High Frequencies in AC Distribution Lines: a New Technical Challenge.

J. L. Frund, F. M. Vincitorio, D. M. N. Balducci, C.E. Freyre, A. Chort, J Favre

Universidad Tecnológica Nacional, Facultad Regional Paraná. Almafuerte 1033 Paraná ER. Argentina
fisicaeletronica@frp.utn.ed.ar

Abstract—In the last ten years it has been observed a considerable growth of non lineal electrical loads. The number of devices, such as PC or compact fluorescent lamps without filters, has dramatically increased due to the lack of proper regulations when the power is under 100 W. As a result, the scientific and technical community has agreed on the possible problems related to massive use of these non lineal loads.

A problem in electrical pollution problem, not widely documented, is the presence of high frequency currents in AC distribution lines. These currents occur when a chopper or inverter configuration is connected through a rectifier to an AC line, without a suitable filter. The choppers, normally used to compensate the power factors, is another typical source of this problem. Therefore, it is possible to detect signals in which the amplitude reach the 50 % of the 50/60 Hz amplitude signal with frequencies that range between 20 kHz and 100 kHz.

In this work, the results of a study of a led street lamp with electronic drivers. These lamp has an elevated level of high frequencies in the first quarter of each semicycle.

The spectrum analysis indicates a different content, depending on the samples mode of high sample rate instruments.

The results of measurements with power analyzer show a high power factor and low harmonic distortion, but they do not show any evidence of the presence of these currents.

As a conclusion, the increment of high frequencies currents in AC line adds a new level of electrical pollution, more difficult to detect and measure and whose effect will be the subject of study.

Index Terms—Distribution Lines, Harmonics, High Frequencies, Instrumentation.

I. INTRODUCTION

IN recent years there has been a large increase in nonlinear loads on electrical distribution networks. This growth is not only observed at home (in equipment such as PC, CFLs and appliances), but also in the industrial field (type electronic welding MMA, MIG / MAG and TIG, induction heating, high power rectifiers). While all this equipment take a sinusoidal voltage signal in the input, its current consumption is far from being a pure and displaced sinusoidal signal, as it would be if they were totally linear loads. An example of this can be seen in figure 1 corresponding to an oscillogram obtained from a 11W CFL [1].
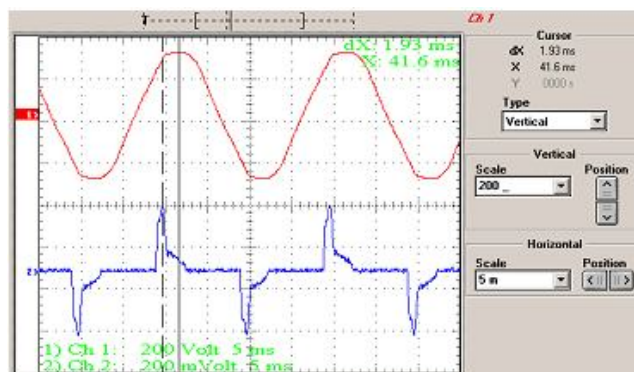

Figure 1. Voltage waveform on channel 1 and current waveform on channel 2. Signs taken from a low energy lamp of 11 W.

This type of signal brings harmonic content that is easily identified with commercial equipment. Within its spectrum, significant harmonics may be found in the order of 2 kHz, with an amplitude of 3% of the fundamental (high-order harmonic). An example of this spectrum can be seen in figure 2 [2].
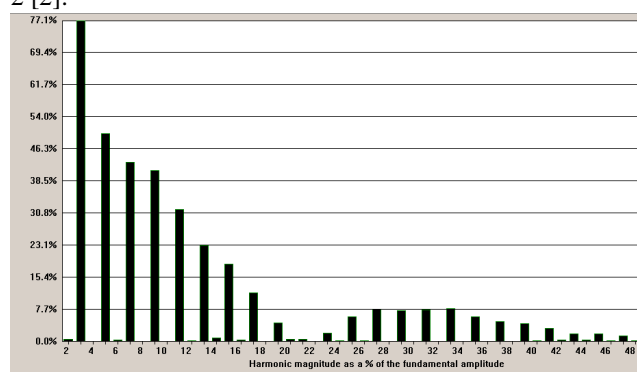

Figure 2. Current spectral content obtained from a CFL of 11 W.

The circulation of harmonic currents on the AC distribution lines causes various undesirable phenomena, both on the network and on the devices connected to it. A defined result of introduction of this type of signals in power networks, is the temperature rise in transformers and conductors [3,4]. It has also been able to detect errors in power measurements [5].

Moreover, in the consultative bibligraphy, there have been found some works where the high frequency harmonic content in CFLs [6] in which the spectrum is analyzed between 10 and

200 KHz are examined.

In order to reduce the harmonic content generated by non-linear loads, new systems, known as Power Factor Correction (PFC), have been developed. Its working principle is based on a switched boost regulator topology or chopper. Internally, the core of these devices is an inductor and a capacitor coupled via diode operating in switching frequency between 50 kHz and 100 kHz. These correctors should operate coupled to the power line through lowpass filters and EMI type.
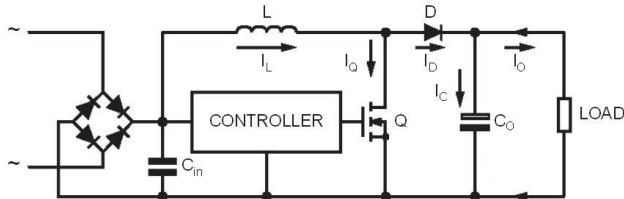

Figure 3. Basic scheme of Power Factor Corrector. Extracted from the AN966, courtesy of STMicroelectronics

This paper analyzes the response of commercial measuring equipment and laboratory to complex signals, in which we find both low and high frequencies. The scope of this work is to open a debate on the number of harmonics to be measured by a commercial instrument because of these new phenomena, updating international standards and define procedures to minimize errors during measurement.

II. TEST METHODOLOGY

A. Measuring Equipment

The equipment used for this test is:
• Network Analyzer MPR-63, BAW brand.
• Oscilloscope TDS 1002B, Tektronix, with current probe of the same firm, model A622.

The MPR-63 is a power network analyzer of the commercial type. It has the ability to measure effective voltage and current of each line and phase, active power, reactive and apparent power, frequency, total harmonic distortion (THD) of voltage and current, power factor (PF) and cosine φ of the three phases. It also has the ability to analyze the harmonic content of voltage and current, up to the 31st harmonic. Another feature is that it has data logging (datalogger).

The TDS 1002B Oscilloscope is a medium to low segment equipment, with two channels, with a bandwidth of 60MHz, sampling rate 1GS/s and record size of 2500 data points. It also has the ability to compute the FFT of the sampled signal.

B. Study case

The device under study is a LED lamp, from Philips, used for street lighting, model BRP361. It consists of a panel of 64 LEDs and LED electronic ballast with Power Factor Corrector, all arranged in a sealed aluminum cabinet.

From the manufacturer's data sheet, it has only been able to extract the maximum power consumption, 115W, and voltage range 220-240V / 50-60Hz. It lacks valuable information such as current consumption, power factor, total harmonic distortion, among other electrical parameters.

C. Measurements

It is defined a long measurement protocol (120 minutes) in which the electrical, thermal and light emission parameters are recorded simultaneously. Within the process of electrical measurements; voltage, current, active power, apparent power, frequency, voltage THD, current THD, power factor and cos φ are recorded. Each of these parameters is recorded at a rate of one sample per minute.

In this long-term, test measurements are taken using the MPR-63 analyzer. A summary of these values can be appreciated in table 1.

TABLE I
SAMPLE RECORD OBTAINED WITH THE NETWORK ANALYZER MPR-63

Date	12/12/2012
Time	07:38 p.m.
Sample nº	10
Voltage [V]	224,3
Current [A]	0,575
Active Power[W]	125
Aparent Power [VA]	129
Frequency [Hz]	50
Voltege THD	2
Current THD	9,9
Power Factor	-0,97
Cos	-0,97

The harmonic content of the current signal is also got by the Network Analyzer.

A second short-term test is conducted by sampling waveform current consumed by the luminaire. This is done with the oscilloscope TDS 1002 and A622 current probe.
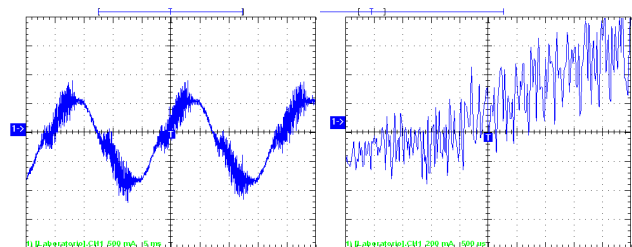

Figure 4. The oscillogram indicates the presence of HF signals modulated on the 50 Hz, obtained by Tektronix TDS 1002B

The oscillograms in figure 4a a nearly sinusoidal signal can be seen, which shows a higher frequency spurious wave mounted on the sinusoidal current. By increasing the sampling rate of the oscilloscope it was determined that the mounted signal has a harmonic frequency of about 100KHz (figure 4b).

Figure 5, a signal obtained by changing the settings of the oscilloscope to perform a average mode of acquisition can be seen.
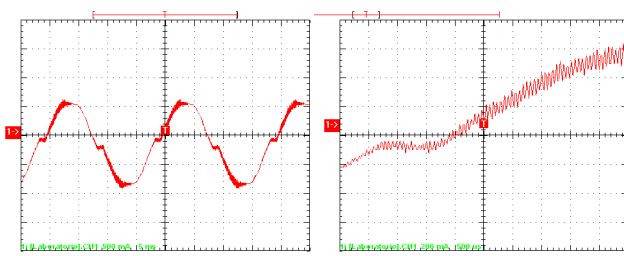
Figure 5. The oscillogram indicates the presence of HF signals modulated on 50 Hz, in an attenuated form obtained by Tektronix TDS 1002B average sampling mode.

D. Analysis of measurement results

From the measurement made with the oscilloscope, configured with sampling acquisition mode, it could be demonstrated a high frequency harmonic component mounted on the fundamental current wave, whose peak value is about 1/3 of the peak value of the 50Hz signal.

Furthermore, the network analyzer gave a THD of 10% and PF of 0.97. Also, analyzing the current harmonic content, this was shown to be similar to the one obtained with the oscilloscope with average acquisition mode.

On the FFT performed by the oscilloscope, it could be seen that the harmonic calculates at a higher frequency is in the order of 60KHz.

From the above mentioned, it is clear that none of the instruments is fully capable of making measurements that produce correct results.

III. SIMULATION AND ANALYSIS

In order to perform the laboratory assay bounded conditions, three signals with similar characteristics to that found in the case study were generated.

These signals are composed of a 50 Hz sinusoidal signal to which is added a high frequency square wave (which we will call "spurious signal"), with 1/3 of the peak value only on sections of growth after zero crossings. The frequencies introduced are 25KHz, 50KHz and 100KHz. A sample of this signal can be seen in figure 6.
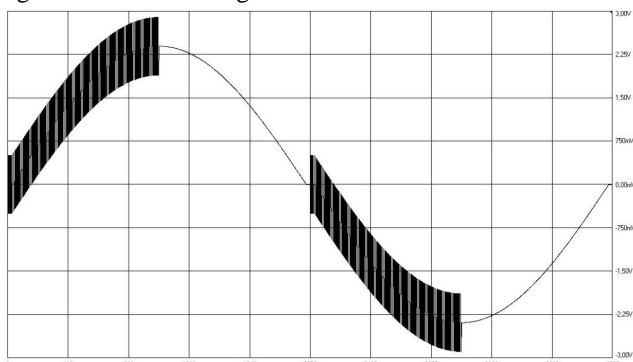

Figure 6. 50Hz sine wave added to a 100KHz square, in the period $[0, \pi / 2]$ and $[\pi, 3\pi / 2]$.

The waveform function generator is used to generate a signal with a vertical resolution of 12bits and a maximum of about 4096 points per periods. If the period is set to 50Hz, and taking into account a number of 4000 points per period, we

can make generate a square signal of maximum frequency of 100KHz.

These signals were inserted into the oscilloscope, simulating the phenomenon found during the case study measurement.

In figures 7, 8 and 9, each of the signals input to the oscilloscope and the respective spectra obtained by FFT on the oscilloscope can be seen.
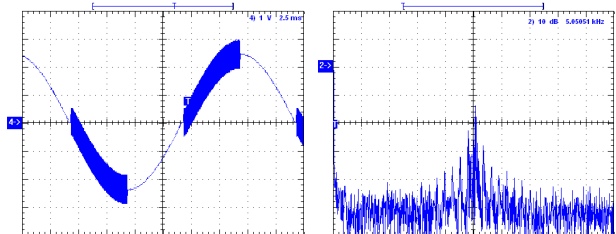

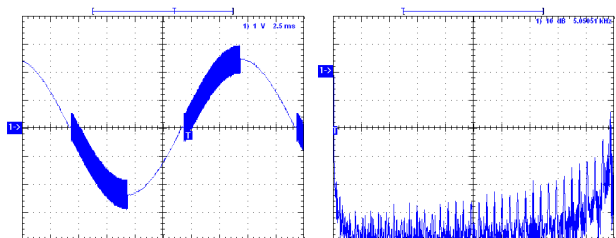Figure 7. Noisy signal of 25 kHz. It clearly shows the noise spectrum.

Figure 8. Noisy signal of 50 kHz. Only a part of the noise spectrum can be seen.
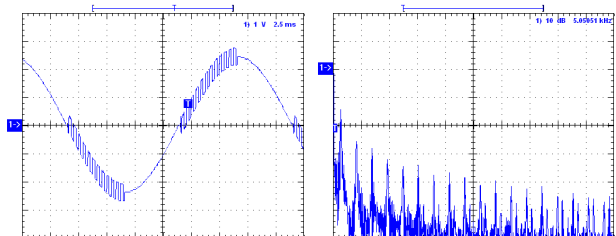

Figure 9. Noisy signal of 100 kHz. There is not evidence of 100 kHz signal. Reflected harmonics (aliasing) are shown.

From these figures, it is shown that the high-frequency signals with 25kHz and 50kHz can be displayed on the oscilloscope without drawbacks. However, to get the FFT, it is only acknowledged the spurious signal fundamental and some harmonics.

The most critical case is the measurement of the composite signal with 100KHz frequency spurious. In the oscillogram, a subsampling of it can be seen, which results in errors in the determination of the FFT. To better observe the high frequency signal, sampling rate must be increased which causes the loss of information from the low frequency signal.

IV. DISCUSSION OF THE RESULTS

According to the manufacturer's manual, the MPR-63 takes 64 samples per signal period. If we consider this sampling rate, we can understand that the higher order harmonic that can be obtained with the analyzer is 31 with a frequency of 1.6 KHz. The conclusion is that the measurement is performed

subsampled.

The latter derives in obtaining not repeatable results of THD and PF parameters, since in its calculation the contents of all harmonics present in the signal should be taken into account.

In the oscilloscope, there are some problems at the moment of measurement. By performing the FFT of the sampled signal, the maximum obtained frequency is in the order of 60KHz, far from the spurious frequency found. According to the manufacturer's manual, the TDS1002B oscilloscope has a size of 2500 contiguous samples data record in time. From this record it is calculated the FFT and it is displayed on the screen. The size frequency record obtained is half the corresponding in the data record in time, leaving about 1250 harmonic values.

If, to represent a 50Hz signal full period at 2500 samples, a 125KHz sampling rate is needed, therefore, the frequency range of the FFT is half the sampling rate and the higher order harmonics obtained in this operation is 62.5 KHz.

Furthermore, the oscilloscope TDS 1002B is not able to obtain the real frequency spectrum of the analyzed signal.

Seeing that the incorporation of the circuits called Power Factor Correctors to the electrical network, whose switching frequency is in the range of 50 kHz to 100 kHz, it is imperative to build network analyzers of broad spectrum which could reach harmonics up to 1MHz (taking into account that it would be the 10th harmonic of the basic signal of 100KHz).

It would be necessary to modify the existing regulations to include high frequency harmonics generated by nonlinear loads.

As it was above mentioned, it is clear the need to define procedures and measurement protocols using oscilloscopes to identify the harmonic content of these complex signals.

Moreover, you should think about a redesign of power analyzers equipment increasing the bandwidth and the sampling rate. Finally, it should be normalized using high capacity filters that eliminate any high frequency signal modulated on 50Hz line.

V. CONCLUSION

We have demonstrated the existence of high frequency signals introduced by electronic devices with power factor correction. The case study, a street LED lamp, lighting technology located at the technological frontier, demonstrates the lack of regulations and studies that force manufacturers to eliminate these signals.

The high frequency present on the line introduces a change in measurement methodologies and their effects on power lines are certainly unknown.

In conclusion, in this paper, it has been proved that commercial network analyzers are obsolete when measuring voltage and current signals with high frequency harmonic content, giving erroneous measurements of THD and PF parameters. Although these follow the current regulations, these regulations exclude harmonics above the 51.

Finally, the oscilloscopes from well-known brands of medium to low gamma, have difficulty to get the full spectrum, due to the large difference in frequency between the fundamental signal and the current generated by electronic elements.

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José Luis Frund was born in the city of Rafaela, Argentina, on November 2nd, 1982. In 2009, he graduated as an electronics engineer at Universidad Tecnológica Nacional (UTN), in Paraná.

He is an assistant professor in Power Electronics. He is also a freelance worker who is specialized in the development and repair of electronics systems of power for illumination applied to industry. He has published many articles about electronics for illumination power and control in national and international journals.
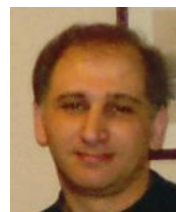
Fabio Miguel Vincitorio was born in the city of Paraná, Argentina, on January 21 st, 1970. He graduated as an electronics engineer in 1998 at Universidad Tecnologica Nacional (UTN), in Paraná. He is finishing his PhD thesis at La Coruña University (Spain).

He is a professor in Physics and he is also working as an assistant professor in the subject Power Electronics at the UTN. In 2004, he founded the firm V-Z Engineering, a company that deals with the production and development of alternative energy and control. He has published many articles about electronics systems for illumination and, applied to holography non-destructive testing that appeared in international and national journals.