

Specification guide no. 9

Active harmonic conditioner from 20 to 480 A

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1 - Installations concerned

This specification applies to buildings or industrial sites where the circulation of harmonic currents may disturb electrical installations. It covers the requirements for electronic equipment specified hereafter aimed at harmonic cancellation, and known as Active Harmonic Conditioners (or Active Filters).

1.1 - New installations

This specification shall be used to apply a *preventive* solution, to problems such as voltage distortion (THDU), particularly when long cables are used, and cable overheating (e.g. neutral conductor).

This solution shall be considered in any new installation where the following equipment shall be used:

- ▶ computers (e.g. PC network, etc.),
- ▶ lifts (i.e. variable speed drives),
- ▶ battery chargers,
- ▶ fluorescent tubes,
- ▶ TV/radio transmitter-receivers, etc.

Particular attention shall be paid to installations having limited power and a standby generator set (i.e. high sub-transient reactance).

1.2 - Existing installations

This specification shall be used to apply a *corrective* solution, to installations where the following problems are encountered:

- ▶ increase in voltage distortion (THDU) and current distortion (THDI),
- ▶ cable overheating (e.g. neutral conductor),
- ▶ unexplained tripping of circuit-breakers,
- ▶ temperature rise in transformers,
- ▶ flicker of fluorescent lighting, etc.

Installations that are particularly sensitive to these phenomena include:

- ▶ high-rise commercial buildings where sensitive equipment, such as computers, medical apparatus, etc., are used;
- ▶ telecommunications, television and broadcast stations where harmonic currents may affect the quality of transmission and the reliability of sophisticated electronic equipment,
- ▶ certain industrial processes, for example those implementing real time computerized management systems.

2 - General

2.1 - Scope

Active Harmonic Conditioners (AHC), shall be used to eliminate harmonic currents circulating within the electrical installation. They shall limit the individual harmonic content of designated current harmonics and the voltage total harmonic distortion (THDU) to a given percentage of the nominal fundamental voltage (voltage at 50 Hz or 60 Hz). For a precise definition of this percentage, reference shall be made to sensitive equipment specifications (i.e. acceptable THDU % for trouble-free operation), or to the applicable standards for the point of connection to the public AC system.

2.2 - Applicable voltage distortion limits

At the design stage, before the equipment has been completely defined, the following values shall be considered as a maximum for the voltage distortion (THDU):

- ▶ computers: < 5%,
- ▶ telecommunications bays: < 5%,
- ▶ television studios: < 5%,
- ▶ general distribution: < 8%,
- ▶ industrial equipment: < 8%,
- ▶ point of connection to the public AC system: < 5 to 8% according to applicable standards.

These values have been taken from standards IEC 61000-2-2 and 61000-2-4 (harmonic compatibility) and EN 50160-3 (network quality).

2.3 - Location of the equipment in the installation

The Active Harmonic Conditioner shall be installed in parallel with the AC distribution system of the building (shunt connected), wherever attenuation of harmonic currents is needed.

It shall be located preferably close to those loads generating harmonic currents, in order to avoid circulation of the currents in the building cables.

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3 – System description

3.1 – Operation principle

The Active Harmonic Conditioner shall be of "shunt"-type topology, i.e. connected in parallel with the AC line. It shall analyze continuously the harmonic currents drawn by the load, and inject the same harmonic current with the appropriate phase. Consequently, the current supplied by the source remains virtually sinusoidal under all operating conditions.

The Active Harmonic Conditioner shall be compatible with any type of load, and shall guarantee efficient harmonic conditioning, even when changes are made to the installation.

3.2 - Technology

The Active Harmonic Conditioner shall use an IGBT (Isolated Gate Bipolar Transistor) bridge to inject the proper harmonic current.

It shall be controlled by a microprocessor-based system, and shall use a DSP (Digital Signal Processing) microcontroller to monitor the harmonic currents.

3.3 - Functions

As a minimum, the Active Harmonic Conditioner shall include the following functions:

- ▶ conditioning of harmonic currents from H2 (2nd harmonic) to H25 (25th harmonic) included,
- ▶ conditioning of the phase displacement ($\cos \varphi$).

To guarantee efficient harmonic conditioning, customization of certain parameters shall be possible:

- ▶ overall conditioning or conditioning of selected harmonics,
- ▶ control parameter for conditioning of the phase displacement ($\cos \varphi$),
- ▶ control parameter for the load type: single-phase load, three-phase load, combination of single and three-phase loads.

4 - Normal service conditions

4.1 - Conditioned current

▶ The Active Harmonic Conditioner shall be capable of delivering its rated output harmonic current to the point of connection whatever the load conditions.

▶ The rated output current shall be indicated in Amperes (rms) per phase.

▶ In the neutral conductor, the Active Harmonic Conditioner shall also be capable of conditioning a harmonic current three times greater than the phase current (i.e. condition third-order harmonic currents and multiples), when the phases are balanced.

4.2 - Voltage distortion

The Active Harmonic Conditioner shall be capable of reducing the Voltage Total Harmonic Distortion (THDU) to a specified level in % of the fundamental voltage (voltage at 50 Hz or 60 Hz). (See § "General – Applicable voltage distortion limits" for specified values.)

When used at its rated current (i.e. Irms of harmonic currents consumed by the load equal to Irms of harmonic current supplied by the Active Harmonic Conditioner), the Active Harmonic Conditioner shall reduce THDI by a factor of at least 10.

4.3 - On/off

▶ It shall be possible to start and stop the Active Harmonic Conditioner manually via pushbuttons. Remote control shall be also possible.

After an AC source failure, it shall be possible to set the Active Harmonic Conditioner so that it restarts automatically.

4.4 - Self-adaptation to the load

It shall be possible to use the Active Harmonic Conditioner with all types of loads. It shall adapt automatically to any changes in the harmonic spectrum of the load.

4.5 - Independence with respect to the source

The Active Harmonic Conditioner shall also be compatible with all types of sources and shall in particular operate independently with respect to the source impedance.

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5 - Overload conditions

Should the Active Harmonic Conditioner be overloaded during transient operation of certain loads (e.g. motor start-up, particular sequences, etc.), or permanently, this shall not affect the reliability of its operation.

In such cases, the Active Harmonic Conditioner shall operate in a current limiting mode, and still deliver to the load its rated harmonic current.

In this case, harmonic conditioning capacity shall be limited to the following ratio:

Conditioner rating (rms value of harmonic currents delivered) / I(rms) load harmonic currents.

For better adaptation to all types of installations, the Active Harmonic Conditioner shall be capable of operating in association with other harmonic-reduction systems (e.g. LC filters, 12-pulse bridges, etc.).

6 - Multi-unit configurations

To enhance conditioning at a given point in the installation, it shall be possible to connect several Active Harmonic Conditioners in various configurations:

6.1 - Active parallel configuration

To increase the conditioning capacity, or to increase the dependability, it shall be possible to connect up to 4 units in parallel, using a single set of current transformers (measurement sensors). In this mode of operation, each Active Harmonic Conditioner shall produce $1/n$ of the injected harmonic current, where n conditioners are parallel connected.

6.2 - Cascade configuration

To condition the harmonics at different levels of the distribution system, it shall be possible to connect two Active Harmonic Conditioners in a series or "cascade" configuration. The downstream conditioner shall condition a specific load, while the upstream conditioner shall provide overall conditioning.

6.3 - "Multi-feeder" configuration

It shall be possible to condition up to three feeders using three sets of current transformers, one set per feeder, connected to a single Active Harmonic Conditioner.

7 – System status and control panel

7.1 - System status

As a minimum, the Active Harmonic Conditioner shall include the following indications:

- ▶ a green LED to indicate normal operation,
- ▶ an orange LED to indicate current limiting,
- ▶ a red LED to indicate conditioner shutdown or alarm condition.

Two pushbuttons shall control ON/OFF operation.

7.2 - System control

A complete display panel shall guide the operator to monitor the system properly, and shall provide help for start-up, maintenance and diagnostics.

7.3 - Display panel

The displayed information shall be available in 5 languages: French, English, German, Italian and Spanish.

The display shall include detailed measurements such as:

- ▶ total current distortion (load and source),
- ▶ total rms current (load and source),
- ▶ harmonic current distortion per order, up to the 13th order.

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8 - Installation and protection

8.1 - Point of connection

For best results, conditioning of harmonic currents shall take place at their point of origin, i.e. close to the harmonic-generating loads.

However, depending of the power-quality objectives (THDU), it shall be possible to connect Active Harmonic Conditioners anywhere in the installation in configurations described in the "Multi-unit configurations" section.

8.2 - Installation

The Active Harmonic Conditioner shall be as small as possible, so that it can be installed anywhere.

Particularly, it shall be possible to install the conditioner in low voltage switchboards or motor control centers.

Finally, wall mounting shall also be possible in plants or electrical rooms.

8.3 - Installation of current sensors

To facilitate installation of the current sensors, they shall be of the split type.

8.4 - Active harmonic conditioner protection

A three or four pole circuit breaker shall be installed close to the point of connection to the AC system to protect the connection cables. It shall be selected according to general selection practice for circuit breakers and manufacturer recommendations.

In addition, the Active Harmonic Conditioner shall include the following protection functions:

- ▶ thermal-overload protection;
- ▶ internal short-circuit;
- ▶ inverter bridge for abnormal operation.

9 - AC-source characteristics

The Active Harmonic Conditioner shall be suitable for connection to an AC electrical installation having the following characteristics:

- ▶ 3 phases with or without neutral (3 or 4 wires);
- ▶ all types of system earthing arrangements;
- ▶ 400 V - 20%, + 15%;
- ▶ 50 Hz or 60 Hz \pm 8%.

10 - Environmental conditions

The Active Harmonic Conditioner enclosure shall provide an IP30 degree of protection as per IEC 60529.

The Active Harmonic Conditioner shall be able to operate without derating under the following ambient conditions:

- ▶ continuous temperature 0 to 40° C;
- ▶ relative humidity 95% without condensation;
- ▶ altitude above sea level: 1000 m maximum.

To allow installation in any location, the Active Harmonic Conditioner shall have a noise level between 55 dBA and 65 dBA (as per ISO 3746) depending on the rating.

11 – Standards and tests

11.1 - Compliance with standards

The Active Harmonic Conditioner shall comply with international standards applicable to this type of equipment and, in particular, meet the recommendations of the following:

- ▶ construction and safety: EN 50091-1,
- ▶ design: IEC 60146,
- ▶ EMC, conducted and radiated emissions: EN 55011 class A,
- ▶ EMC, immunity to electrostatic discharges: IEC 61000-4-2 / level 3,
- ▶ EMC, immunity to radiated fields: IEC 61000-4-3 / level 3,
- ▶ EMC, immunity to low-energy impulse waves: IEC 61000-4-4 / level 4,
- ▶ EMC, immunity to high-energy impulse waves: IEC 61000-4-5 / level 4,
- ▶ IEC 439: Low-voltage switchgear and controlgear assemblies.
- ▶ IEC 60529: Degrees of protection provided by enclosures (IP Code).
- ▶ ISO 3746: Sound power levels.
- ▶ CE marking.

What is more, the equipment must comply with environmental-protection standards, with production taking place on premises certified ISO 14001.

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11.2 - Certification of conformity

The manufacturer shall provide, on request, a complete qualification file demonstrating compliance with the above standards.

What is more, the indicated levels of performance shall be confirmed by certification from independent laboratories (e.g. TÜV or Veritas).

12 - Test procedure and quality system

12.1 - Test procedure

The equipment manufacturer shall provide proof of a stringent Quality Assurance programme. In particular, the main equipment manufacturing stages shall be sanctioned by appropriate tests such as:

- ▶ incoming components inspection, discrete subassembly testing,
- ▶ complete functional checks on the final product.

Equipment shall undergo on-load burn-in before leaving the factory.

Final inspection and adjustments shall be documented in a report drawn up by the supplier's Quality Inspection department.

ISO 9001 or 9002 certification of the production site shall be compulsory.

12.2 - Quality system

The equipment design procedure shall be covered by an ISO 9001 quality system as well as a dependability study to ensure maximum reliability.

13 - Start-up

Equipment start-up on site shall be carried out by the manufacturer or an approved representative. It shall include on-site acceptance during which a check on system characteristics shall be made.

14 - Replacement parts

The supplier undertakes to provide replacement parts for at least ten years following the date of delivery. A set of emergency spare parts shall be supplied with the equipment.

15 - Warranty

The equipment shall be guaranteed (parts and labor on site) for one year following the start-up date.

16 - Services

Required services include:

- ▶ supply of the Active Harmonic Conditioner and any accessory parts or elements;
- ▶ carriage-paid equipment transportation and delivery to the site.

Options:

- ▶ equipment handling and installation on the site;
- ▶ connection of input cables;
- ▶ connection of output cables.

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17 - Electrical diagrams

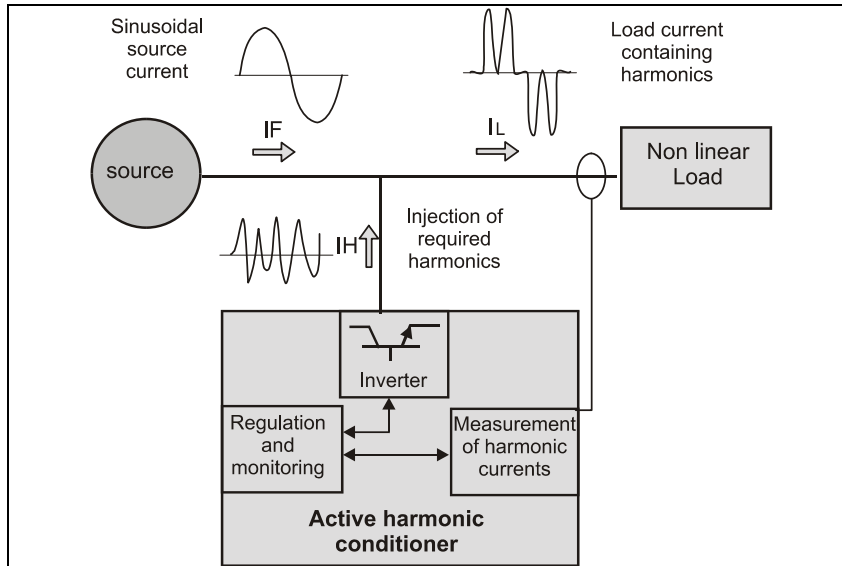


Fig. Active Harmonic Conditioner operating principle

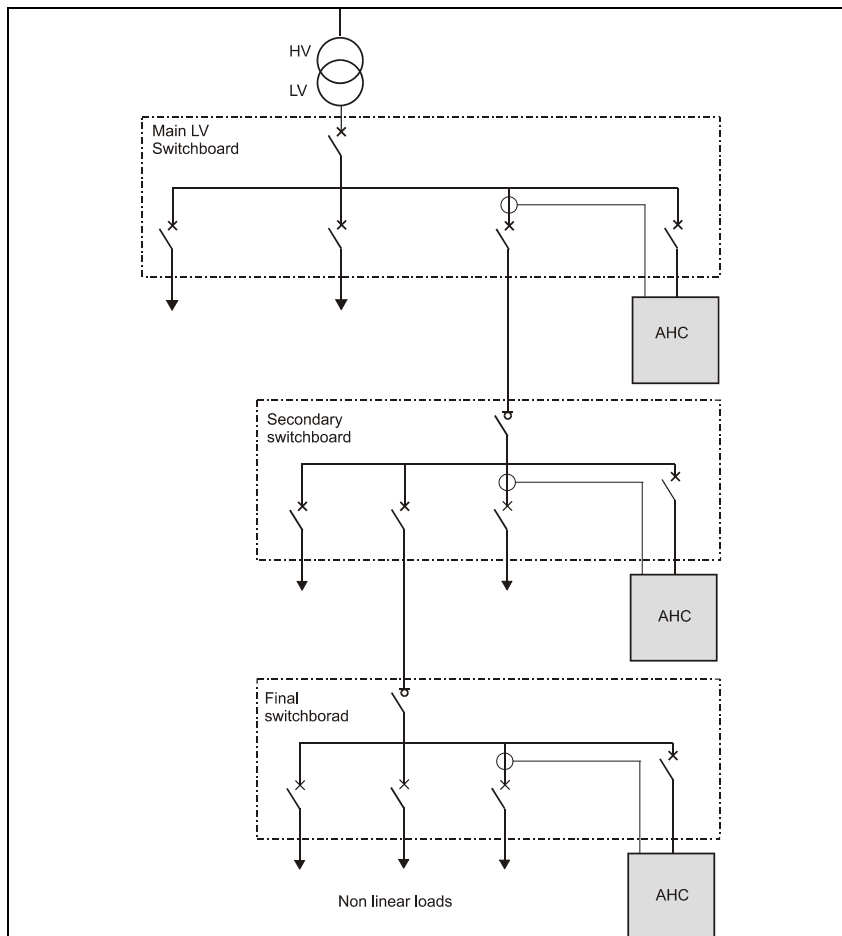


Fig. Example of an Active Harmonic Conditioner (AHC) installation

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The characteristics specified for the Active Harmonic Conditioner shall include the following:

Electrical characteristics

| Input | | |
|---|--|--|
| ▶ rated voltage | | 400 V -20 % + 15 % |
| ▶ rated frequency | | 50 Hz / 60 Hz +/- 8 % |
| ▶ number of phases | | 3 phases without or with neutral (operation possible with single-phase or unbalanced loads) |
| ▶ connection type | | 3 or 4 wires |
| Features | | |
| ▶ conditioning of harmonics | | overall or selected harmonics |
| ▶ phase displacement (cos φ) conditioning | | adjustable, up to 0.94 |
| Configurations | | |
| ▶ single unit | | yes |
| ▶ parallel configuration | | up to four units |
| Technical characteristics | | |
| ▶ harmonic-conditioning capacity: | per phase in the neutral conductor | 20 A rms, 30 A rms, 45 A rms, 60 A rms, 90 A rms, 120 A rms 60 A rms, 90 A rms, 135 A rms, 180 A rms, 270 A rms, 360 A rms |
| ▶ harmonic orders conditioned | | H2 to H25 overall or selective conditioning |
| ▶ response time | | < 40 ms |
| ▶ attenuation ratio | | THDI load / THDI source > 10 at rated current THDI = Iharmonic / Ifundamental |
| ▶ power factor correction | | up to 1 |
| ▶ overload | | conditioning limited to nominal rms current, but continuous operation with overload possible |
| ▶ inrush current | | < 2 times the nominal peak current |
| ▶ losses | | < 1000 W 20 A 2600 W 60 A < 1300 W 30 A 4200 W 90 A < 2100 W 45 A 5200 W 120 A |
| ▶ ventilation | | forced air (entry through bottom and exit through top) |
| ▶ audible noise (according to ISO 3746) | | < 55 dBA 20 A & 30 A < 60 dBA 45 A & 60 A < 65 dBA 90 A & 120 A |

Configuration and front panel

| Configuration | |
|--|--|
| ▶ languages | French, UK English, Italian, Spanish, German, Dutch, US English |
| ▶ type of AC system | with or without neutral |
| ▶ current sensor ratings | 300/1, 500/1, 600/1, 1000/1, 1500/1, 2000/1, 3000/1, 4000/1 |
| ▶ conditioning of phase displacement (cos φ) | YES or NO, selectable |
| ▶ remote control | YES or NO, selectable |
| ▶ selection of harmonic orders to condition | YES or NO, selectable |
| ▶ operation in parallel | active parallel or cascade modes; up to 4 units |
| User interface | |
| ▶ indications | green LED : normal operation red LED : OFF or alarm orange LED : overload/limitation operation |
| ▶ 7-language alphanumeric display | measurements and alarms start-up assistance help menu for diagnostics and maintenance custom menu |
| ▶ control | ON pushbutton OFF pushbutton |
| ▶ remote indications 3 relay contacts | 2 x ON / OFF 1 x overload/limitation operation |

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Environment conditions/reference standards

| Environment | |
|---|--|
| ▶ ambient temperature | < 25° C recommended, 0 to 40° C continuous |
| ▶ relative humidity | < 95% without condensation |
| ▶ altitude | < 1000 m |
| Reference standards | |
| ▶ construction/safety | EN 50091-1 |
| ▶ design | IEC 146 |
| ▶ degree of protection | IP 30 (IEC 529) |
| Electromagnetic compatibility | |
| ▶ conducted and radiated emissions | EN 55011 class A |
| ▶ immunity to electrostatic discharges | IEC 61000-4-2 level 3 |
| ▶ immunity to radiated fields | IEC 61000-4-3 level 3 |
| ▶ immunity to low-energy impulse waves | IEC 61000-4-4 level 4 |
| ▶ immunity to high-energy impulse waves | IEC 61000-4-5 level 4 |