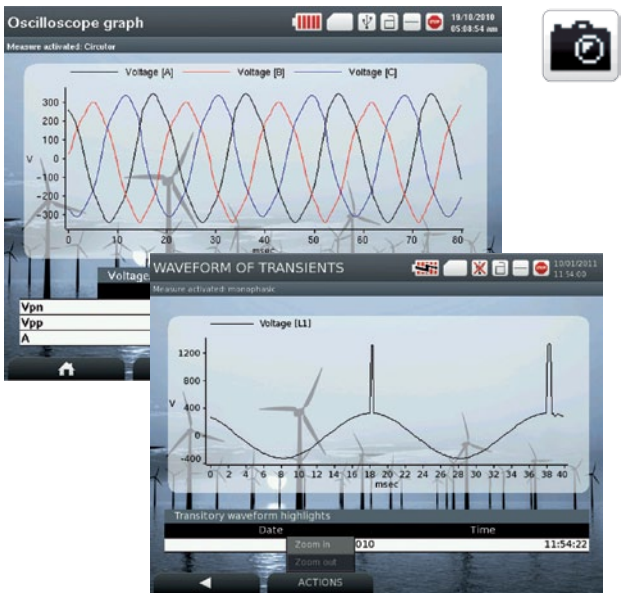
- Detection of transients (voltage and current) (>39 µs)
- Analysis of resets in machines and fast network switching
- 512 simultaneous samples/cycle per channel
- Log of 60 continuous cycles per event
- Analysis in accordance with CBEMA / ITIC curve. Detects if electronic equipments have been affected.

AR6

Three-phase power and quality analyzers

Detailed and in-depth analysis of any point of the electrical network

- Portable power analyzer for three-phase and single-phase electrical networks with simultaneous measurement of leakage current, power quality and recording of transients.
- **AR6** is the best tool for visualizing and analyzing the network's problems regardless of whether it is a single-phase or three-phase network.
- It allows recordings of the most common electrical parameters and also those specifically related to supply quality such as overvoltages, swell, sags and transients.
- Thanks to the graphical display of harmonics, phasors and waveforms, the user can detect anomalies in the installation simply by connecting the device.
- Measurement of the main electrical parameters.
- True root mean square measure (TRMS).



Harmonics graphs

- The harmonics screen displays the amplitude value information of each harmonic.
- The user can scroll to select the desired harmonic to display in the below table the most important values of this harmonic.

Waveform

- With the waveform visualization, it is possible to detect any waveform defect.
- It is also possible to pause the image and zoom-in on the oscilloscope image any time in order to get a better definition of the image.

Photo

- The device captures the waveform of 9 channels measured together with the instantaneous values of the most important electric variables so that each photo allows a detailed analysis of the installation..
- The photo capture can be programmed with trigger (electrical parameters comparison) or can be taken manually.

Transients capture

- It is possible to activate and configure the detection and registration of quality events such as over-voltages, swells, dips and transients.
- The events are show in a table with the most important parameters of the event. The user can select any event and visualize the waveform and values of the event.

Application

- With the AR6 you can perform a full study of the electrical installation. It is possible to perform an analysis of consumption, load curves, voltage disturbances in the installation and to display waveshapes, study harmonics or measure flicker, as well as other options.

Filtering solutions
for improving energy efficiency

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