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TECHNICAL **RELATIONSHIP**

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Energy efficiency division

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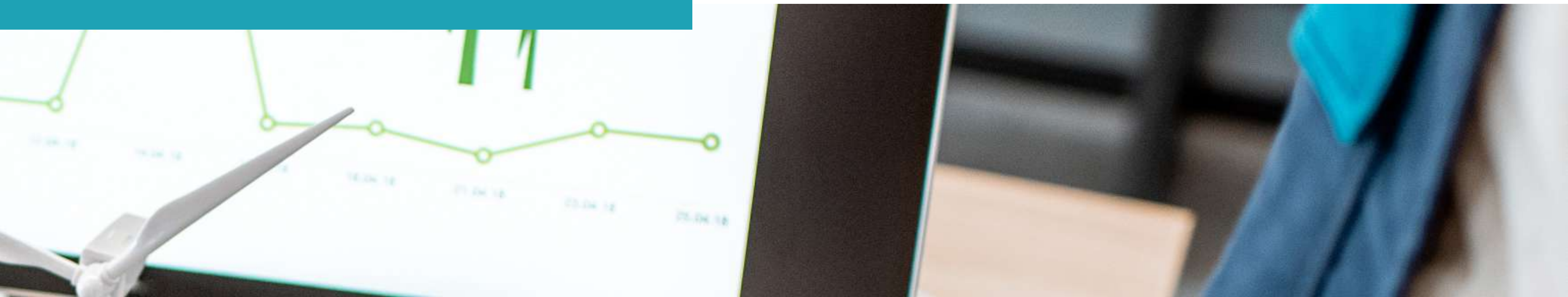

1. Current supply situation

Over the last few years we have witnessed 2 very important phenomena in the field of distribution and use of electricity globally:

• The transition to the digital age

• Distributed generation

These 2 phenomena are having a major impact on the distribution of electricity and on correct management of the same. Let's analyze them in detail.

Later in the discussion we will examine the consequences of this phenomenon on energy issues and efficient energy management, for the moment we observe that ever more massive development of digital technologies, always generates presence in our plants greater than non-linear loads connected to the plants themselves.

1.1 The transition to the digital age

A real revolution has begun in all areas for just over a decade, due to the growing use of digital technologies in order to improve system performances used to perform the most important technological functions. Computers are used now intensively in all facilities and in all areas, starting from the home environment up to get to the most complex industrial processes. By now all machines of common use are controlled and managed by completely digital computerized systems. Not only that, they appear in our lives, tools that until a few years ago were simply unthinkable (tablet, smartphone etc ...). Even basic concepts, such as lighting and heating and air conditioning are moving more and more on digital technologies especially thanks with the advent of LEDs and inverter heat pumps.

1.2 The distributed generation

In the last years, especially in Europe, but all over the world, the generation of energy electricity is profoundly changing, only up to 2 decades ago, the generation of electricity it was essentially centralized, mainly thanks to the exploitation of atomic energy, which has given the possibility of setting up large power stations to serve an increasingly vast user and energy-consuming. In recent years, however, there has also been a notable revolution in production of electricity, mainly thanks to photovoltaics which, also due to strong policies incentives has increasingly made its way into our lives, but also other technologies such as wind power, hydroelectricity, cogeneration etc ... are experiencing an ever greater development.

How this phenomenon will affect the transmission of energy to end users is not purpose of this discussion, but it can certainly be interesting to evaluate in the first instance what are the main differences in the two approaches. In order to simplify the discussion, we outline below the situation of the electricity transmission network in the two cases in order to qualitatively assess the impact that this change has on the end user:

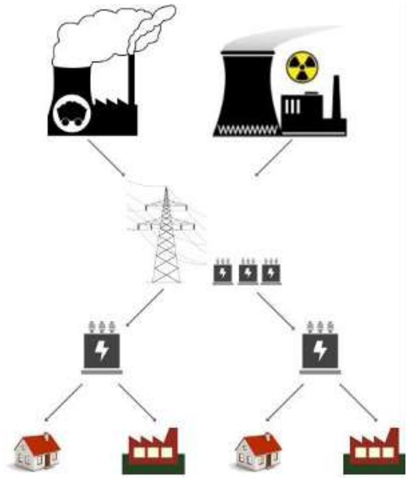

Image 1 Centralized generation transmission network

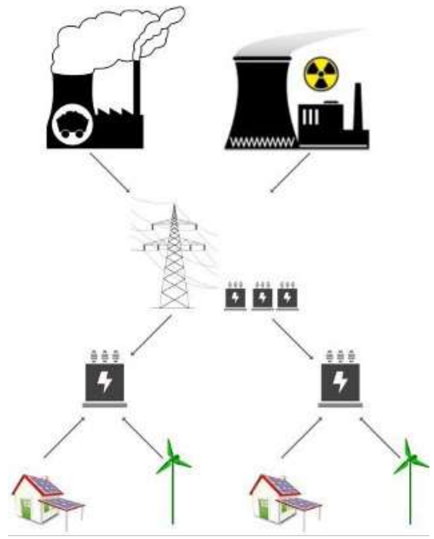

Image 2 - Distributed generation transmission network

As we can see from the 2 overexposed figures, the most important difference we can to detect is topological. In particular, in the case of distributed generation, power fed into the network, it always passes through central distribution systems before reaching the end users, while in the case of distributed generation, this is not always the case, in practice they can have energy exchanges directly from the generator to the user without going through the centralized distribution systems.

This phenomenon has a significant impact on the quality of the power delivered by the generators, as there are no intermediate steps for the distribution equipment, the power delivered from distributed generators it is less efficient than that supplied by centralized generators. In recent years, in the electrical and electrotechnical fields, we hear more and more often about Power Quality, referring to the quality of the power transmitted by the power lines to the users.

1.3 Overvoltage or undervoltage

Overvoltage is a phenomenon whereby the grid transfers power at a higher voltage of the rated voltage. The phenomenon can be transient or stationary. In the first case, the deviation from the nominal value occurs for a few moments or a few cycles, with amplitudes of a few Volts up to hundreds of Volts, often caused by switching inductive loads, transformers under load etc..., of course this type of disturbance can also generate energy inefficiencies, but the real problem associated with this type of disturbance is the possibility of be able to damage the devices connected to the system. While in the second case, the ailment can be considered stationary when the supply voltage is constantly higher than the nominal operating voltage which in Italy is 230V for single-phase low voltage systems 400V for low voltage three-phase systems. Again, the ailment could cause, in the long term, damage to the devices connected to the system, even if the phenomenon should be related to the design of the appliances themselves, which should have one input voltage tolerance of + - 10%, but the real problem is related in many cases the resulting energy efficiency. In particular, for most linear loads connected to the networks, an increase in voltage causes a reduction in the useful life of the device and it increases the use of energy without appreciable improvements in performance. In parallel the situation of stationary undervoltage can also cause transmission inefficiencies especially on constant power loads, requiring in fact higher operating currents.

1.4 Harmonic distortion

The transmission of power on the electrical network should take place through a type wave sinusoidal at a frequency of 50Hz (in Italy) with a nominal voltage of 230V, also this wave closing on linear type impedances should generate in the electrical circuit circulation of a current also of a sinusoidal type with a frequency of 50 Hz, with an amplitude dependent on the Ohmic part of the impedance and at most a phase shift with respect to the voltage wave dependent on the imaginary part of the impedance itself. We used the term "should" both with reference to the voltage input and to the generation of the current line, as in the first case, the voltage wave is not necessarily perfectly sinusoidal at the input, but even if it were, it is not certain that the resulting current wave is perfectly sinusoidal.

From a mathematical point of view, the wave in question is still of a periodic type, and therefore can be developed in a Fourier series, representing it as the sum of infinite components sinusoidal with frequency, amplitude and phase different from each other. Technically the singles components of the series development are defined harmonics, in particular also the sine wave at fundamental frequency is a harmonic.

Considering any electrical circuit powered by a pure and closed sine wave only on linear loads, as we have just mentioned, the resulting current wave will have a single component at the frequency of the power supply and will not have any harmonic component of frequency different from the fundamental, while in the case in which at least one of the loads is non-linear, it will be possible to have harmonics of current at a frequency other than the fundamental, neglecting the phenomenon of interharmonics at the moment, for electrical loads the current components resulting with a higher contribution are usually those at multiple frequencies of the fundamental, therefore the harmonics produced can be ordered numerically by referring to multiple of the frequency of interest, for example the second harmonic means an harmonic at the double frequency of the fundamental. Also for most loads not linear connected to networks (e.g. switching power supplies) the harmonics with greater amplitude are those with odd order the third the fifth the seventh etc … moreover, in real cases, usually the harmonics have a larger amplitude contribution in lower ordinal numbers and are therefore decreasing, i.e. in general the third harmonic has a greater amplitude than the fifth, the fifth with respect to the seventh and so on. Of course, also in this case the single situations must be analyzed as different non-linear loads connected to the network in question can generate a harmonic contribution different from each other, and therefore the sum of these contributions could result different.

Referring to the current wave generated, the total harmonic distortion can be defined as follows:

$$THD_i = \frac{I_t - I_f}{I_f} = \frac{\sum_2^\infty I_n - I_f}{I_f}$$

Where:
l is the total current
l is the current at the fundamental frequency
The same applies to the voltage wave:

$$THD_v = \frac{V_t - V_f}{V_f} = \frac{\sum_2^\infty V_n - V_f}{V_f}$$

And more generally for the transmitted power:

$$THD_p = \frac{P_t - P_f}{P_f}$$

This index gives us information, as the name itself tells us about the overall distortion present in wave forms. Of course, the more the value is greater than 0, the more the wave shape it moves away from the ideal case.

The presence of harmonic distortions in itself also creates problems of an energy type in the plants. It is in fact possible to demonstrate that the distortion in current also causes effects on the shape of voltage wave that powers the loads, and therefore this phenomenon generates consequences, even on linear loads connected to the plants, as well as generating other losses in the system as a result of the greater power dissipation on the line impedance and the internal impedance of the generator.

In general, a linear load has an almost infinite bandwidth, for example a light bulb incandescence transforms all the electrical power supplied in a band into thermal energy practically infinite, which means that for example I power the bulb at 5V at one frequency of 400 Hz the filament present in it will heat up, and heat will be generated by the Joule effect, the problem is that the transformation in question does not generate light emissions in the band of visible, or rather it will generate a minimum amount of light emissions in the visible and maybe others emissions in light bands not visible to the naked eye, eg. ultraviolet or infrared, this because the filament is designed to work at the mains frequency. This has 3 very important implications:

- Operation outside of rated parameters can lead to premature failure of the appliance.
- The light energy supplied has an unwanted component, therefore it can be said that the excess energy is not used to carry out the work for which the appliance has been created, but basically it is just a nuisance.

- The emission of radiation outside of visible light could be harmful to the human body that is exposed to it.

If we consider other types of loads such as electric motors, pumps or other the consequences could be even worse.

The result in general is that such distortions transfer power to the loads that use it in part to carry out the work for which they are designed and in part to generate inefficiencies that they increase the possibility of breaking the loads themselves. Therefore in addition to the resulting economic damage the increased use of energy also generates damage due to the shortening of the useful life of the devices themselves.

1.5 Phases balance

In the case of three-phase systems, another factor that negatively contributes to the quality of the supply is the imbalance between the phases, i.e. the difference between the waveforms on the individual phases power supply, these differences in general can be both attributable to the voltage at the fundamental frequency and harmonic type. Usually such ailments arise when they use single-phase and three-phase loads on the same line in a mixed way. Also in this case the phenomenon has both energy consequences on the connected three-phase loads and consequences in terms efficiency and useful life of the devices. From the literature in this area we learn how the most of the inefficiencies are generated on the three-phase motors connected to the system.

1.6 Phase shift

Another important disturbance that occurs in loads connected to an electrical network is the phase shift between the voltage wave form and the current generated one.

The phase shift between voltage and current in general does not in itself generate energy problems loads, or at least it does not generate problems in terms of active energy absorbed by the loads, naturally, the presence of phase displacement generates inefficiencies and greater use of power in the power transmission phase.

In general, even a linear load, which is not completely ohmic, generates a phase difference of the current with respect to the supply voltage, both leading and lagging, depending on whether the load in question is ohmic-capacitive or ohmic-inductive. This generates the transmission of the so called reactive power, especially reactive power is power which is not used by loads to do a job but simply to sustain the magnetic field. The problem is that the reactive power is transmitted through an inductive current which increases the engagement of the electrical cables connected to the network, moreover a greater circulation of current in the circuit generates higher losses on the series impedances of the circuit itself, in particular on the internal impedance of the generator and on the line impedance, thus generating ohmic losses (therefore of active power) on the system itself. In this case 2 factors are important in the energy and economic balance of the plant:

- In some cases, the use of reactive energy generates a cost for the user in terms of penalties on the bill.
- The circulating reactive current generates dissipation of active energy on the line.

Not only that, it is possible to simply demonstrate that this factor also has consequences on the power supply voltage of the loads, as the voltage drop on the line generates a lower one useful voltage on the load itself with the same total power used, in other words the power transmission becomes highly inefficient. Most often referring to electrical networks it is customary to speak of power factor referring to the ratio between the total power transmitted (apparent power) and active power, and usually this factor is confused with the so-called cosphi. In in particular, this last statement is true only if linear loads are considered, therefore for a network of linear loads the cosphi corresponds to the power factor. In general, however, the power factor also takes into account the total harmonic distortion.

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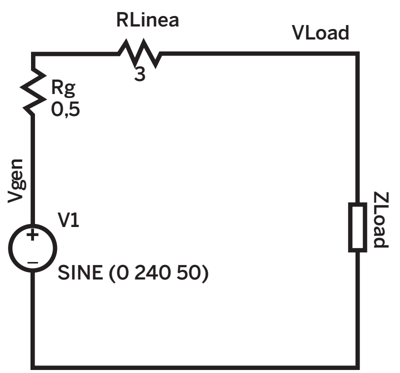
2 Response of loads

2.1 Introduction

In this section we will analyze, also using some simulations, the behavior of loads in the presence of the disturbances listed above.

Let us refer for simplicity to a domestic type electrical circuit, with a contractual power of 3 kW, which can be schematized as follows:

A lumped parameter model will be used for the simulations.



In particular:

- Rg is the "internal" resistance of generator
- RLinea is the line resistance of the network mainly due to the presence of electrical cables for the distribution of power. They will be neglected for simplicity the capacitive and inductive effects of impedance itself, the resistive value set to 3 Ohm corresponds to approx. 350 m of cable with an average section of 2 sq. Mm.
- Z Load is the load impedance, schematized as the impedance

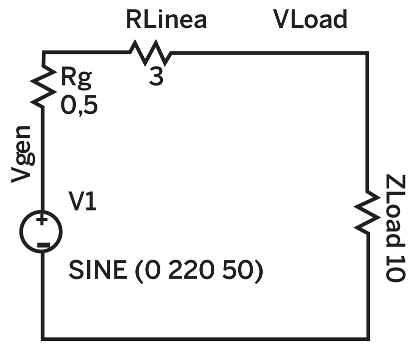
equivalent seen from the generator.

The circuit in question can be divided into two sections, one is the part relating to the power supply and the other is the part relating to the loads.

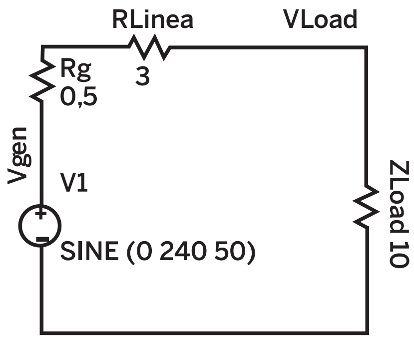
In order to evaluate the energy balance of the circuit itself we will consider a series of factors that from time to time they will make themselves useful, but in general we will focus on the active power delivered by the generator and on the active power absorbed by the load, in such a way as to be able to evaluate the efficiency in the transfer of power in various situations.

2.2 Stationary overvoltage on ohmic load

Let us consider as a first example the presence of a purely Ohmic load and go to analyze the effects of a power supply at a voltage higher than the optimal voltage on the system, we will assume an optimal voltage of 220V:



Active power supplied by the generator: 1785W
Active power absorbed by the load: 1322W.



Active power supplied by the generator: 2124W
Active power absorbed by the load: 1573W

Summarizing

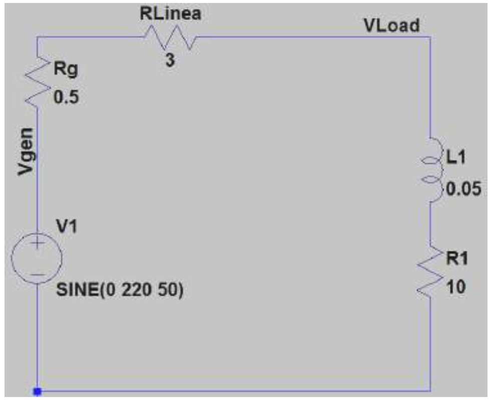
OHMIC LOAD – EFFECTS OF STATIONARY VOLTAGE VARIATIONS		
	Optimal mains voltage	High mains voltage
Power supply voltage:	220V	240V
Line current:	16.28A	17.73A
Power factor:	≈ 1	≈ 1
Total harmonic distortion:	0%	0%
Load resistive impedance:	10 Ohm	10 Ohm
Power supplied by the generator:	1785 W	2124 W
Power dissipated on the load:	1322 W	1573 W

Considerations:

The first consideration to be made is that in the present case the power as a whole engaged by the generator is about 16% lower in the case of an optimal power supply. Of course, due to the linearity of the circuit also the power distributed to the load turns out to be 16% lower, but as we have been able to evaluate by treating the effects of high voltages on loads, this does not always translate into an increase in the efficiency of the load in question, for example if the load is represented by one or more incandescent lamps connected in parallel, surely by feeding them with a higher voltage at the fundamental frequency, you will have one greater light energy in the visible band, but there will also be greater energy in the other emission bands of the luminaire, therefore the overall light power in the band of the visible will not be increased by 16% but by a lower percentage. Moreover, get out of the optimal voltage range, for the device in question means shortening its life span by much more than 16%, some Omran studies, in the case of incandescent lamps, show that powering a 240V light bulb decreases its useful life by 55% with respect to a power supply at its rated operating voltage.
Another factor to consider is the loss of ohmic energy across the grid, just in case of the optimal power supply we have a loss of (1785 - 1322) W = 463W, while in the case of higher voltage power supply we have (2124 - 1173) W = 551W, also in this case, from relative point of view the percentage loss is the same, but in absolute value, the power loss is greater in the case of a higher voltage power supply, as we have about 100W more dispersed on the line, which means more energy accounted for at the meter, and greater heating and inefficiency of electrical cables.

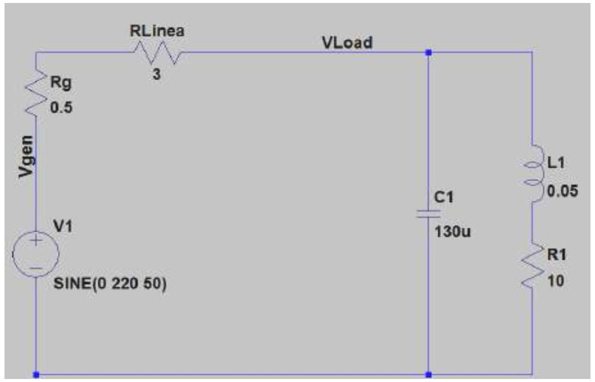
2.3 Phase shift

Let's now consider the presence in the circuit of a ohmic-inductive load:



Power supplied by the generator: 632 W
Power absorbed by the load: 561 W

We introduce a capacitive impedance in parallel to the load in order to obtain from the same circuit an equivalent ohmic impedance seen by the generator:



Power supplied by the generator: 758 W
Power absorbed by the load: 573 W

Recap:

OHMIC-INDUCTIVE LOAD - PHASE SHIFT EFFECTS		
	Equivalent ohmic load	Equivalent ohmic inductive load
Power supply voltage:	220V	220V
Line current:	5.73A	8.03A
Power factor:	0.99	0.66
Total harmonic distortion:	0%	0%
Power supplied by the generator:	758 W	632 W
Power dissipated on the load:	561 W	573 W

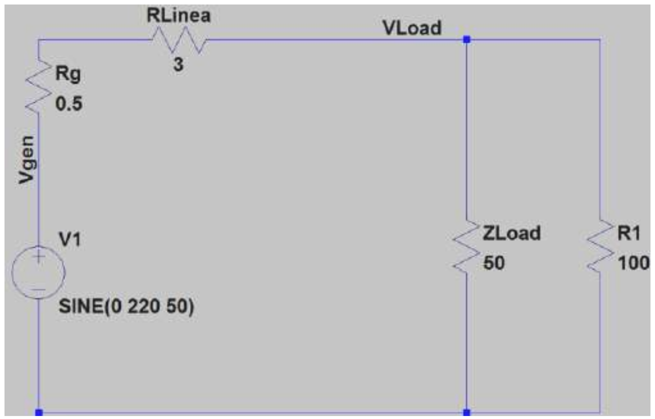
Considerations:

For this case, we can highlight 2 important considerations:
1. The power delivered by the generator in the case of an ohmic inductive load, compared to the case of its ohmic equivalent is greater than about 18%.
2. The actual power used on the load is approximately 3% higher.

The first affirmation puts us in a position to affirm that by improving the factor of circuit power, we also obtain a substantial saving on the overall power committed, therefore the energy balance turns out to be positive in the case in question, we also note how the load itself benefits as the power it uses under the same conditions is slightly larger than in the previous case.
Obviously this condition is verified with a power supply voltage of 220V, for voltages higher, the problem is more complex, as the insertion of inductive loads generates one phase shift with consequent voltage drop on the load due to the effect of the impedance of line, of course by carrying out the power factor correction of the system, the situation improves from the point of view energetic, with the same modalities that we have just analyzed, but in reality we find ourselves in the previous steady overvoltage condition of the load, therefore the dissipation on the load goes however remodeled in order to make it work in its optimal operating conditions, this last factor generates even greater savings and is therefore a desirable element of which there we will deal in the following.

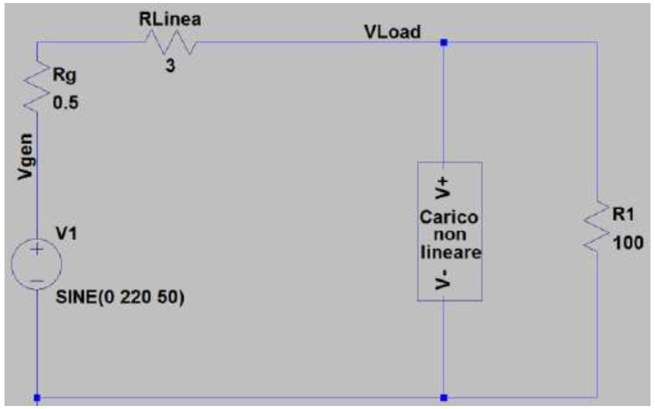
2.4 Distorsione armonica

Let's now consider the presence in the circuit of mixed linear and non-linear loads:



Power supplied by the generator: 654 W
Power absorbed by the load: 592 W

We replace the 50 ohm ohm load with a load of the same power but not linear:

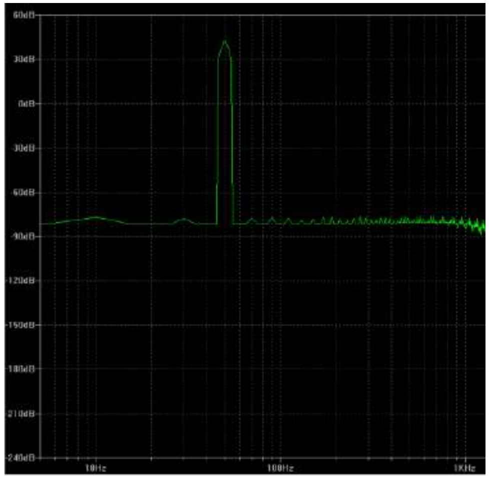


Power supplied by the generator: 656 W

Power absorbed by the load: 586 W

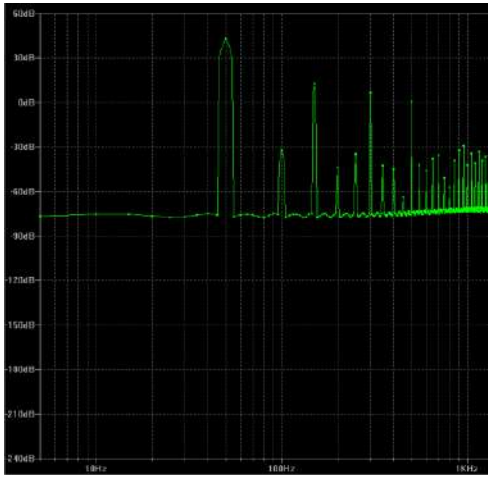
Let's see this situation in detail, let's consider the Fourier transform of the voltage on load in the 0 - 1kHz band.

Fully linear circuit.



Total harmonic distortion: 0.000473%

Circuit with non-linear load



Total harmonic distortion: 3.550619%

Recap:

OHMIC-INDUCTIVE LOAD - HARMONIC EFFECTS		
	Linear load	Equivalent load partially non linear
Power supply voltage:	220V	220V
Line current:	4.21A	4.46A
Power factor:	≈ 1	0.95
Total harmonic distortion:	≈ 0%	3.55%
Power supplied by the generator:	654 W	656 W
Power dissipated on the load:	592 W	586 W

Considerations:

For the case in question, we can highlight 3 considerations:

1. The power delivered by the generator in the case of a non-linear circuit, compared to his own ohmic equivalent is greater than about 0.4%.
2. The overall power transmitted to the load is approximately 1% higher.
3. The power transmitted to the load at the frequency of 50 Hz is less than 3.5%, that percentage power is transmitted out of band.

In this case, the non-linear load generates a circulation of a current with a high content harmonic out of band, this current in itself does not generate problems for the other loads as it circulates only between the generator and the load concerned. The problem is that the voltage variation on Line impedance also has a high harmonic content and therefore the overall voltage power supply of the loads is affected by harmonic distortions which depend, as mentioned, from the power of the distorting load and from the line impedance, naturally such distortions come absorbed by ohmic loads and transformed into heat, presumably without any advantage from the from the point of view of efficiency, indeed with sometimes significant disadvantages regarding the duration of the device.

Therefore we can say that, although in the first instance from the point of view of the energy balance it would seem that there are no consistent variations (1%), from the point of view of the efficiency of the loads there are more consistent variations (3-4%), therefore, the total power absorbed by the load is virtually 5% lower if we consider the useful power at work (that delivered at 50Hz).

3 Current technologies

3.1 Voltage optimization

Voltage optimization is an energy saving technique that is adopted by installing in series to the power supply line a transformer in order to decrease or increase the voltage available to load.

The optimization can take place statically or dynamically depending on whether the voltage has decreased fixed by a certain percentage or has varied dynamically during normal circuit operation.

Normally there is an energy saving, as we have been able to appreciate in the previous simulations, in the presence of mainly ohmic loads with problems of stationary overvoltage, or in any case linear, in the case of particular non-linear loads (such as for example switching power supplies) the voltage decrease can even lead to increases of consumption, in fact, these loads operate at constant power, that is they always absorb the same power amount of power even in the face of voltage variations, therefore a voltage variation in decrease leads to an increase in current in the node, and therefore in the line, this current, naturally increases the losses on the transmission cables.

3.2 Power factor correction

Power factor correction is any measure used to increase (or as they say commonly to improve) the power factor (cos) of a given load, in order to reduce it to equal active power absorbed, the value of the current circulating in the system. The purpose of the power factor correction it is above all to reduce energy losses and reduce apparent power absorption proportionally to the existing machinery and lines in an industrial site. The power factor correction of systems has acquired importance since the electricity distribution body has imposed contractual clauses through the tariff provisions of the CIP (n° 12/1984 and n° 26/1989) which oblige the user to re-phase their system under penalty of paying a penalty.

In circuits with particular users such as filament lamps, water heaters, certain types of ovens, the apparent power absorbed is all active power. In circuits with users having their internal windings such as motors, welders, fluorescent lamp power supplies, transformers, a part of the apparent power absorbed is used to excite the circuits magnetic and is therefore not used as an active power but as a power generally called reactive power.

From the point of view of the overall energy balance, power factor correction reduces the quantity of reactive energy absorbed by the circuit, but the active energy used does not work directly, that is, the tendency of active energy is in general a consequence of the fact that the time wasters decrease on the conductors as the series impedance of the conductors themselves is crossed by one overall lower current, but in reality not all that active energy is actually real spared, as the lower dissipation on the conductors leads to a lower voltage drop on the load, and in the case of ohmic loads this means greater energy dissipation. It's clear however that in this case that excess of energy is good for the load, unless not be in the case of stationary overvoltages.

The power factor correction of the loads can be centralized, distributed or mixed, in the first case it is rephased the whole system upstream of the load and downstream of the generator, therefore at the generator output the cosfi improves but there is not necessarily an improvement in every jersey of the circuit, in the second case, the loads are individually rephased, and the effect is an improvement in the overall power factor at the downstream of the generator, in the third case, there is a mixed solution between the first two.

Normally the power factor correction of the loads is obtained by placing a generator in parallel to the loads themselves of reactive power in counterphase with respect to the reactive power of the load, in such a way as to cancel the reactive power output. The simplest reactive power generator in sinusoidal circuits is the capacitor, therefore one or more capacitors are inserted in parallel to the loads in order to obtain an improvement of the cosfi. However, there are other techniques such as the static compensators or active filters.

3.3 Harmonic filtering

Filtering of harmonics in power systems is usually done by inserting devices into the circuit acts to decrease the total harmonic distortion normally in current, in order to improve also the effects of distortion on voltage. There are 2 main categories of filters suitable for this purpose:

- Passive filters
- Active filters

In the first case there is a further distinction between tuned filters and inductive filters. The tuned filters are particular rlc filters tuned to a specific frequency and usually connected to ground, in some cases you can also use band pass or high pass filters in order to create for disturbances at those frequencies a low impedance path to ground and eliminate the disturbances at the origin. In case instead of line inductances, the principle is that of low-pass LR filters, in fact the inductance of line forms a low-pass filter with the ohmic circuit downstream which does not let power pass through frequencies far from 50 Hz.

This type of solution naturally improves the load situation by mitigating the factor of total harmonic distortion, but from the point of view of the energy balance the situation remains unchanged, in fact the disturbances are conveyed to the ground, after crossing the meter and therefore the energy that is diverted to the mass is still accounted for (even if the part does not dissipated on the load is in any case spared).

Active filters are from the load point of view of the parallel current generators they inject a current equal and opposite to that of the out-of-band distorting load and thus cancel the harmonic currents generated by the loads themselves. They work through voltage modulation line, make an analysis of the network situation, and inject the compensation currents, naturally to correctly inject these currents they need switching frequencies very high higher than more than double the frequency of the maximum compensation harmonic, therefore they need particularly efficient and fast internal devices, they usually come IGBTs used to work at the desired switching frequency. This of course makes such devices particularly expensive. Furthermore, from the point of view of the energy balance the situation is similar to the case of passive filters, as depending on the efficiency of the filters to compensate for disturbances, an equivalent amount of power is absorbed.

The interesting thing is that active filters can also improve the cosfi of the system as they also work as a reactive energy generators. Furthermore, another very interesting aspect is that flow filters also different from each other, they can be connected in parallel and do not cause disturbances to the circuit or risks of resonance.

3.4 EMI filter

The EMI filter is a passive filter present in most electronic equipment to allow such devices to comply with the electromagnetic compatibility regulations, in particular to those concerning conducted emissions. Basically, the EMI filter is a pass filter low which is connected as the last stage between the equipment and the power supply network to attenuate the disturbing components that any electronic device would tend to issue. Obviously, the filter must be transparent to the power supply frequency (50-60 Hz) to allow the device to function correctly, while it must act in the frequency range established by the regulations (150kHz-30MHz).

3.5 Profiling of consumption

There is a number of devices on the market that allows to profile the consumption of users, that is to understand how users use electricity during a certain period of interest. Of course, these systems in themselves do not produce any improvement on the power commitment from part of the user, but they have 2 important implications that allow to optimize consumption:

- Consumption awareness for users can lead to greater attention and savings.
- The implementation of an expert system that analyzes the data in question and reprocesses them can lead to more efficient energy management and substantial savings, without change their consumption habits.

4. ANT DEVICE

4.1 Initial Considerations

Before entering into the merits of the project, it is good to make some clarifications on the problems that we have dealt with in previous chapters and on the solutions currently on the market.

We have just analyzed the voltage optimization systems, there are various types on the market, even if in practice they are devices that simply reduce the mains voltage, some statically, others dynamically, in particular the stabilizers of voltage. Clearly, in this case a voltage optimization system could be useful for saving but you have to be very careful about the operation. To low statically it is certainly not an efficient solution as the raising or voltage drop normally depend on load conditions. Of course in in this case it is also necessary to pay attention to the conditions of the power supply line, as we could create malfunctions or damage the loads themselves. In practice, a stationary overvoltage or undervoltage can be positive or negative for a plant depending

on whether we are in the presence of loads with variable power or loads with constant power (powered - non-linear), therefore it is not possible to predict the correct mode of operation.
We then studied the power factor correction and filtering systems, also in this case there are many clarifications to be made in terms of energy and plant safety. In particular, supposing we are faced with the case of a system with a predominantly ohmic-inductive load and in the presence of stationary overvoltage, in this case depending on the power factor of the load there will be a voltage drop of a certain value between the generator and the load itself, such voltage drop could bring the load to the rated voltage value, the introduction of a power factor correction and filtering system therefore benefits from an increase in the power factor a lower current circulation in the series branch of the circuit and therefore an increase in the useful voltage to the load. The latter aspect very often results a bigger waste of active energy depending on the relationship between the line impedance and the load impedance. The same regards, as we have been able to see from the simulations, the contribution harmonic to line currents and voltages, in this case accentuated and aggravated by the fact that in the presence of harmonic disturbances there is also the problem of the safety of the loads and of the whole plant.

The ANT project arises exactly from the need to combine the positive contributions of individuals technologies considered in a single product. The real news and the most important value added to the product is its dynamic approach to load management, in particular the device is able instant by instant to analyze the electrical network to which it is connected both under the profile of the power supply and of the load and to power the loads in an optimal manner in any operating configuration. The device is able to analyze the network parameters with an accuracy of 0.1% both on the voltage spectrum and on the current spectrum and by analyzing the emission level of the loads is able to understand the internal composition of the network as well as of interpret the contribution of the individual impedances by inference, with particular reference to the difference between the load impedances and the transmission and parasitic impedances, in this way the equipment is able to optimize the power transfer towards the load impedances, minimizing transmission and parasite losses.

The ANT project has been created to respond to the growing need to optimize the power transfer between any electric generator and a network of loads connected to it.
In this context, by optimization we mean a series of measures aimed at improving the power quality entering the system and compensate for the negative effects due to the insertion of loads, as we have been able to appreciate from the analyzed simulations.
It should be noted that at the moment, due to the way the system is composed, there are no equal alternative solutions, but there are in any case substitute products that come close to the proposed solution.

4.2 Current project

Description of the device

Impedance adaptation system of user electrical circuits to the impedance of the generator, to improve the efficiency of the systems, the protection of the devices and the energy saving.
The device, once connected to the mains, is able to analyze all the operating parameters of the network, both those relating to external power quality and those relating to the interior disturbance factors. The same is able to mitigate disturbances, and use its energy to optimize the internal voltage and current flows. It is also able to balance the load profile on phases and power supply voltages, therefore it is also able to balance the 3 currents and the 3 currents of phase. The operating profile is fully configurable and manageable even remotely as well as data deriving from network analysis.
The product includes the basic variant called ANT version 2.1, the TG variant which includes the remote management functionality of the device, as better specified above and the TL variant which includes remote reading functions as specified above.
The device must be connected to the system, both domestic and corporate, downstream of the meter and in entrance to the primary distribution line. Once connected to the circuit, it is able to calculate the impedance seen by the meter towards the circuit and optimize this impedance in order to improve the transfer of energy between the meter and the system, effectively reducing energy dissipated by the system for factors not attributable to the use of the devices themselves. Furthermore the device also acts as an optimizer of the Power Quality relative to the incoming line. The Power Quality is the characteristic of the electrical grid to transfer power efficiently to the utilities and as much as possible eliminating waste.

Remote management

The remote managed device includes all the basic functions plus the possibility of managing all installed appliances completely remotely. Remote management of devices is very important for the purpose of improving the operating parameters of the device, as it exists the ability to reconfigure remotely each individual device based on the standard functioning situation of the period of operation. Furthermore, through remote management it is possible to have at any time from your office the complete picture of the operating situation of the devices and, if necessary, by intervening from your office it is possible to bypass each device by disconnecting the device itself from the system to which it is connected. Furthermore, there is the possibility, if some anomaly occurs on the devices, to have a notification of the type of anomaly that is verified, and possibly on which component there is an anomaly.
The product, of course, is sold with an internal sensor network that tests the operation of all individual internal components, in order to monitor all the parameters of operation of the device, and is therefo-

re able to immediately understand if there are any anomalies or malfunctions in the system and report the problem to the after-sales service found and the possible solutions to be applied to promptly resolve the problem.

Software

The remotely managed product from an architectural point of view is composed by a central and dedicated server which communicates with all the devices in such a way to always have a clear view of the situation and operating parameters of all connected devices.

In addition, the company provides the ability to access to the software and check each moment the status of all devices, it is also possible through the same software to change the configuration of each individual device and possibly disconnect it from the system, all in quick and easy way.

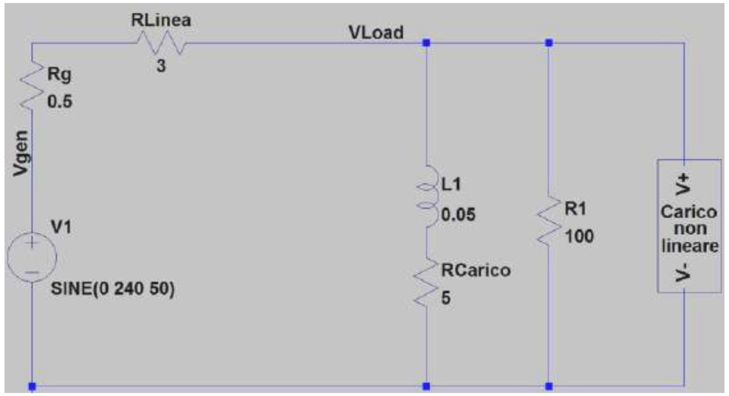
It is also possible to provide a software dedicated to other users who deal with assistance on individual areas, in such a way as to give them the opportunity to manage all devices in your area. Of course, in any case, both the company and the person providing assistance they receive notifications about any device malfunctions, and possibly the tickets of assistance to manage.

Remote reading

The remote-read product includes all the functions of the remote managed product, with the possibility to have also all the data relating to user consumption available, all on a single platform, simple and functional. The remote reading functions are accessible to the company, at discretion of the company they can be made available to the assistance network, but above all can be made available to individual users who own the device. Users can conveniently access to their consumption profiles both via the web on the company website and via smartphones and tablets, with a single simple and intuitive interface. The big news is that thanks to the system it is possible to monitor not only electricity consumption but also water and gas consumption, moreover it is even possible to manage the production data of any renewable energy plants present in the building, such as photovoltaic systems, mini wind turbines, solar thermal systems and more.

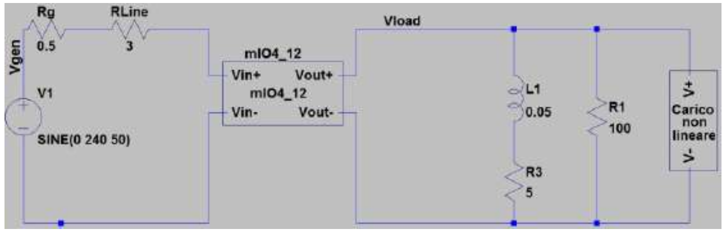
4.3 Design data and simulations

Let's now see how the system interacts with the electrical system, simulating a real situation, where there are phenomena of stationary overvoltage, phase shift and presence of nonlinear loads, in this case, as can be seen from the diagram, we are not taking into consideration the non-linearity of the power supply line, that means disturbances from outside are not taken in consideration, but only disturbances generated in the internal line:



Power supplied by the generator: 1094 W

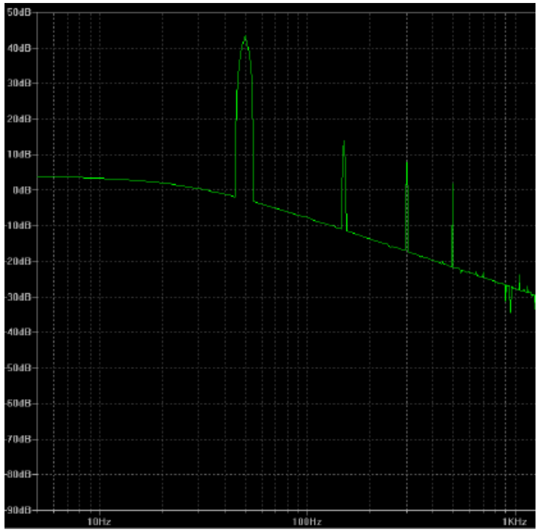
Power absorbed by the load: 738 W



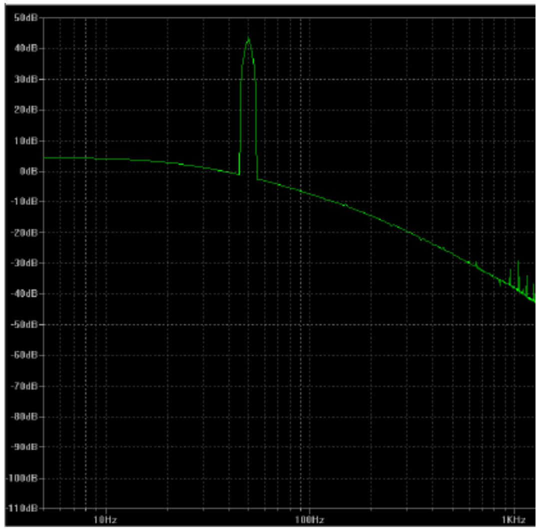
Power supplied by the generator: 843 W

Power absorbed by the load: 756 W

Harmonic analysis on the power supply voltage of the loads (VLoad):

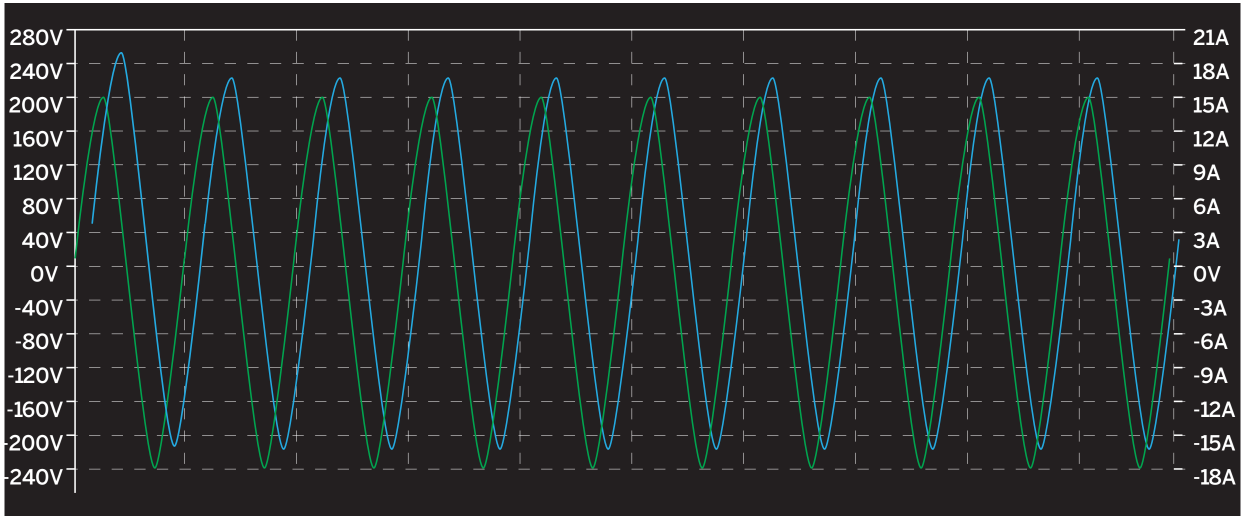


Total harmonic distortion: 3.479955%

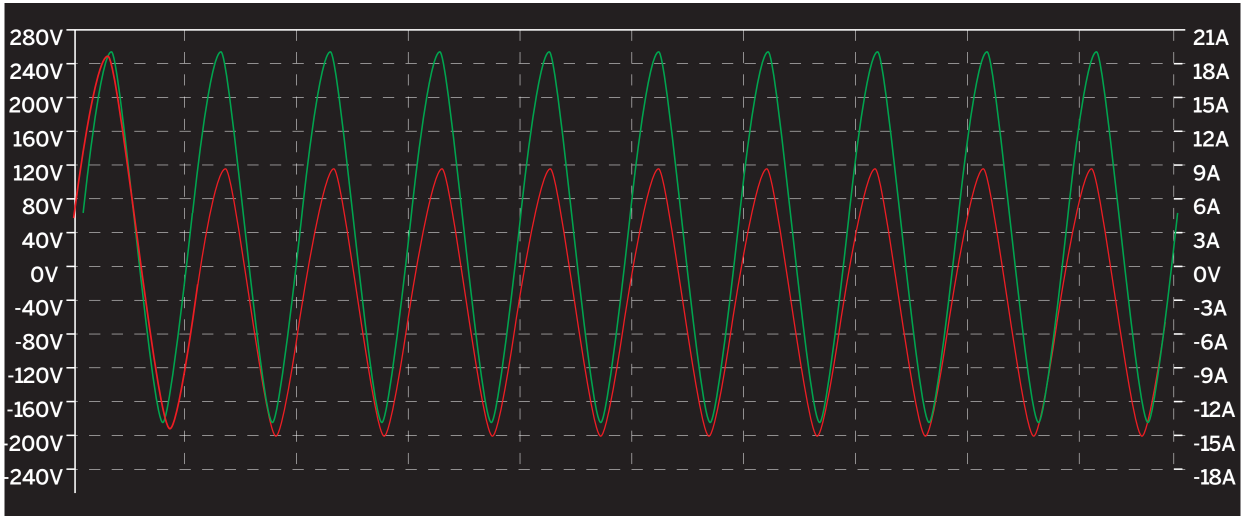


Total harmonic distortion: 0.014909%

The resulting waveforms:
Without ANT:



With ANT



ANT listing effects		
	Without ANT	**With ANT**
Power supply voltage:	240V	240V
Line current:	10A	5A
Power factor:	0.64	0.99
Total harmonic distortion:	3.5%	0.01%
Active power supplied by the generator:	1094 W	843 W
Active power dissipated on the load:	738 W	756 W

CONSIDERATIONS:

1. The active power delivered by the generator without inserting the device is approximately 18% higher than the case of insertion of the device.
2. The power actually used on the load is approximately 3% higher with the insertion of the device.
3. The total harmonic distortion in voltage on the load is practically zero with the insertion of the device while it is about 3.5% without device. Therefore the useful power transmitted to the load (50 Hz) is greater than another 3.5% considering the insertion of the device.
4. The power factor of the circuit (cosfi x thd) increases significantly and approaches unity.
5. The circulating current is about 50% lower after the device is switched on and therefore the dissipations on the cables are significantly lower.

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