ENERGY SAVING WITH OPTIMIZATION OF VOLTAGE AND CURRENT QUALITY

Approximation based on the know-how of SENERQON GROUP

The non-linear nature of modern electric loads makes the reception of measures for the confrontation of harmonics problem quite necessary. The power quality optimization in electric installations with high energy consumption constitutes one of the most important measures of saving of energy.

A. The Harmonics Issue

The previous years, most electric loads were linear (inductive motors, heating resistances, incandescence lighting bulbs), namely the waveform of voltage was the same with that of the current (figure.1). However, nowadays, non-linear loads are used widely (figure.2). These loads connected to a sinusoidal waveform voltage source conduct a current of non-sinusoidal waveform. As a result of this phenomenon, the network is polluted with harmonics and especially with current components in frequencies of multiple 50 Hz (3^{rd}, 5^{th}, 7^{th}…order) that run through the electric power supply cables and affects the entire electric installation.

The main categories of such (non-linear) loads are:

1. Power Electronics (e.g. inverters)
2. Rectification Transformers
3. Devices used for electric arc production (e.g. blast furnaces for metals fusion, welding etc.)

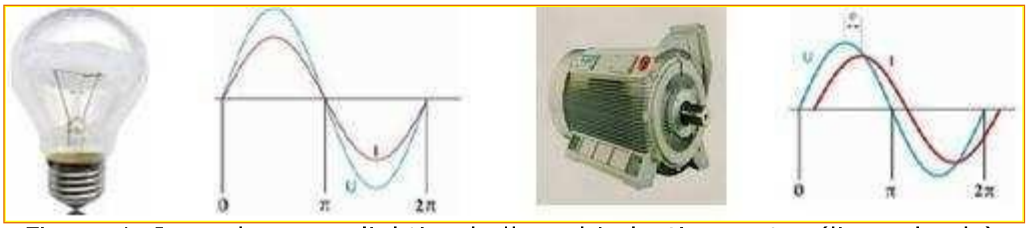

Figure 1. Incandescence lighting bulb and inductive motor (linear loads)

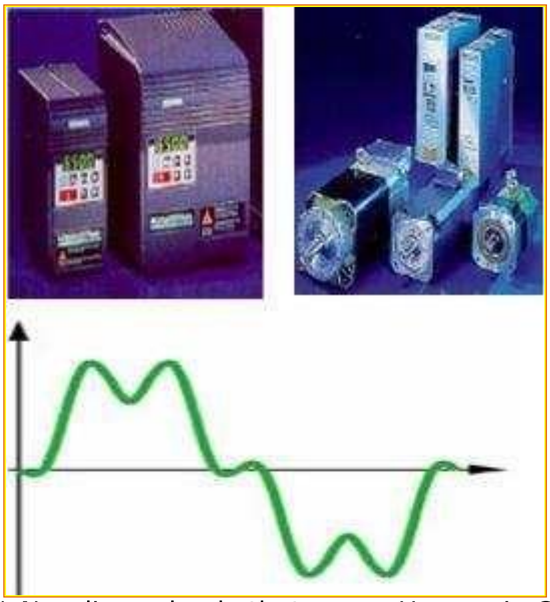
Figure 1.Non-linear loads that cause Harmonic Currents

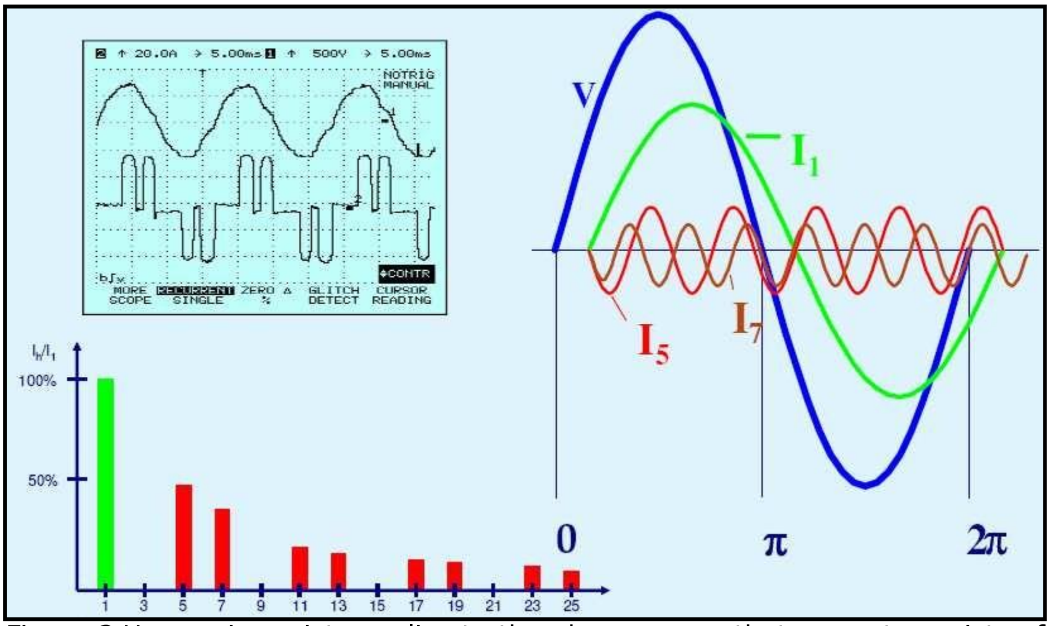

Figure 2.Harmonics existence lies to the phenomenon that current consists of components in frequencies multiple of the fundamental (50Hz)

B. Harmonics Consequences

Harmonics cause problems that in most cases are various and multifunctional. These in brevity are summarized as follows:

1. The transformers and the motors are superheated because of the additional loading that they go through. Also they wear down mechanically and because of that vibrations and their noise during their operation increase dramatically.
2. The neutral conductor is overloaded, while the vector sum of currents that they run through it does no longer equal with zero (case of symmetrical loads). Currents of various frequencies are added and so they constitute a considerable quantity, while the values of voltage between neutral and ground are no longer acceptable. As a result of this, the current of neutral conductor is no longer inside the acceptable limits most of the times.
3. Existing capacitors banks may be in great danger in cases where the branch in which they are connected, presents the same frequency with some of the existing harmonics inside the grid. In this case, the complex resistance of this particular branch is minimized and the current that runs through it increases by far. Thus the width of harmonic currents increases (electric swing), the active voltage and current increases as well and finally the capacitors being overheated. So it is likely, either their dielectric material be destroyed or the fuses that protect them melt and the capacitors be out of order.
4. The means of junction and protection decay and it is likely to operate undesirably, especially if their functional principals depend on thermal models or if in the calculation of active price of current the waveform width is used, which in this case is distorted.

5. The operation of electronic equipment and generators becomes unreliable.
6. The measuring devices proceed to erroneous recordings of electric sizes.
7. Energy extravagance takes place and as a direct result of this the invoices of energy consumption increase.
8. The electric installation backup decreases, while the currents that run through the cables and the electric panels, are critically bigger because of the harmonics.

All the above drives the electric installation to a crucial burden which equals to a considerable economic cost. Analytically the reasons why this economic cost can be significant are the followings:

1. There is a bigger consumption of electrical energy and therefore the invoices from the provider of the electric power are much higher
2. There are unjustified stops in the production and so an additional cost emerges as a result
3. The equipment decays faster and so additional investments must be scheduled more often
4. The cost of maintenance and repairing is higher
5. The quality of produced product or provided service is poor.

C. The scientific solution for encountering the harmonics problem that *SENERQON GROUP* proposes.

SENERQON GROUP innovates by giving pioneering solutions to the harmonics problem. These solutions include a know-how that its competent scientists have developed. Indicative it is the fact that 20% of SENERQON's GROUP executives are scientists that have worked out doctoral discourses on subjects that had to do with harmonics suppression and energy saving. **Dr. Konstantinos Satsios has been honoured by** Cambridge International Biographical Center **and the American Biographical Institute.**

These solutions lead to important money saving as the invoices from the electric power provider decrease. Moreover the protection of all equipment inside an electric installation increases.

Sum of these solutions that SENERQON GROUP applies based to its know-how concern the Detuned Harmonic Filters.

D. Harmonics Suppression Filters

Harmonics Suppression Filters are systems which trap the harmonic components and do not allow them to penetrate inside the power network. They are suitably constituted by a combination of inductors and special capacitors designed with this way that cause a resonance (their complex reaction is minimized) in selected frequencies and they are separated in different gradients. These systems have the possibility to be controlled by an electronic controller which depending on the loading demands it can either sets on or off these gradients (combined by inductors and capacitors), so that the phenomenon of overcompensation can be avoided.

Detuned Harmonic Filters are designed to cut off currents in frequencies close to the harmonic currents that are present in the power grid. The reason for this design is to cut off a big amount of currents that constitute the harmonics spectrum (in the region of frequencies that interests in its special case). This leads to a simultaneously decreasing of more than one harmonic currents and of course to the decrease of the Total Harmonic Distortion (THD-I %). These Filters require particular know-how at their design, as they are not absolutely tuned in harmonics that are present in each power network and so there is not such a big danger of very high currents run inside the loop they are connected.

The way the Detuned Harmonic Filters cut off harmonics that run through the power network, is shown in the following diagram (Figure.4) where the correlation between the Impedance of the Detuned Harmonic Filter branch and the Frequency of the current that runs through it, is being presented.

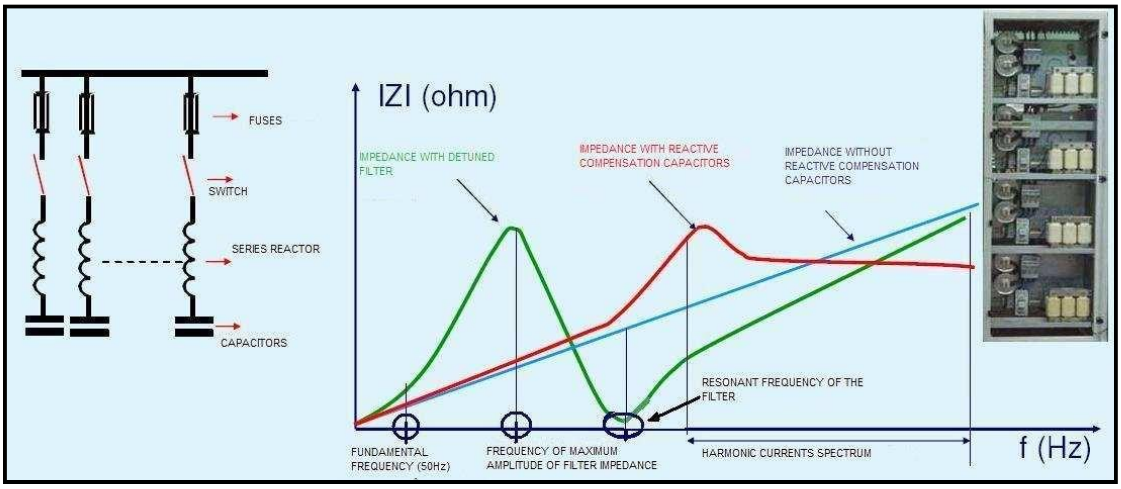

Figure 3.Schematic display of a Detuned Harmonic Filter and its principle of operation

In the above diagram it is shown clearly that there is a big difference between the impedance of a detuned harmonic filter branch and the impedance of the same branch without the existence of the detuned filter. Therefore in its case a detuned harmonic filter is installed in a specific part of an electric grid, this branch displays very low impedance in the resonant frequency. As a result of the above not only the currents of this frequency but also the currents of frequencies close to the resonant, existing inside the electric grid, will flow through this branch (cut off). This is the reason why detuned harmonic filters cut off a wide spectrum of harmonic currents and not a specific harmonic current (e.g. only the 5^{th} harmonic current etc.). However the main disadvantage of these filters is the fact that they cannot filter 100% of the harmonic content inside the grid and therefore some of the existing harmonic currents remain into the electric network after the Detuned Harmonic Filter is installed.

Tuned Harmonic Filters on the other hand are designed so as to cut off currents in the exact frequencies with those of harmonics currents that are present in the electric power network. They are constituted by series of capacitors and inductors in multiple gradients. Each gradient has its own resonant frequency that cuts off a particular harmonic current. All the above appear analytically in the following figure (Figure 5).

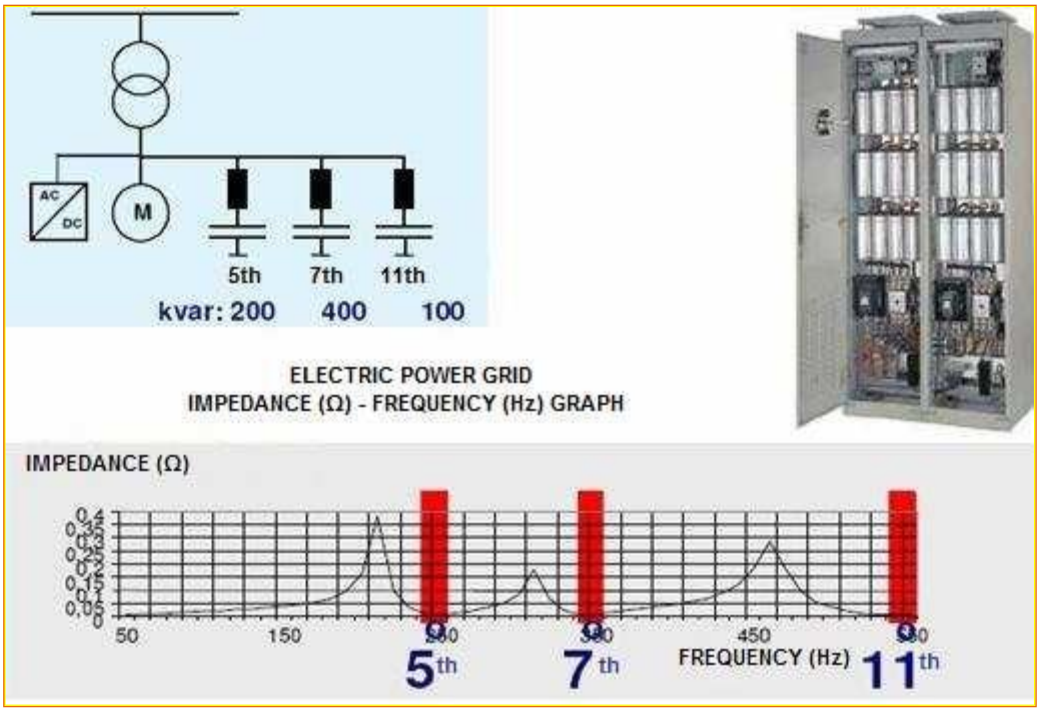

Figure 4. Schematic description of a Tuned Harmonic Filter and its basic operation principal.

With Tuned Harmonic Filters operation the most excellent reduction of Total Harmonic Distortion (THD %) inside the electric grid can be achieved, while cutting off exactly the currents of 5th, 7th, 11th etc. harmonic frequency of the fundamental (50Hz) that are being present inside the power electric network. The resonant frequencies of Tuned Harmonic Filters branches are very close (almost the same) to the frequencies of the harmonics currents are designed to cut off. As a result the impedance of each filter branch is excessively small at the specific harmonic frequency and thus the harmonic current that flow through it is very big leading the branch to exhaustion. Furthermore, as they cannot easily compensate reactive power in dynamic loads and because they threaten to absorb harmonic currents from the High Voltage side of the power transformer, it makes it very difficult for them to be designed, constructed and finally installed inside the power electric grid of a plant.

The know-how of SENERQON though ensures the most excellent filter design for each case. At the same time, their basic advantages constitute not only the most excellent reduction of the total harmonic distortion (THD %)
- in bigger percentage than that being achieved by the Detuned Harmonic Filters – but also the fact that they compensate the reactive power of the power electric network in which they are installed.

Active Harmonic Filters are power electronics systems that produce and provide to the network the opposite harmonic current from that being created by the harmonic sources of the power electric network. Schematically this appears in the following figures (Figures. 6, 7).

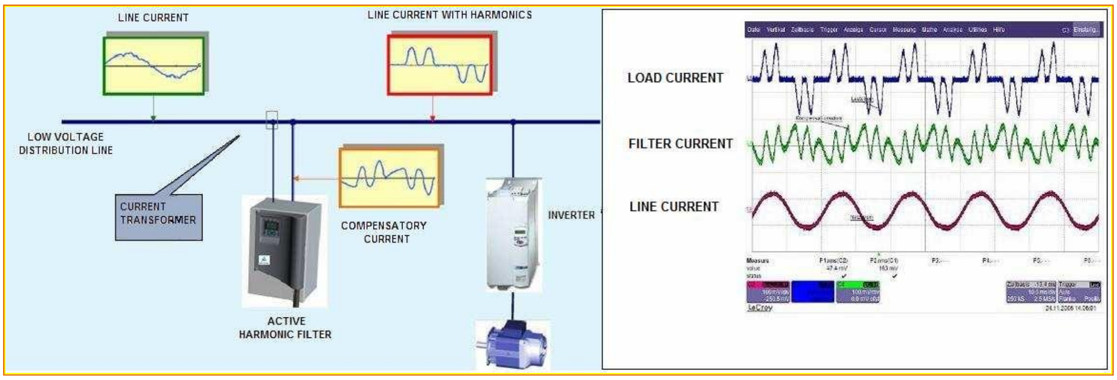

Figure 5. Schematic description of an Active Harmonic Filter and its basic operation principle.

They are used in cases where the non-compensated power factor of the load is close to one (cosφ=1) and consequently reactive compensation is not required, but what is needed is the Total Harmonics Distortion reduction (THD %).

They are quite expensive solutions and therefore are used in cases where many or all of the following cases stand for in an electric installation:

- There is a big content in NON-Linear loads
- The requirements for the best voltage and current quality are particularly high (THD V % < 3)
- There is Dynamic Variation of Total Harmonics Distortion (THD %)
- There is Rapid Variation of NON-Linear loads (e.g. Hospitals, X-rays, etc.)
- Sensitive Electronic Equipment is installed

Active Harmonic Filters most basic advantage is that they achieve absolute elimination of harmonics being present inside the electric power grid, decreasing Total Harmonics Distortion almost 100%. Moreover, they are easily installed, because of their very compact construction. Active Harmonic Filters are also not being overcharged and furthermore Dynamic Variation of Total Harmonics Distortion (THD %) of the grid does not influence their operation, as long as they produce and channel inside the power electric network the opposite current from the harmonics current every second that passes.

Their basic disadvantage though is their price, which is much bigger than a passive filter, as they do not compensate the reactive power demanded. So this price is increased by far concerning the solution of a passive filter, which also achieves power factor improvement inside the power electric network were installed.

The picture that follows (Figure. 7) is quite enlightening not only to understand the way an Active Filter operates but also the great effectiveness of its operation when installed inside an electric grid.

In Figure 7, on the left, the Total Harmonics Distortion (THD-I %) that is caused in the line current from an Inverter connected with an asynchronous three-phase motor, is shown. The nominal active power of the motor is 45 kW and it works at 30 kW. On the right of Figure 7, the new Total Harmonics Distortion that results from the installation of an Active Filter is shown. As being observed THD % in this case is obviously smaller and inside the official limits of the regulations.

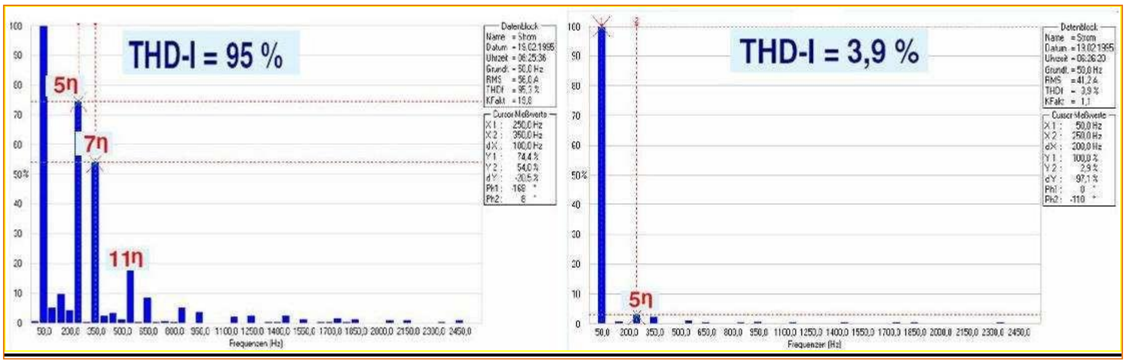

Figure 6.Example of reducing the Total Harmonics Distortion (THD-I %) that is caused in the line current from an Inverter connected with an asynchronous three-phase motor

The know-how of SENERQON SA ensures the application of active filters in combination with passive filters with the most optimal technical and economical result.

E. Conclusions

To sum up, as it is being clearly understood, each enterprise in the future would have to or it would be forced to seek ways to achieve two fundamental objectives: energy saving and quality optimization of electric power inside its electrical installation. The interventions analyzed in the above passage constitute the most optimal solutions that incorporate peak know-how and top technology equipment for suppressing the electric current and voltage harmonics. Harmonics existence, as it has been *analyzed, creates terrible problems inside the electric installation. Therefore it leads to an increased cost of energy consumption and also damage and premature decay of the electrical equipment, which have as a consequence a big waste of money and a need for more frequent maintenance of the electrical equipment, as a big percentage of the equipment has to be changed before the expecting life time passes by.*

In conclusion, the direct profits for a power electric grid by the practical application of SENERQON SA know-how that comes along with the planning, manufacturing and installing the appropriate systems for the most optimalenergy management and saving and also for suppressing the undesirable harmonic content are the following:

1. *Electric Energy Saving.*
2. *Reduction of the Maximum Electric Power Demand.*
3. *Optimization of power factor (cosφ=1).*
4. *Electric current and voltage harmonics reduction in the permissible levels of the official regulations, so that they no longer pollute the electric installation of the factory and the losses that they create reduce to the minimum level.*
5. *Motors performance degree improvement, because of the minimization of the counter-clockwise electromagnetic forces that the harmonics create.*

Moreover, collateral profits that lead to effective reduction of production and maintenance cost of the factory and also increase life duration of all the electrical equipment are the following:

1. *Decrease of the destruction of relays, fuses, switches and losses of PLC's memory programs.*

2. *Smaller damage and decay and also bigger discharge of all the electrical equipment and therefore increase of equipment's life time.*
3. *Optimization of electric current and voltage quality.*
4. *Minimization of problems created inside the power electric network, that leads to the loss of precious time for the functional period and the productive process and allow additional economic losses take place.*
5. *Avoidance of problems that being created in the motors, as it is for example the windings burning.*