

HARMONIC ANALYSIS OF LED STREET LIGHTING ACCORDING TO IEC61000-3-2; A CASE STUDY

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ABSTRACT

This paper investigates harmonic pollution aspects to be taken into consideration in utilizing LED lighting products in street lighting projects. It also summarizes the IEC limits for class C equipment. An experimental setup utilizing a HIOKI 3197 Power quality analyzer is assembled to achieve exact data of harmonic components of equipment under test. A personal computer is also used for analyzing the data. Results show that LED lamps are compliant with IEC61000-3-2 Standard.

INTRODUCTION

One of the most challenging discussions in distribution companies is power quality. The issue of harmonic distortion and the impacts of nonlinear loads were reported as well in 2011 [1]. The presence of harmonics in distribution networks can lead to various problems such as equipment overheating, reducing the power factor, failure or malfunction of electrical equipment and protective relays, interference with communication circuits and other types of severe damages.

In recent years LED lighting plays a crucial role in the field of street lighting systems that offer the advantages of increased energy efficiency and can provide consequential energy savings as well as color quality. This paper tries to investigate harmonic distortion in recently commerce street lighting systems according to IEC61000-3-2 standard.

For the utility companies in Iran, there is not any permanent grid measurement giving evidence of a poor power quality in the distribution network.

The purpose of this examination is to provide electric utilities with certification that the public lighting has been designed to meet the illumination standards and requirements of the IEC61000-3-2 and that the design does achieve those requirements. Whilst distributor is not responsible for determining whether public lighting should meet the IEC61000-3-2 standard, MEEDC requires this information as the public lighting infrastructure becomes part of MEEDC's distribution network and MEEDC is responsible for the ongoing maintenance of the infrastructure.

In MEEDC, public lighting sector constitutes around 0.1% of the total consumption. That is why practical measurements on the street lighting sector have not been developed due to changing to LED lighting.

LED Luminaire consists of a solid-state light source, a control gear and optics for light distribution. Basic block diagram of LED driver is shown in figure 1 [2].

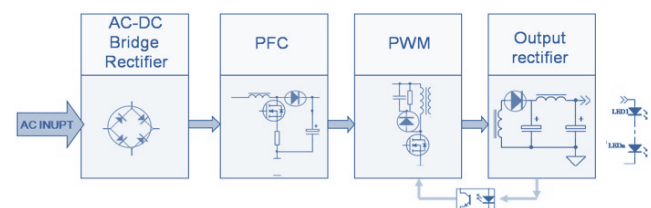


Fig. 1: basic block diagram of LED driver.

The measurements were carried out using HIOKI power quality analyzer at the R&D laboratory of Mashhad Electric Energy Distribution Company.

IEC61000-3-2 STANDARD

While the relevant standards and requirements applicable to the public lighting projects are considered, distributors should also take into account operating requirements and specific circumstances of their network. The authorization to connect equipment to the low voltage system depends on the levels of disturbance caused by the equipment [3,4].

IEC61000-3-2 specifies the limits for harmonic currents of equipment connected to low voltage distribution networks. This standard assesses and sets the limit for equipment with the input current $\leq 16A$ per phase and covers both quasi-stationary harmonics and fluctuating harmonics. According to this standard equipment is classified into 4 classes in which class C is lighting equipment including dimming devices [5,6].

Equipment can be grouped into one of 4 classes based on the following [7]:

- Number of pieces of equipment in use
- Duration of use
- Simultaneity of use
- Power consumption
- Harmonics spectrum

Taking the aforementioned criteria into consideration equipment is classified as listed in Table 1.

Note that in amendment 2 of IEC 61000-3-2 on 2009, it was decided to separate limits for lighting equipment with consumed power over 25.

Table 1: Equipment classification

Class A	<ul style="list-style-type: none"> Balanced three-phase equipment Household appliances, excluding equipment identified by Class D Tools excluding portable tools Dimmers for incandescent lamps Audio equipment Everything else that is not classified as B, C or D
Class B	<ul style="list-style-type: none"> Portable tools Arc welding equipment which is not professional equipment
Class C	<ul style="list-style-type: none"> Lighting equipment over 25 W including dimming devices
Class D	<ul style="list-style-type: none"> Equipment having an active power of less than or equal to 600W and is either a PC or PC monitor, or a television.

The harmonic current limit for class C equipment is shown in Tables 2 in which λ is power factor of the equipment. It should be taken into consideration that these limits are for individual harmonics and do not specify total harmonic distortion (THD) [8,9]. As it can be seen, only odd-order harmonics are shown because the even-order harmonics are almost zero due to sine-wave symmetry.

Table 2: Harmonic limits for class C equipment

Harmonic order (n)	Maximum value expressed as a percentage of the fundamental input current of luminaires
3	$30 \cdot \lambda$
5	10
7	7
9	5
$11 < n < 39$	3

HARMONIC MEASUREMENT

This section illustrates the design of the experimental setup and the testing procedures for determining the harmonic performance of LED lamps. The experiment consists of an ac power source, LED luminaires of various commercial brands with different power ratings and a power quality analyzer. LED luminaires investigated in this paper are manufactured by three different companies.

For each test, harmonic measurement is carried out using HIOKI 3197 power quality analyzer as depicted in Figure 2. This measuring instrument is a handheld power quality analyzer for monitoring and recording power supply anomalies, allowing their causes to be quickly investigated according to IEC61000-3-2.


Fig. 2: experimental test using a power quality analyzer.

Measuring the equipment that its power consumption remains unchanged is relatively easier as it has a constant current harmonic spectrum throughout the test duration. In this survey, 5 different types of LED luminaires from various manufacturers were investigated.

If the measured values are less than, or equal to the limits given in IEC 61000-3-2, it could be declared that the LED luminaire meets the Electromagnetic Compatibility (EMC) of IEC61000-3-2.

It should be noted that power factor measurement is also required to evaluate 3rd harmonic of equipment current according to IEC61000-3-2 [6,7].

RESULTS AND ANALYSIS

5 samples of high brightness LED lamps with different power ratings from various manufacturers were tested to analyze the harmonic characteristics of LED lamps.

Figure 3 shows harmonic content of the current through the LED luminaires. The sum of all these harmonics will lead to the waveform as represented by figure 3. The purpose of illuminating voltage and current waveforms in time domain is to record any time-varying changes in voltage and current distortion. Taking this figure into account, it can be concluded that the current waveforms are not purely sinusoidal, indicating that they contain harmonic components.

As was mentioned earlier, it is necessary to measure power factor in order to verify 3rd harmonic distortion. Figure 4 reveals PF values obtained from the tested LED lamps. Consequently, 3rd harmonic limits as a percent of fundamental current is shown in figure 5.

Having considered the maximum permissible harmonic currents in accordance with table 2, it can be concluded that all LED luminaires are compliant with IEC61000-3-2 standard.

Comparison of electrical quantities, such as RMS values of voltage and current, active/reactive power, power factor, and total harmonic distortion (THD) for LEDs is presented in Table 3.

There is also a requirement for the applied voltage

waveform. As it can be obviously seen, whilst the harmonic content of the voltage waveform fulfills the harmonic limits mentioned in IEC 61000-3-2, the harmonics are not far outside the allowable limits.

However care should be taken into account that a distorted voltage waveform will have its effect on the current waveform as well.

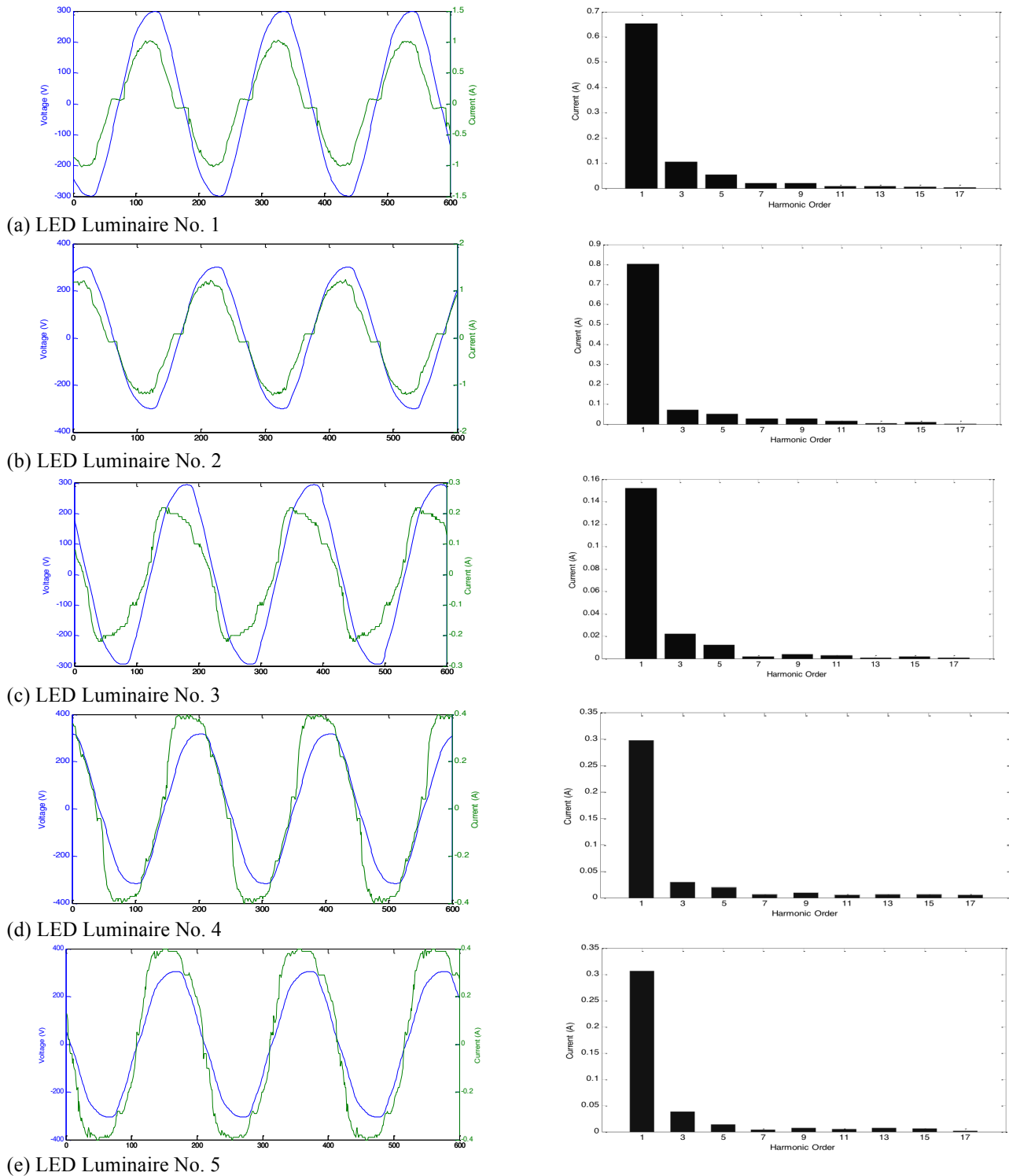


Fig. 3: Voltage vs. current waveforms of LED lights along with current harmonic spectrum.

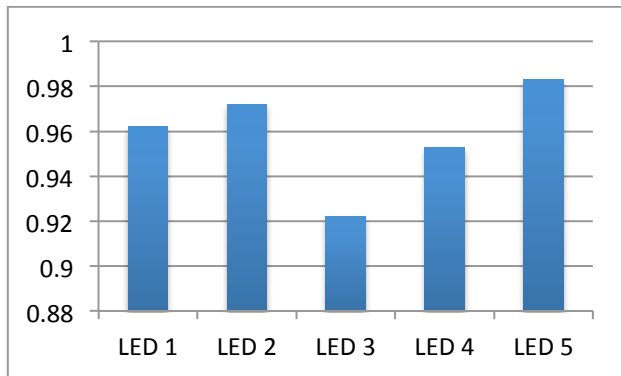


Fig. 4: power factor of LED lamps

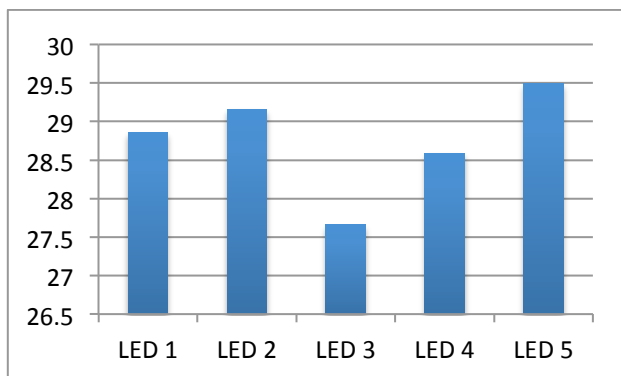


Fig. 5: 3rd harmonic limit (% of fundamental)

Table 3: Experimental results of LED modules

LED Lamp	LED1	LED2	LED3	LED4	LED5
Voltage (V)	229.0	229.3	229.3	229.5	229.1
Current (A)	0.667	0.820	0.157	0.298	0.309
Active Power (W)	147	182	32	65	67
Reactive Power (VAr)	39	41	12	21	12
Power Factor	0.962	0.972	0.922	0.953	0.983
Current THD (%)	18.5	12.5	17.3	13.5	14.0

CONCLUSION

In general, this paper examines harmonic distortion of LED lighting equipment in low voltage distribution utilities. The present study, however, reveals several field measurement results. Evaluation of harmonics generated by LED luminaires is conducted using a power quality analyzer. It is shown that measured values are less than the limits given in IEC61000-3-2. Consequently, the LED luminaires meet the Electromagnetic Compatibility (EMC) of IEC61000-3-2. Analyzing this topic, it is important to note that if the harmonic level exceeds the limits mentioned in IEC 61000-3-2 standard, it must be reduced by a mitigation approach.

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