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## Harmonics study of common low wattage LED lamps

This article presents experimental data on Light Emitting Diode (LED) lamps of low wattage that are commonly found both in commercial and residential applications. A comparison with the existing regulations is performed. The measurements are performed using power and energy quality analyzer intended also for avionic and military systems.

Keywords: LED lamps, Harmonics, THD, Power Quality in vessels electrical installations.

### 1. Introduction

This study has been commenced due to global tendency to use as lighting devices the LED (Light Emitting Diode). This trend is clearly underlined in many market studies, such as [1]-[6].

The LED lamps become more popular especially due to their advantages, such as: high energy efficiency reaching up to 110 Lm/W, longer life time, reaching up to 50000 hours of operation.

In comparison with present common lighting equipment, i.e. CFL (Compact Fluorescent Lamps), LEDs are three times more energy efficient and the life time is also three to four times longer than CFLs. When compared to incandescent lamps, the LED lamps are ten times more efficient [7][8].

An example of commercial application is the lighting of transportation vehicles, such is the case of vessels. In [9] it is presented a case study for replacement of fluorescent lamps with LED lamps. Also, the energy savings obtained in the case of 6500 TEU container vessel is 4% for the power supplied by the electric generator. The cost savings per year are increasing to about 10% year on year (during 5 years after the investment).

Even though the marine industry has oriented to electric drives and other equipment, there is an important issue that has to be considered. This is the power quality concern, as shown in [10].

The harmonic content is an important issue both for voltage and current waveforms. The presence of harmonics implies power loss, i.e. the equipment supplied with a distorted voltage has additional losses. The equipment also includes that cables between the power source and the load. These additional losses represent in fact an overloading of the electronic and electric devices along with the distribution cables. The overloading leads directly to additional heating and thus the malfunction of the equipment is inherent or the operation is not safe. Moreover, some equipment that has been designed for a sinusoidal proper operation, when supplied with non-sinusoidal wave forms, might become a source of electromagnetic interference, which can harm near by sensitive electronic equipment, such as telecommunication modules [11].

The distortion degree is defined by the Total Harmonic Distortion factor [12]:

$$THD_x = \sqrt{\frac{\sum_{h=2}^n X_h^2}{X_1^2}}, \quad (1)$$

where:  $X$  is the electrical quantity (RMS voltage or current) for which the distortion is computed,  $h$  is the harmonic number.

Reverting to the performed study, the LED lamps from two manufacturers (Philips and Total Green) have been analyzed regarding the harmonic content and the total harmonic distortion of the absorbed current.

## 2. Standard of harmonic distortion limits

In order to maintain the quality of the AC power supply system, especially in vessels power electrical installation [10], regulatory standards should be met. For LED lamps the applicable directives are found in IEC 61000-3-2 which sets the limits for lighting equipment under 25W. In Table 1 are provided the harmonic limits found in IEC 61000-3-2 Class C limits for lighting equipment.

Table 1

| Harmonics [order] | Class C [% of fundamental] |
|-------------------|----------------------------|
| 3                 | 30 x Cosφ                  |
| 5                 | 10                         |
| 7                 | 7                          |
| 9                 | 3                          |
| 11                | 3                          |
| 13                | 3                          |
| 15÷39             | 3                          |

Also, IEC 61000-3-2 draws voltage distortion limits which isn't allow to exceed 5% for supply voltage Total Harmonic Distortion (THDv).

### 3. Measurements and results

Technical characteristics of the measured LED lamps are given in [Table 2](#).

[Table 2](#)

| LED lamp manufacturer | Rated Power [W] | cos $\phi$ [-] | Color temp. [K] |
|-----------------------|-----------------|----------------|-----------------|
| Philips               | 4               | 0.69           | 2700            |
|                       | 6               | 0.71           | 2700            |
|                       | 9.5             | 0.62           | 2700            |
|                       | 10.5            | 0.6            | 6400            |
|                       | 13.5            | 0.68           | 2700            |
| Total Green           | 8               | 0.58           | 2700            |
|                       | 13              | 0.62           | 2700            |
|                       | 16              | 0.65           | 2700            |

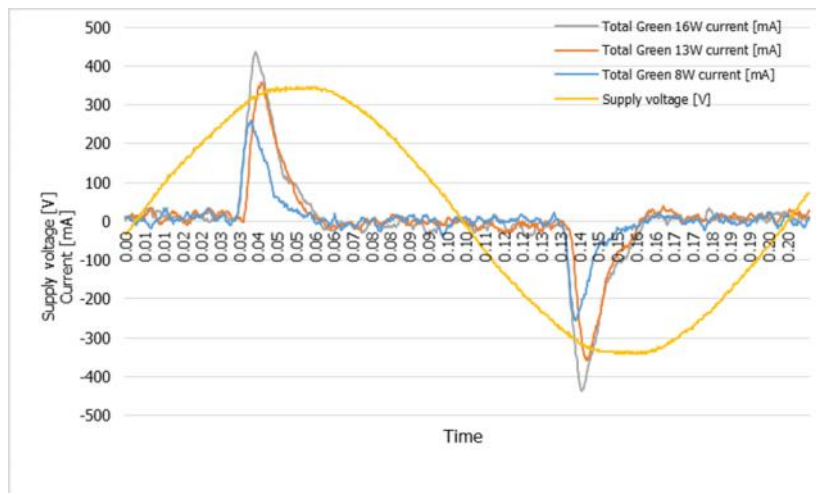
The experimental setup is depicted in [Figure 1](#) and it contains a power quality and energy analyzer Fluke 437 series II, an oscilloscope Tektronix TPS 2024B, a laptop, a lamp tester and a voltage divisor for the oscilloscope. The power analyzer is compliant with IEC 61000-4-30 Class-A standard.



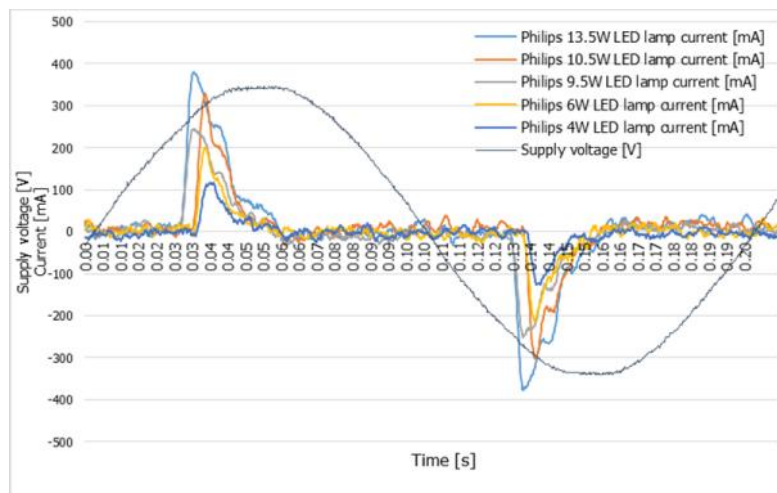
[Figure 1](#). Experimental setup

Before performing the final measurements each lamp has been kept on for 5 minutes for stabilization. The THD values of the voltage (THDu) and current (THDi) have been computed by the power analyzer. The instantaneous waveforms have been recorded using the oscilloscope. The oscilloscope has acquired data for 5 ms with a 0.002 ms step, i.e. 2500 points.

In **Figure 2** and **Figure 3** are presented the wave shapes of the absorbed currents by the measured Total Green and Philips LED lamps respectively.

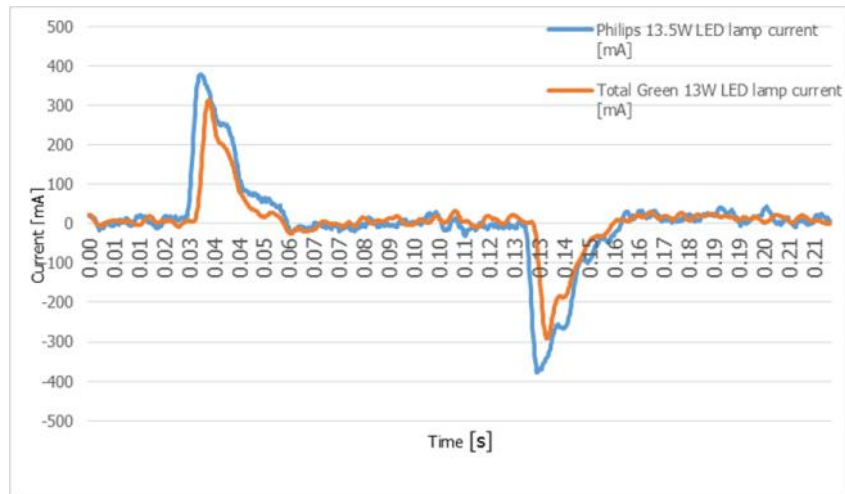


**Figure 2.** Total Green LED lamps current waveforms



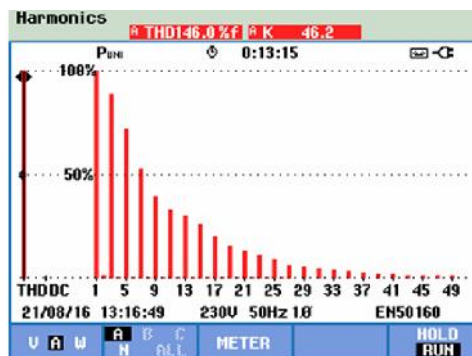
**Figure 3.** Philips LED lamps current waveforms

In **Figure 4** is presented a comparison in time domain of the current waveform for similar LED lamps (about 13W) from the two providers. The shape is similar and the 13.5W lamp has a current with greater amplitude.



**Figure 4.** Philips versus Total Green LED lamps current waveforms

A better analysis is in frequency domain. Thus, in **Figure 5** and **Figure 5** are depicted the screenshots from the power analyzer for the Total Green 13 W and Philips 13.5W Led lamps respectively regarding the current harmonic content and THDi factor.



**Figure 5.** Total Green 13W LED lamp - (THDi=146 %, THDu=1.7 %).

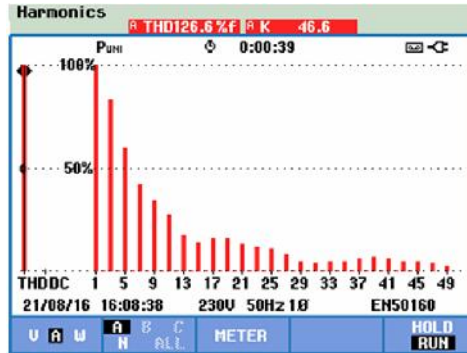


Figure 6. Philips 13.5W LED lamp - (THDi=126.6 %, THDu=1.1 %).

Results regarding the harmonic content and THD values are given in Table 3 and Table 4 for Total Green and Philips LED lamps respectively.

Table 3

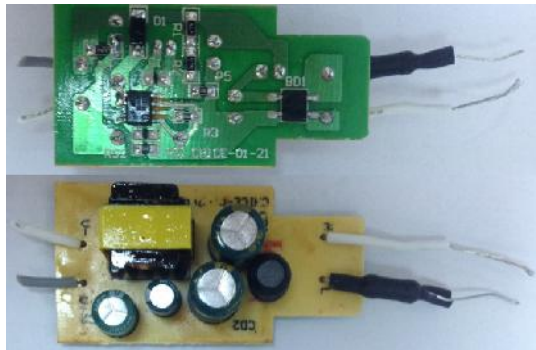
| TOTAL GREEN LED lamps |               |       |       |       |       |       |       |       |        |
|-----------------------|---------------|-------|-------|-------|-------|-------|-------|-------|--------|
| LED Power [W]         | Harmonics [%] |       |       |       |       |       |       |       |        |
|                       | Fund.         | 3 rd  | 5 th  | 7 th  | 9 th  | 11 th | 13 th | 15 th | THDi   |
| 8                     | 100           | 87.1  | 68.4  | 51.5  | 44.4  | 41.1  | 34.9  | 28.35 | 149.12 |
| 13                    | 100           | 85.81 | 67.47 | 49.83 | 39.08 | 34.28 | 29.84 | 23.55 | 146.00 |
| 16                    | 100           | 88.31 | 70.13 | 51.24 | 41.05 | 35.74 | 30.79 | 23.84 | 144.14 |

Table 4

| PHILIPS LED lamps |               |       |       |       |       |       |       |       |        |
|-------------------|---------------|-------|-------|-------|-------|-------|-------|-------|--------|
| LED Power [W]     | Harmonics [%] |       |       |       |       |       |       |       |        |
|                   | Fund.         | 3 rd  | 5 th  | 7 th  | 9 th  | 11 th | 13 th | 15 th | THDi   |
| 4                 | 100           | 88.13 | 71.9  | 55.12 | 42.79 | 35.72 | 30.41 | 23.98 | 149.84 |
| 6                 | 100           | 88.43 | 71.78 | 55.92 | 46.3  | 40.6  | 34.32 | 26.24 | 154.92 |
| 9.5               | 100           | 84.15 | 62.29 | 45.34 | 36.87 | 29.01 | 19.31 | 15.11 | 131.34 |
| 10.5              | 100           | 87.89 | 69.98 | 53.25 | 43.25 | 37.03 | 29.52 | 20.35 | 147.82 |
| 13.5              | 100           | 83.73 | 60.29 | 42.17 | 34.46 | 27.18 | 17.53 | 13.31 | 126.60 |

To be noted that THDi is about the same for both brands. All measured LED lamps generate a high level of harmonic distortion that does not comply with IEC 61000-3-2 standard (comparison of data found in Table 2, Table 3 and Table 4 versus Table 1).

The main reason for the harmonic distortion seems to be the lack of an input low-pass filter before the AC/DC converter. The PCB of a measured LED lamp is depicted in **Figure 7**.



**Figure 7**. PCB board of a measured LED lamp.

#### 4. Conclusion

The paper presents experimental data regarding the behavior of low wattage LED lamps, commonly found within commercial and residential lighting applications. The data is presented in two formats: time domain and frequency domain, i.e. harmonic content analysis and current total harmonic distortion (THDi). The results show that for the measured LED lamps the THDi does not comply with the IEC 61000-3-2 Class C limits for lighting equipment.

As the future trend is to design the lighting installation with LED lamps, in cases of sensitive applications regarding the THD factors, harmonic content mitigation methods are required. A solution for this issue is to mount low-pass filters within the lighting installation.

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#### References

- [1] Transparency Market Research Pvt. Ltd., Smart Lighting Market is Expected to Reach USD 56.62 billion in 2020;
- [2] Technavio, Global LED General Lighting Market 2014-2018;

- [3] P&S Market Research, GLOBAL INDUSTRY INSIGHT: Outdoor Lighting Market Size, Share, Development, Growth and Demand Forecast to 2020;
- [4] BIS Research, Global Smart Light Fixture (LED, HID), Control (Sensor, Ballast, Relays and Switches) & Services Market: 2015-2020;
- [5] Philip Smallwood - Strategies Unlimited / PennWell, LED Lighting Global Market Trends;
- [6] <http://www.ledsmagazine.com/articles/print/volume-9/issue-9/features/led-lighting-market-holds-steady-in-2012-magazine.html>;
- [7] Forbes, LED vs. CFL: Which Bulb is Best? (<http://www.forbes.com/sites/trulia/2014/04/25/led-vs-cfl-which-bulb-is-best/#74fd03ab6ead>);
- [8] Magazinul de leduri, Comparatie intre becurile incandescente, economice si LED (<https://www.magazin-leduri.ro/comparatia-intre-becurilor-incandescente-economice-si-led/>);
- [9] Navgathi Marine, Energy saving by lighting - 6500 TEU Container Vessel (<http://www.navgathi.com/wp-content/uploads/2015/06/9-Energy-Saving-by-Lighting-6500-TEU-Container-Vessel.pdf>);
- [10] Evans I. C. , Hoevenaars A. H. , Eng P., Meeting Harmonic Limits on Marine Vessels, IEEE Electric Ship Technologies Symposium, 2007. ESTS '07;
- [11] Hortopan Gh., Principii i tehnici de compatibilitate electromagnetica , Editura Tehnic , Bucure ti, 2005;
- [12] Brown B., P.E., Square D Engineering Services, Section 11: Power Quality Considerations.

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