ECONELEC ®

ENERGY SAVING SYSTEM

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QUALITY,
EXPERIENCE,
PROFESSIONAL SERVICE
AND SOCIAL RESPONSABILITY

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Technological advance, experienced in the last period, has incorporated to the market electronic elements with higher performances and smaller size. This reduction in the size of the devices has meant that the power supplies of these devices achieve power density ratios (measured in watts per cubic inch) unimaginable just a few years ago.

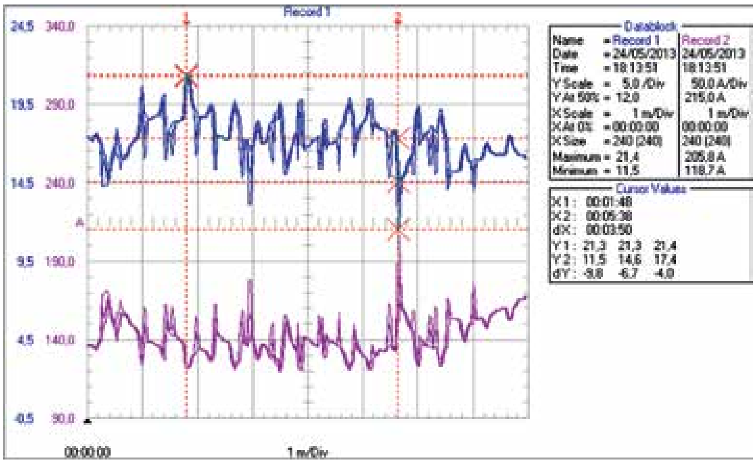

Figure 1. Waveform of current in typical GLVB (General Low Voltage Boards).

The mentioned devices use internally to operate, switching topologies and power semiconductors which work at high frequencies. These technologies allow handling large powers in very small sizes.

The great disadvantage of these devices is derived from using that such equipments are doing of power supply. Using semiconductors devices, both controlled (IGBT, MOSFET, TRIAC, etc.) and uncontrolled (diode rectifiers) causes a consumption of switched and non-linear loads, which views from the supply side generate high degree of electrical pollution.

We will denominate, therefore, electrical pollution the totally circumstances due to the high harmonic content on the sinusoid corresponding to the main frequency of electrical installation, without prejudice to other phenomenon comprehended by what is called power quality or power supply quality.

To illustrate the polluted phenomenon of low voltage electrical networks, the phase current waveforms in bus bar inside GLVB of a Hotel in Madrid are presented.

Different models ECONELEC®.

Although it may seem that the poor wave quality in an electrical system is determined by the quality of supply, in most cases this is not so, and pollution of the network produces the contrary, from the loads up to supply.

This is because a pure supply without disturbances, to undertake an inner low voltage electrical installation (in which receptors are formed by elements with non-linear loads, switched, or generative harmonics) causes a disturbed current regarding to a voltage sinusoid. Because the impedances of power supplies, this current causes disturbed voltage drops along whole route, from the distribution and transformation centers up to supply points, after in some cases, the disturbances are exported from the loads up to the distribution company and the rest of subscribers connected to TC.

Such as collected in the Standard UNE_EN-50160: 2011, "Voltage characteristics of electricity supplied by public distribution systems", the source of pollution in the indoor facilities is clearly the behavior of the loads connected to the network. The standard cites literally:

> The harmonic voltages of supply power system supply are mainly due to the nonlinear loads of users which are connected at all levels of mains power supply. The harmonic currents flowing through the network impedances cause harmonic voltages. The harmonic currents, the impedances of the network and therefore the harmonic voltages at the supply points change in time.

Also, in the same standard, in relation with the quality of electricity supply, the mainly following disturbances are identified:

- Conducted disturbances.
- Flicker of different severity.
- Frequency drift.
- Harmonic voltage (up to the 40th harmonic).
- Total harmonic distortion of the supply voltage.
- Fast voltage range.
- Power interruption.
- Voltage dips.
- Transient overvoltage.
- Voltage fluctuations.
- Voltage unbalance.

Regarding to harmonics, the standard establishes maximum permitted levels for harmonic voltage of each individual harmonics up to 25^{th}. Values are showed in table 1.

Odd harmonics				Even harmonics	
Not multiple of 3		Multiple of 3			
Order h	Relative amplitude uh	Order h	Relative amplitude uh	Order h	Relative amplitude uh
5	6,0 %	3	5,0 %	2	2,0 %
7	5,0 %	9	1,5 %	4	1,0 %
11	3,5 %	15	0,5 %	6 … 24	0,5 %
13	3,0 %	21	0,5 %		
17	2,0 %				
19	1,5 %				
23	1,5 %				
25	1,5 %				

NOTE: The values correspond to the harmonics of order 25, which are generally weak and very unpredictable due to resonance effects, are not indicated in this table.

Values of individual harmonic voltages at the point of supply, up to the 25^{th} harmonic, showed as a percentage of the fundamental voltage u1.

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GENERATING SOURCES OF DISTURBANCES

Apart from the large number of factors which are affecting the supply quality of an electrical installation, as defined in the previous section, then we are going to describe in more detail the generation of harmonics in indoor facilities and as such disturbances occur.

It has already been mentioned, that the intensive use of power electronic equipments in networks is generating an increasing amount of harmonics in distribution networks. Usually, these components gather on the data processing equipments (computers, big servers), uninterruptible power supply (UPS), starters and motor speed variators in general (fans, elevators, lifts, cranes and all type of machinery), air conditioning systems (inverter type), lighting with electronic ballasts and compact fluorescent and LED lamps.

Furthermore, all electrical components in which a discontinuous current flow due to its intrinsic operation occurs, they are by far the major disturbances are originating. In this section are comprehended arc welding equipments (in which the current is completely irregular depending on electrode contact with the welded joint), and the motors with brushes collectors (as they cause a discontinuous contact in the change of segment). The waveforms that cause these equipments are the ones that generate the largest electricity emissions. These engines are still found in older machines and hand tools (drills, radial, cutters, saws, jigsaws, etc).

Therefore, in summary, we can say that the main causes for the generation of harmonic in the loads are:

- Equipments with semiconductor components:
  - Starters and electronic drives.
  - UPS and Inverters.
  - Three-phase and single-phase rectifiers.
  - Switching power supplies for small equipments.
  - Battery chargers.
- Equipments with ferromagnetic elements:
  - Transformers, coils and other magnetic elements with high induction flux, core material with large hysteresis or operation near saturation material.
  - Electromagnetic ballasts for lighting equipments.
- Elements with discontinuity in electricity consumption.
  - Arc welding.
  - Motors with brushes collectors.

When we talk of harmonics of the fundamental frequency network, it is common to denominate them by their order (third, fifth, ninth, etc.), its frequency (150Hz, 350Hz, etc), but it is also important to know their sequence.

A harmonic sequence identifies the direction of rotation of its (provided that it is represented as a vector), in relation to the main frequency or first order harmonic. In this way, there are three types of sequences:

- Positive (+): Indicates that rotates in the same direction as the main frequency and therefore adds in absolute value at the point of maximum amplitude.
- Negative (-): Indicates that rotates in the opposite direction to the main frequency and therefore remains in absolute value at the point of maximum amplitude.
- Zero (0): They are coincident homopolar vectors which move the center of the three-phase vector, usually coincident with the neutral.

The sequence can be determined from the following table (up to 21st order):

Sequence	**Harmonic order**						
+	1	4	7	10	13	16	19
-	2	5	8	11	14	17	20
0	3	6	9	12	15	18	21

Table 2.

This sequence causes some problems on networks. Then they are analyzed on the basis of the most commonly found harmonics:

- Third harmonic: Its sequence is zero, resulting homopolar vectors in three phases. It may circulate in delta circuits causing no detectable dangerous heating by measure elements and exterior protection. Also in single-phase networks with neutral it can generate significant imbalances in neutral, moving the center point.
- Fifth harmonic: Its sequence is negative (like the eleventh), in the case of supply of electrical motors, it is causing the existence of a restoring torque on the drive shaft. That is, a torque which opposes the main stress of the engines in their rotation and therefore causes losses, reduce the power supplied by the engine and overheating in the windings and magnetic sheet packs. The existence of these harmonics causes vibrations that correlate with the number of engine's pairs of poles and the frequency of this harmonic, so they are mechanically detectable by accelerometers. These vibrations age the mechanical components of the rolling motor (bearings, shafts, etc).
- Seventh harmonic: Its sequence is positive and therefore it is added to the main sinusoid, causing an overvoltage peak which becomes a overcurrent, which must be absorbed by the load. This overload generates various types of problems depending on the type of load involved, but in all cases it is detrimental to the equipment, conductors and insulators.

The disorder of harmonics to transformers and magnetic elements should especially be mentioned. The dimensions of the magnetic sheets are calculated for a magnetic flux resulting from sine wave to industrial frequency. The appearance of harmonics in transformers causes significant losses in the iron, since they increase with the square of the frequency. Moreover, the response of the magnetic elements to high frequency components is not usually good, which ultimately becomes heating, losses and degradation of the insulation.

In conclusion, we can say that the main effects of the existence of harmonics in the electrical network are:

- Increased apparent to carry power.
- Need for oversized facilities.
- Nuisance tripping of protections.
- Overloading drivers.
- Vibration and overloads in rotating machines.
- Power system instability.
- Premature aging.
- Errors in the measurement equipment.
- Possible pollution penalties general mains, often lead to system shutdown.
- Conducted disturbance by electromagnetic interference (EMC) in control equipment.

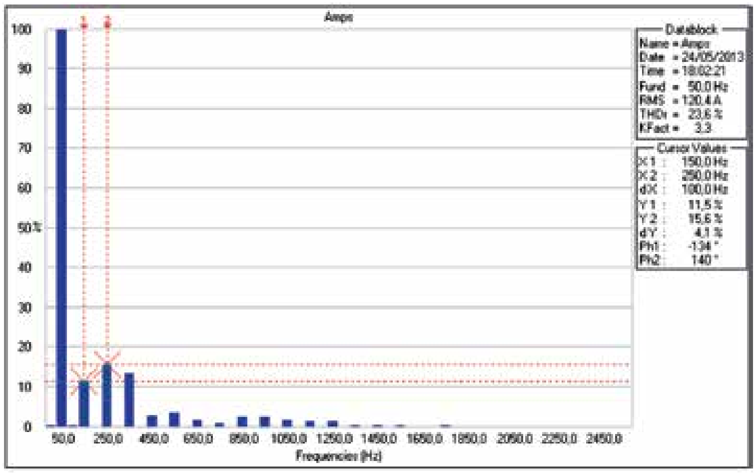


Figure 2. FFT waveform of current in typical GLVB.

Figure 2 illustrates the decomposition by means of Fast Fourier Transform (FFT) of the harmonic content in the waveform illustrated in figure 1, the most noteworthy of which is the existence of third (150Hz) with 11.5%, fifth (250Hz) with around 15.6% and seventh harmonic (350Hz) with around 13.2%. The remaining harmonics feature lower values. The corresponding THD to these values gives a harmonic distortion of 23.4%.

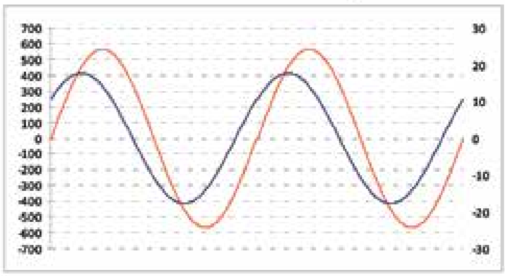
POWER FACTOR CORRECTION

Vast amounts of literature exist on the power factor correction in electrical installations, reason for which this issue will be only be presented in a general manner only.

It is a well-known fact that receivers powered by alternate current (engines, transformers, inductors, etc.), which require the generation of magnetic fields in order to operate, produce a vectorially delayed current with regard to the voltage that powers them. This entails a pendulum energy flow between the supply and the load. A power (known as apparent S power) greater than that required is delivered. A part of it will be consumed to obtain the work necessary in the machine (active P power), while the other part will be subsequently returned to the supply (reactive Q power).

Figure 3 illustrates this circumstance in the time domain, the left side of which shows the performance of a circuit which consumes 4kW with a Cos Phi 0.8, which requires an apparent power of 5kVA. The rights side shows the circuit has been compensated capacitively and only 4kVA are required to supply the 4kW load, reason for which no energy is returned to the grid.

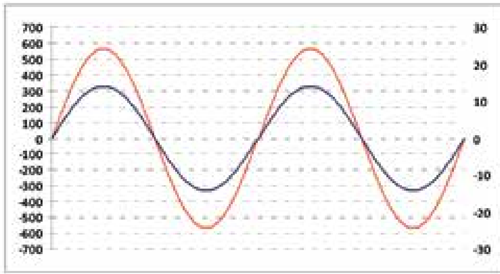
Installation with reactive energy consumption.



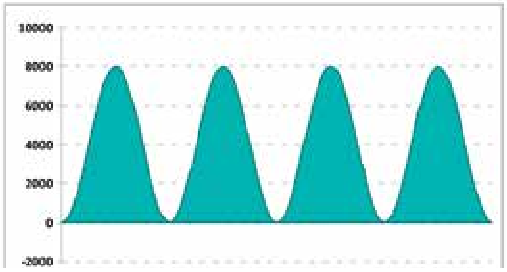
Cos Phi=0.8

S=5 kVA, P=4kW

Capacitively compensated installation.



Cos Phi=1



S=4 kVA, P=4kW

Figure 3. Example of power factor compensation. Temporal representation.

Figure 4 represents the same effect in vector mode, where the Qr vector is reduced due to the appearance of an opposite Qc vector (corresponding to the capacitive compensation), resulting in an S′ vector less than the initial S.

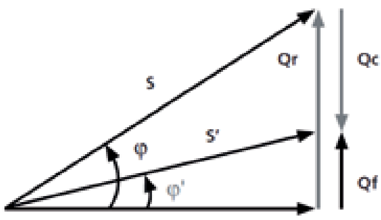


Figure 4. Example of power factor compensation. Vector representation

The existence of this circulating reactive energy produces several negative phenomena, the most noteworthy of which include the overheating of the installation´s conductors, a reduction in the service power of the transformers, the generation of Joule effect losses in cables and transformers, etc.

Given the unproductive and harmful nature of reactive energy, with the aim of minimizing the circulation of the same through the distribution networks, power companies have defined penalties for users who fail to adequately compensate their installations. This penalty is applied in the form of an additional charge to the electricity bill and may imply a significant increase in the final amount of the same.

OPERATING PRINCIPLE OF THE ECONELEC® EQUIPMENT

As illustrated up to this point, there are two major harmful phenomena to be dealt with in electrical networks:

- The removal of all harmful harmonics.
- The compensation of the reactive energy existing in the installation.

Both phenomena are dealt with simultaneously by means of the combined action of the smart capacitor bank and the simultaneous harmonic filter comprising the ECONELEC® equipment.

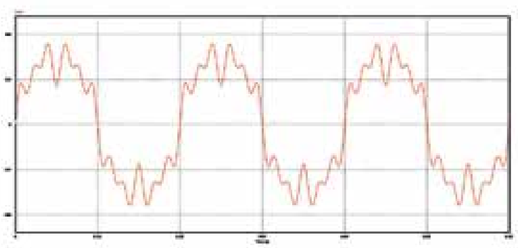
The operating principle of the ECONELEC® equipment is the following:

- The microprocessor monitoring device measures the main variables of the electrical system in real time and decides on which is the best strategy to adopt based on these readings.
- As such, and when necessary, the system will implement several configurations of capacitive and inductive elements with the dual function of maintaining the power factor at its optimum value and a band-pass filter for the pre-selected frequencies, which provides a low-impedance path to minimize the harmful harmonics existing in the installation, 3rd, 5th, 7th…

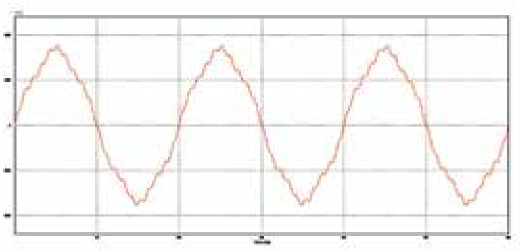
As such, the performance of the equipment is similar to that of a capacitor bank for the compensation of reactive energy, which instead of using capacitors exclusively, provides a resonant filter for one or more pre-selected frequencies in order to present a very low impedance for the harmonics present in the network, and thereby removing the frequencies of the predominant selected harmonics, leaving the sine waveform of the electricity supply clean. This is known as an LC band-pass filter (a combination of capacitors and inductors tuned to the frequencies to be removed). The choice of the appropriate filter in each case and the integration of the same with the enhanced power factor involve a complex issue which the equipment needs to deal with in real time.

Figure 5 below illustrates two electrical installations with networks polluted by harmonics of a different order and sequence, in addition to the satisfactory results obtained with the harmonic filter systems comprising the ECONELEC® equipment.

Installation with a high harmonic content.
Example 1.

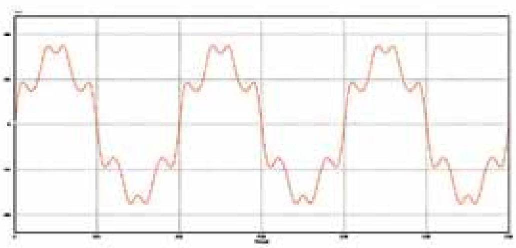


Without a filter

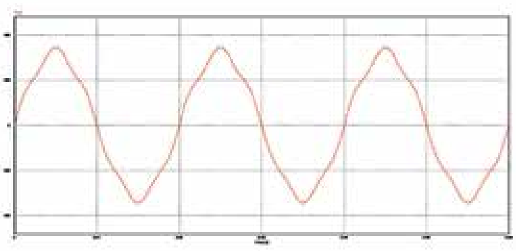


With a filter

Installation with a high harmonic content.
Example 2.



Without a filter



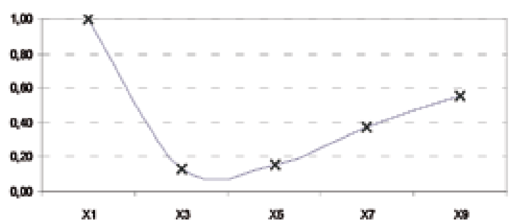
With a filter

Figure 5. Exterior view of the ECONELEC® equipment.

The typical applications for the ECONELEC® equipment encompass medium and high-power installations (from 10 to 600 kW), and may be used in systems which include variable speed drives, induction furnaces, arc and rectification furnaces in three-phase/single-phase 230/400V, 50 Hz networks.

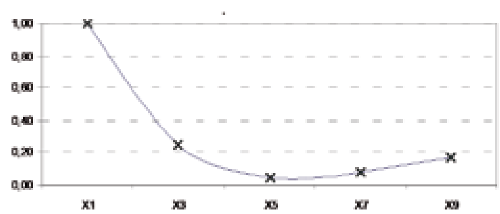
Figure 6 below illustrates the frequency response of the harmonic filter system for several cases involving the preponderance of harmonics, including the joint action of several simultaneous filters. The values represent the unit impedance of the band-pass filter to the harmonic in the corresponding order.

Unit impedance



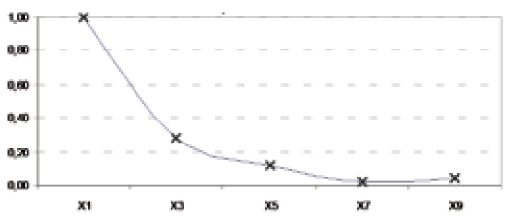
3rd and 5th harmonic

Unit impedance



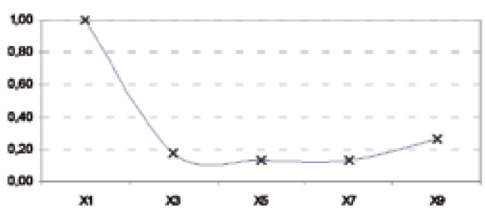
5th and 7th harmonic

Unit impedance



7th and 9th harmonic

Unit impedance



Joint action

Figure 6. Several different ECONELEC® equipment filtering solutions.

FINAL CONCLUSIONS AND SAVINGS GENERATED

The previous text has shown how the joint action of the capacitor bank and harmonic filter comprising the ECONELEC® equipment generates major benefits for electrical installations. A brief summary of all these benefits follows below, stating the main component in each case:

Function	Capacitor bank	Harmonic filter
Enhances the power factor.	✓	
Reduction in the apparent power to be transmitted.	✓	
Removal of circulating reactive power.	✓	
Reduction in the consumption of active energy.	✓	✓
Reduction in Joule effect losses.	✓	✓
Less overheating in cabling and capacitors.	✓	✓
Reduction in transformer losses.	✓	✓
Reduction in the maximum power demanded and registered on maximeters.	✓	✓
An increase in the efficiency and a prolonged service life of the receivers connected to the installation.		✓
A reduction in voltage stress (less power surges) in elements working with electrical fields and which require dielectrics in order to function.		✓
A reduction in current stress (less intensity surges) in elements working with magnetic fields and which require a current flow in order to function.		✓
A reduction in the untimely triggering of protective devices.		✓
A reduction in vibrations and overloading in rotating machinery.		✓
The removal of instabilities in electrical systems as a whole.		✓
The removal of errors in measuring equipment.		✓
Ease of compliance with international regulations in relation to conducted electromagnetic interference in monitoring equipment.		✓
A reduction in the rate of harmonic distortion in the installation.		✓
An enhanced voltage waveform in the installation.		✓

Benefits in electrical installations generated by ECONELEC®.

The Energy Saving System ECONELEC ® has been designed and produced in Spain for our company and it is the result of years of work and experience.

TECHNICAL DATA
ENERGY SAVING SYSTEM

10-600 KW/400 V 50 Hz

- Eliminates Reactive Energy consumed.
- Reduces consumption between 5% and 20%.
- Reduces Maximum Power demanded between 3% and 10%.
- Decreases the harmonic distortion of load.
- Improves the wave form voltage facility.

ECONELEC ® is able to meet, on single equipment, with different important functions to the proper operation of the electrical facilities and achieve a significant reduction in electricity bills.

Installing our Energy Saving System, our customers get a return on investment quickly and a great total savings thanks to its 150,000 hours of life expectancy. It is a strong and easy to maintain.

ECONELEC® contributes efficiently to lower CO_2 emissions to the environment, thus protecting our planet.

It can be installed in any industry, local, business, hospital, housing, ... that meets the required safe conditions.

TR4001 SERIES (THREE-PHASE NETWORKS 400 V)

Code	Power (KW)	Voltage (V)	Dimensions (mm)
PEETR0010004005	10	400	550 x 350 x 240
PEETR0015004005	15	400	550 x 350 x 240
PEETR0025004005	25	400	550 x 350 x 240
PEETR0035004005	35	400	550 x 350 x 240
PEETR0045004005	45	400	550 x 350 x 240
PEETR0055004005	55	400	550 x 350 x 240
PEETR0075004005E001	75	400	650 x 460 x 257
PEETR0100004005E002	100	400	650 x 460 x 257

TR4002 SERIES (THREE-PHASE NETWORKS 400 V)

Code	Power (KW)	Voltage (V)	Dimensions (mm)
PEETR0150004005	150	400	2100 x 600 x 600
PEETR0200004005	200	400	2100 x 600 x 600
PEETR0250004005	250	400	2100 x 600 x 600
PEETR0300004005	300	400	2100 x 1200 x 600
PEETR0350004005	350	400	2100 x 1200 x 600
PEETR0400004005	400	400	2100 x 1200 x 600
PEETR0450004005	450	400	2100 x 1200 x 600
PEETR0500004005	500	400	2100 x 1200 x 600
PEETR0550004005	550	400	2100 x 1800 x 600
PEETR0600004005	600	400	2100 x 1800 x 600

Other power ratings, voltages o frequency available upon request.

Safety system · Depositing in recycle center · Halogen free · Do not spread frame · Technical service · Polluted nets · Technical advice · Clean energy

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CERTIFICATE OF FUNCTIONALITY

Certificate Functionality

PRODUCT:
Energy Saving System ECONELEC ® TR4001 and TR4002 series.

SCOPE OF APPLICATION:
400V Three-phase networks. Industrial frequency 50 Hz.

POWER:
The entire product range from 10 up to 600 kW.

VERIFIED RESULTS:

- Ability to eliminate reactive energy used in a facility.
- Ability to reduce energy consumption by an average installation between 5% and 20% of the total.
- Ability to reduce the quarter-hourly maximum power measured by maximum demand meter, between 3% and 10%.
- Ability to decrease the voltage harmonic distortion (THD) in the load.
- Ability to improve waveform voltage facility.
- Ability to reduce losses due to voltage drops in electric wires.

The Energy Saving System ECONELEC ®, designed and manufactured in Spain by AENER ENERGIA, has been tested in the laboratory, to verify the compliance with product specifications for which it was designed.

Verification date: May 21, 2014.

Carlos Rodriguez
Doctor Industrial Engineer
Department of Electronic Technology

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TAKE ADVANTAGE OF OUR **CALCULATION SOFTWARE**

‹CALBAT

CALBAT, developed by Aener, is software **for the calculation of Automatic Capacitor Banks and Energy Saving System,** ECONELEC®, designed for distributors, electrical installers, engineers and marketers of electricity.

This software helps to make calculations of equipments simply by introducing the standard data of your installation, in addition to the consumption of electricity stated on the invoices of energy suppliers.

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