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Study Of The Harmonic Content In Public Lighting Lines Fed By Electrical Components Between Phases Or Using Autotransformers

Alonso Velo*; Ezequiel Marzano*; Marcos Azcune*; Tomas Gabrieli*
Ing. Federico Conte**;Ing.Marioblume***
**(Undergraduate student, Department of Electrical Engineering, GEEE[1]–FRSN, UTN)*
***(Assistant Professor, Department of Electrical Engineering, GEEE –FRSN-UTN)*
****(Professor, Department of Electrical Engineering, GEEE – FRSN- UTN)*
Corresponding Author: Ing.Mario O.

ABSTRACT: *Nowadays, electronic devicesare frequently usedin street lightning. Theequipment variesfrom electronic ballasts for sodium vapor lamps to modern led devices. They provide substantial benefits, for examplethey improve lamps' performance and energy efficiency. However, they may also present the great disadvantage of generating harmonic currents that harm the quality of the energy available in thesurroundings. This detriment in energy quality results in home users, shops, workshops, etc. having high harmonic content in the electric energy they receive from the network. This, in turn, interferes in the correct and safe use of equipment such as computers, radio receivers, engines, etc., or untimely trips differential protections.*
This study comparesthe harmonics content of a set of LED devicesconnected in a conventional way,i.e. between a phase and neutral, witha similar set connected by means oftransformers. The aim is to investigate whether these transformers actually affectthe harmonic currents generated by these devices and the power system that feeds themthereby affectingthe harmful effects on energy quality. The results suggest that the harmonic distortion changes using autotransformers without attenuating the problem.Finally, new research lines are proposed.
KEYWORDS: *Power quality, harmonic distortion, LED street lighting, non-linear charge model.*

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I. INTRODUCTION

Standard UNE-EN-60150: 2011 defines harmonic voltage as "a sine-wave voltage whose frequency is an integral multiple of the fundamental frequency of the supply voltage in the system" [1]. Fourier defined this phenomenon stating that "any periodic signal, however complex it may be, can be decomposed into a sum of sinusoidal signals whose frequency is a multiple of the fundamental or the reference frequency " [2].

In general, harmonics are generated by non-linear loads,which means that their impedance is not constant and is given as a function of voltage. These non-linear loads, despite being fed with a sinusoidal voltage, absorb a non-sinusoidal current. In simple terms, non-linear loads behave as sources of intensity that inject harmonics into the network.

The most common non-linear loads are those found in receivers fed by power electronics, such as variable frequency drivers, rectifiers, converters, saturable reactors, welding equipment, arc furnaces, etc.

It is evident that LED lighting, being a non-linear load, is a considerable source of harmonics and its widespread use in street lighting could create additional ammonium losses, which could also be significant in the low voltage lines that feed them. This suggests that the quality of energy, in terms of harmonic distortion, is affected.

Some studies suggest that the use of autotransformers to feed LED artifacts could reduce the amount of harmonics that are sent to the network [3]. This research project aims to corroborate these effects by measuring the electric variables which make it possible to compare the harmonic distortion in one case and the other.

Harmonics affect protection systems, and cause equipment and electrical networks overheating and resonance effects, among other problems. [4]. When these types of loads are connected to the network the quality of the energy is negatively affected, due to the increase in harmonic distortion. Therefore, it becomes necessary to reduce the harmonic content that is generated.

[1]EnergyEfficiencyResearchGroup – Facultad Regional San Nicolás – Universidad Tecnológica Nacional

II. MEASUREMENTS AND ANALYSIS

The objective of the measurements is to comparethe harmonic distortion when a device or series of devices are feddirectly from the network voltage and when they are fed by autotransformers connected to the same voltage source.

For this purpose, a test board was made where the lighting devices were connected independently. The test board also allows the voltage supply to be provideddirectly from the grid or by means of a transformer, simply by changing the connections.

Fig. 1. Test board developed for measurements

The cable coils observed in the board have the purpose of minimizing errors in the measurement, taking advantage of the effect of multiplication of the current as a function of the number of turns.In this way the amperometric clamps of the network analyzer correctly measure the currents.

The successive measurements carried out involved the measurement of harmonics in the following alternatives:

1) Direct supply with mains voltage: One LED device only; Two LED devices; Three LED devices

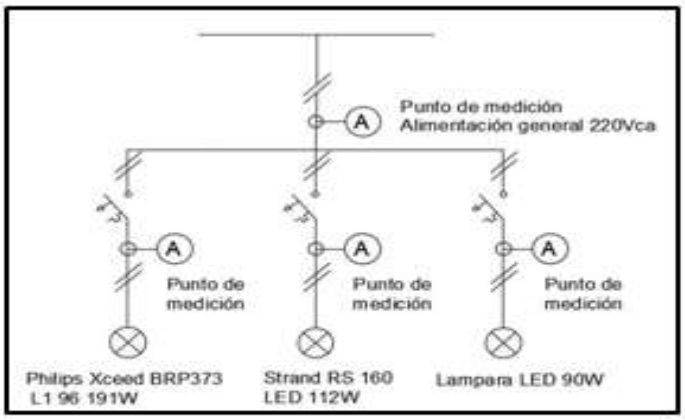

Fig. 2. Connection of devices with direct voltage supply of the network and the indication of current measuring points

2) Feeding with Autotransformer: One LED device only; Two LED devices; Three LED devices

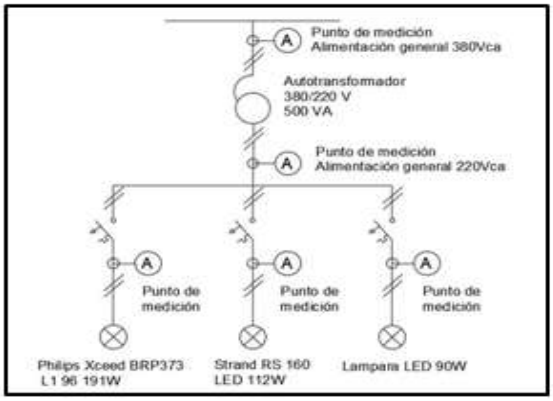

Fig. 3. Connection of devices with voltage supply by means of autotransformer, and the indication of the current measurement points

The autotransformer employed has a transformation ratio of 380/220, which would allow it to be used in the distribution networks of our country. Its apparent power is 500VA.
To perform harmonic level measurements, a Square-D PowerLogicPCM4000 network analyzer was used. The interface software used to obtain the data was Powerlogic System Manager SMS 121.

Fig. 4. Square-D PCM4000 network analyzer and test board

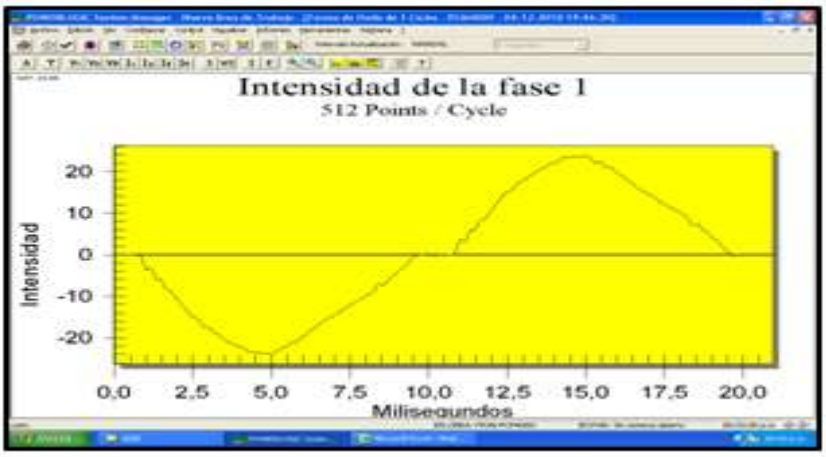

Fig. 5: Screen of the software POWERLOGIC System Manager SMS 121 with the resulting waveform obtained in one measure

The LED artifacts used in the measurements were: Philips Xceed BRP373 L1 96 191W, Strand RS 160 LED 112W and ageneric 90W lamp.Current measurements were made on each appliance, in the 220Vac general power supply and, in the case of autotransformer power, in the 380Vac power supply.

III. RESULTS

The resultsobtainedfrom the measurements suggest that the distortion of harmonics is greater when autotransformers are used to feed light fixtures than when they are not used, i.e., when the fixtures are connected directly to the power supply.

The first graphic showsthat harmonics of third order are higher when the light fixture is fed with 220 V directly from power supply than when the whole system is fed with 380 V using autotransformer. This phenomenon can also be observedin the seventh harmonic; maybe this last one is not as important as the third one, but this effect is worth highlighting.

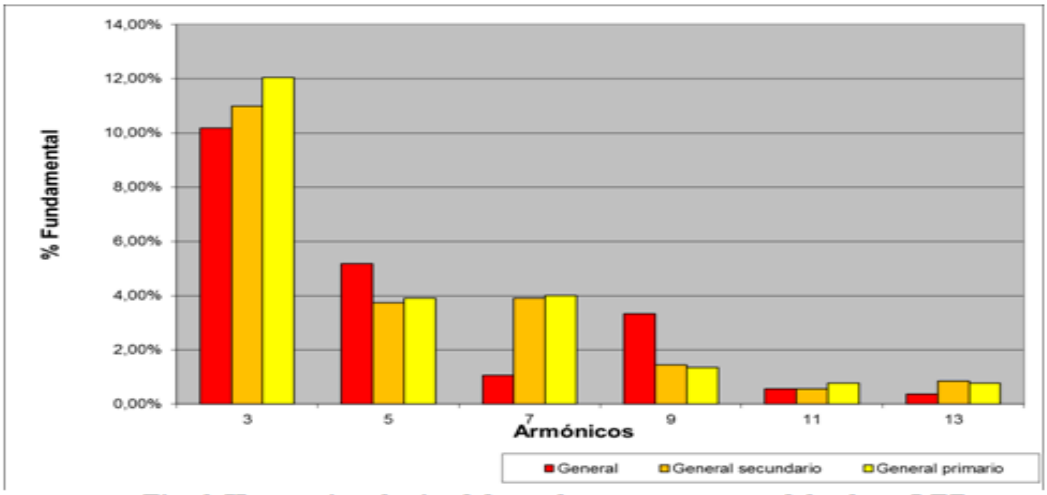

Fig. 6. Harmonics obtained from the measurement of the three LEDs.
Red: fed with 220 V;
Orange: fed with 220 V through an autotransformer;
Yellow: fed with 380 V or primary of autotransformer.

The Total Harmonic Distortion (THD) for each case was:

1) Fed directly with 220 V: 12,73
2) Fed with 220 V through secondary of autotransformers: 12,74
3) Fed with 380 V or primary of autotransformer: 13,8

IV. CONCLUSIONS

The use of individual autotransformers to feed LED road lighting devices shows an evident non-linearity, and it does not solve the harmful effects of the harmonic currents sent to the network.On the contrary, autotransformers increase harmonic currents, making harmonic distortion greater. A possible reason lies in the connection scheme used.

The connection used for the measurements was a 380Vac 2 phase onein a three-phase network as power to the autotransformers; their output is 220 Vac. In this way, and although the secondary of the transformer that feeds the low voltage network (380Vac + Neutral) is connected in a star configuration with its neutral to ground, it allows the third harmonics (the most important) to travel along the lines of the phases until they close in the neutral. But the cancellation in the neutral does not imply that they have been eliminated from the network due to what was mentioned before.

In addition, the quality of the autotransformers used must be evaluated. In general, for low power, the transformers and autotransformers that are commercially available tend to have a quality in accordance with the load they will feed. Then, if the quality of the transformers and autotransformers should be improved, we could be facing a cost-benefit relation impossible to justify.

This conclusion invites us to think that an alternative may be to use a group of transformers dedicated exclusively to the power supply of the public lighting system. Their voltage tap should be from the distribution network of 380Vac + N and the connection diagram to be evaluated should imply that the transformation ratio is 1 to 1 (i.e. 380V to 380V), whose primary winding is connected in a triangle configuration and the secondary in

star layout with neutral to ground. This secondary voltage will be dedicated to the power supply of the public lighting network.

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