STUDY OF POWER QUALITY IMPROVEMENT. FILTERS.

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Abstract: *This paper is intended to present the study of power quality improvement based on performance evaluation of some kind of filters. An experimental model based on Compact Fluorescent Lamps in an electrical wiring Power Filter has been developed. This study is based on the analysis of harmonics presence in current curves. In Romania, the national agency -ANRE- introduced requirements for performance and quality of electric power. The results show an inherent power quality improvement in terms of reduced Total Harmonic Distortion (THD) of source current. The experimental study highlights that some equipment, in this case Compact Fluorescent Lamps, produce harmonics as results of their operation. This harmonics increase the value of total harmonic distortions current to an important level. Using the filters power quality can be improved.*

1. INTRODUCTION

The Power Quality, according to IEEE, is the term for supply and earthed accurate of the electrical equipment's in order to operate properly. The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment. In fact, this term is used is a large scale including harmonic presence in the voltage and current waveforms. The electric user connected to power supply demands the amplitude and form of wave according to the operating mode. It is known that the voltage it is not a perfect sine wave. In order to maintain the perturbation in acceptable limits it is necessary to impose the limits to electric pollution. This purpose is obtained by link between acceptable deviations of voltage, in common supply point, and absorbed current of the receiver. In many cases, the electric users are themselves perturbations sources. [1], [2], [3], [4]

The most important devices that operated like non-linear loads are:

- Urban electric traction (tramway, subway, et. all), induction installations, electrolysis installations that absorb non-sinusoidal current leading to harmonics presence at supply bars;
- unsymmetric electric consumer (welding equipment's, public illumination) that absorbs different current on each phase giving in the same time unsymmetric system voltage at buses;
- Variable loads, such as induction motors in starting process, welding installations by points leading flicker effect.

Primary parameters of power quality are referring to:

-frequency;
-amplitude of main supply voltage;
-overvoltage;
-gaps voltage.

Secondary parameters of power quality are definite by harmonics' presences and flicker effect. [5], [6], [7], [8]

This paper presents an experimental comparative study analyzing the impact of power filters, in a compact fluorescent lamps electric wiring, on the electric power quality by using current spectrum analysis.

2. HARMONICS

Each part of the power system is design to work in a sinusoidal system of the voltages and currents. In fact, in many nodes of a power

system, the sinusoidal waves of current and voltage presented distortions (Fig. 1). [10], [11] these distortions are the results of harmonic presences in waveforms of electrical parameters [12], [13], [14].

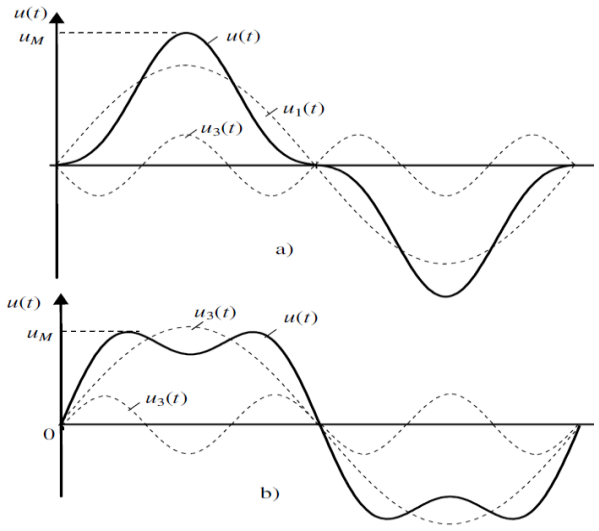

Fig. 1 The voltage waveforms with distortions

3. POLLUTION SOURCES IN POWER SYSTEM

Most electrical equipment's in their operation gives harmonics in a power system. Every equipment with electronically module with AC-DC convertor function produces harmonic pollution. [15], [16], [17]. The wide spreads of pollution sources are computers, UPS, TV receivers and the following also:

- Single-phase controlled rectifier, bi-alternation with resistance load;
- Arc furnace and welding equipment;
- Electric locomotive equipped with rectifier installations.

All of these sources come in the power system with an important value of odd harmonic staring with three ranks. [18], [19], [20], [21]

4. PROBLEM'S CAUSED BY THE HARMONICS

The harmonics' presence in electrical networks provoke some problems, such as: increasing of active power, or inference problems in network communications systems. [22], [23], [24]. The effects of distortions above electrical equipment's functionality are described detailed herein[25] [PE143/94]:

- Malfunction of electronically equipment with power supply connection, including rectifier's command equipment;
- Supplementary errors of measurement apparatus and disturbing functionality of protection relays;
- Up to loading of bank capacitors, as a power factor compensator, over normal operating duty in a consequence of power factor low;
- Active power supplementary losses in an electrical network because of the apparent power increase with deformed power add;
- Increasing impedance of electric network elements. Based on Ohm law the impedance is defined as a proportion of rated circuit voltage and current;
- High level harmonics produce in power system resonance phenomena.

Most of the industrial and home equipment's have a non-linear characteristic. As a consequence, the level of harmonic distortion in the low-voltage network became an important problem. In order to solve that was settled some procedures and standards such as to reduce the harmonic pollution. The electrical receivers have the responsibility to ensure that the harmonics will be filtered, realizing this when is necessary.

5. FILTERS

There are three methods for the reducing harmonic influence. Each of them has advantages and disadvantages. These methods are the following:

- passive filter utilization;
- combined filters;
- active filter utilization

In generally, a filter has in structure inductance, capacitance and/or resistance. The filter is linear when its inductance is unsaturated. [26],[27]

In order to reduce the harmonics are very usefully harmonic's filters. The harmonic's filters are cut-band type with bank capacitors in series with an inductance. In this way the elements of filter will be in resonance with the harmonics' frequency, these harmonics that follow to diminish or eliminate.

On resonance, for the harmonic with k rank, the filter will fill the following equation: [11]

$$X_{bk} - X_{ck} = 0\,, or\ k\omega L = \frac{1}{k\omega C} \qquad (1)$$

where,

L – coil inductance, determinate for main frequency;

C – value of bank capacitors;
$\omega = 2\pi f_1$ – f_1 is main frequency.

6. FILTER'S IMPOVEMENT IN THE QUALITY POWER

The electrical equipment tested in this paper is a laboratory model with six lamps (Fig. 2) and four type of filters.

Experimental stand is composed of: the lamps' assembly, the filter, a power quality analyzer and a computer for storing and data processing.

Data acquisition has been done with a power quality analyzer type C.A.8230 on Harmonics Analyzer mode connected on computer. The analyzed waveforms' are visualized by analyzer software. Using data acquisition has been observed waveforms of currents.

A fundamental tool of analysis of harmonics signals is Fast Fourier Transformation. In practice, the signal is analysed on a restricted time frame using a restricted number of samples of the real signal. [19], [20]

Together with harmonic analysis, the Total Harmonic Distortion (THD) of a waveform is defined as the root of the sum of the square of the harmonic amplitudes divided by the amplitude of the fundamental component of the waveform given by the equation (2) for current:

$$THD_i = \frac{\sqrt{\sum_{N=2}^{\infty} I_N^2}}{I_1} 100 \quad [\%] \qquad (2)$$

where N denotes ration between the highest harmonic order taken into consideration and the amplitude of the fundamental component. [29]

Experimental determinations were carried using four types of filters. [28]

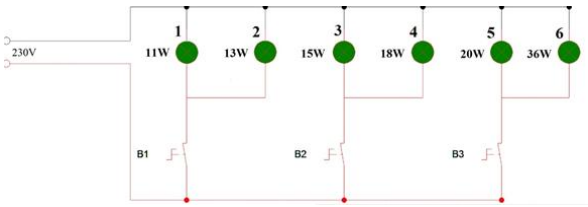

Fig. 2 Wiring diagram used for experimental measurements on lighting sources

The harmonics' current spectrum from figures are generated from data obtained by the power quality analyzer.

For the beginning in the study is analyzed the load current without any filters.

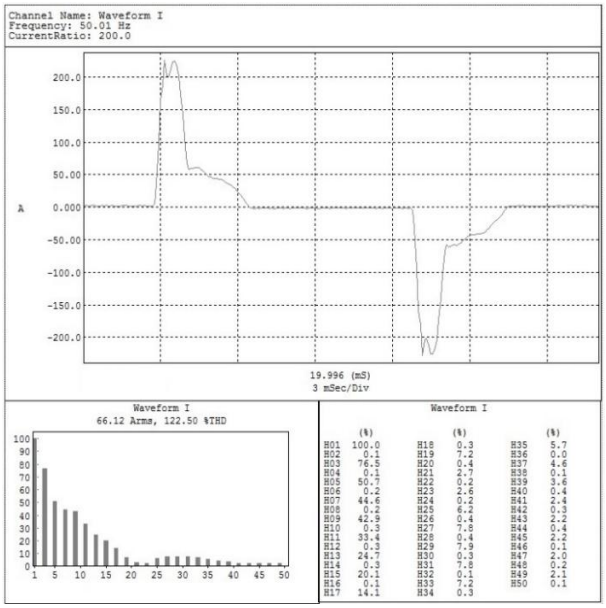

Fig. 3 Waveform of current and current harmonic spectrum without any filters connected

The waveform of the current is periodical, but it is very disturbed. This discrepancy from the sinusoidal form is given by the odd harmonics presented by the 19th rank as in Fig 3. In this case, THD is 122.5%. The next steps consist in put in line by turns every filter.

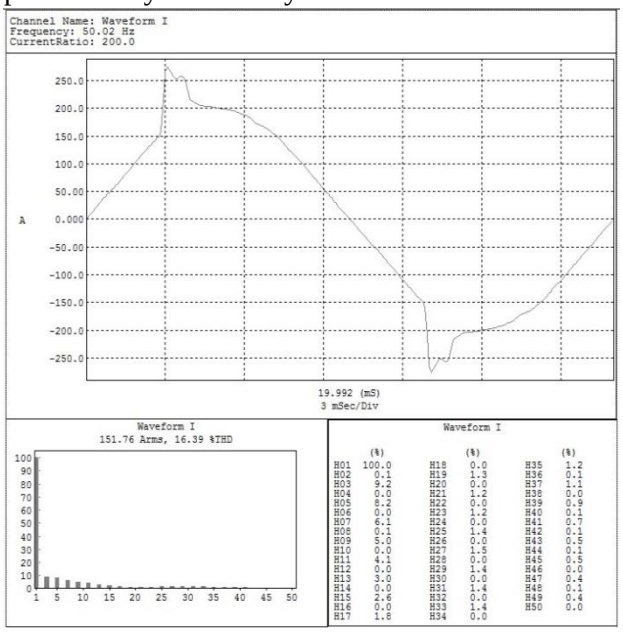

Fig. 4 Waveform of current and current harmonic spectrum with passive filter connected

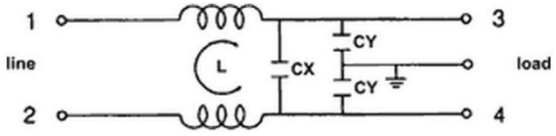

Fig. 5 Passive filter

In Fig. 4 and 5 are presented waveform of the current and current harmonic spectrum with passive filter connected together with the details of this filter. The bigger harmonic it's with the 3rd rank. The filter's efficiency good enough.

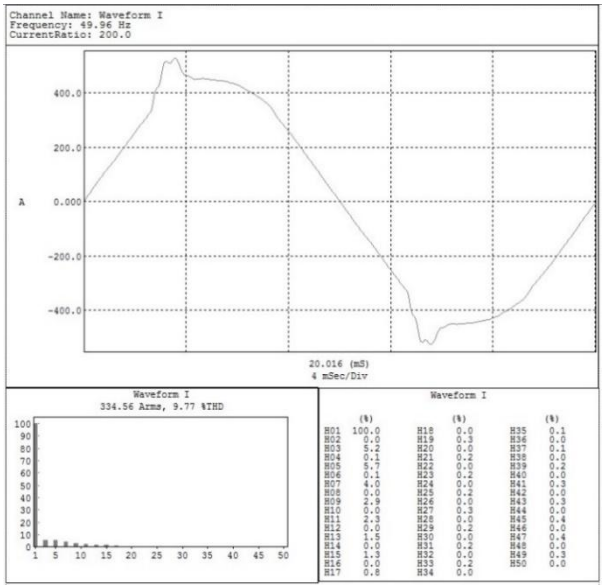

Fig. 6 Waveform of current and current harmonic spectrum with active filter connected

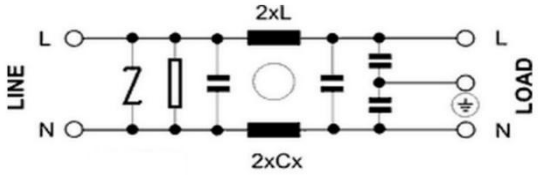

Fig. 7 Active filter

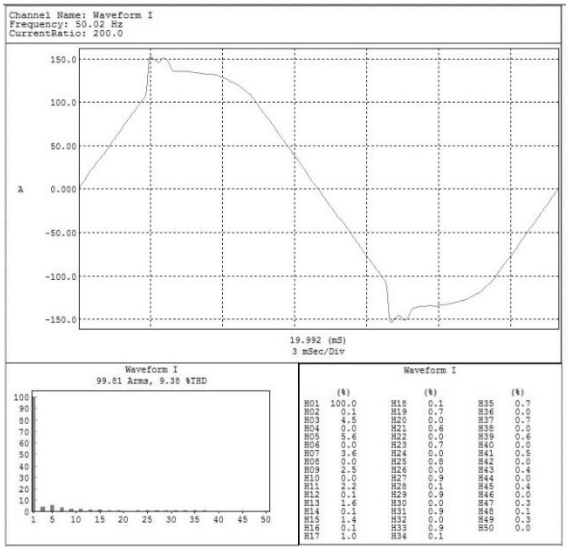

Fig. 8 Waveform of current and current harmonic spectrum with active filter connected

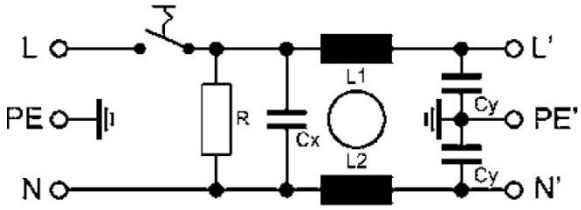

Fig. 9 Active filter

The figures 6,7,8,9 present the waveform of the current and current harmonic spectrum with two types active filter connected and the electrical schemes of these filters. It is observed that every filter improves the THD and the level of odd harmonics.

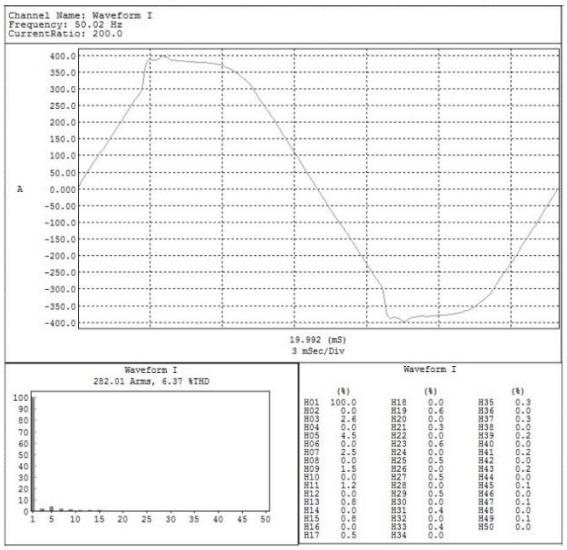

Fig. 10 Waveform of current and current harmonic spectrum with combined filter connected

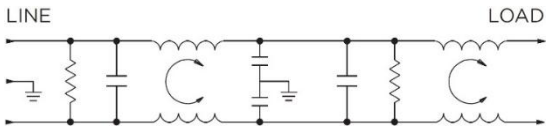

Fig. 11 Combined filter

In the last case, the combined filter is connected (Fig. 10 and 11). It is the best-case condition for the power quality. The third harmonic in current is around 2.6% from main, with important consequences in the sinusoidal form of current. The value of THD*i* is 6.37%.

7. DISCUSSION

"The general intent of IEEE 519-1992 is to limit harmonic current from individual customers and to limit distortion of the system voltage provided by utilities. Customers should not cause excessive harmonic currents to flow, and utilities should provide a nearly sinusoidal voltage." [29]

The THD of first harmonic, according to IEEE 519-1992, is limited to 9.1%, nominal current 225A.

The measures to limit the distortion of power system functionality are:

- decrease of harmonics current, produce by non-linear loads;
- frequency-response modification in point non-linear consumer nodes, by the realization of special electrical supply;
- limitation of harmonic currents flow by the utilization of specialized installation for decrease or elimination of these types of currents.

CONCLUSIONS

In conclusion, compensation of current harmonics can be done with power filters. In the experimental work was proved that the power filters reduce the THD of source current starting at 16.39% in passive filter case to 6.37% in the best case. The power filters decrease or eliminates the source current harmonics making near sinusoidal wave form of load current.

In this way, the THD of source current is according to IEEE-519 standard of harmonic.

This analysis can be continued taking into account the other non-linear loads, such as televisions or clusters of personal computers.

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