American Journal of Electrical Power and Energy Systems
2015; 4(6-1): 13-18
Published online September 28, 2015 (http://www.sciencepublishinggroup.com/j/epes)
doi: 10.11648/j.epes.s.2015040601.13
ISSN: 2326-912X (Print); ISSN: 2326-9200 (Online)

Energy Saving Lamps as Sources of Harmonic Currents

Zahari Ivanov[1], Hristo Antchev[2]

[1]Department of Electrical Supply, Electrical Equipment and Electrical Transport, Faculty of Electrical Engineering, Technical University - Sofia, Sofia, Bulgaria
[2]Power Electronics Department, Faculty of Electronic Engineering and Technologies, Technical University - Sofia, Sofia, Bulgaria

Email address:
zai@tu-sofia.bg (Z. Ivanov), hristo_antchev@tu-sofia.bg (H. Antchev)

To cite this article:
Zahari Ivanov, Hristo Antchev. Energy Saving Lamps as Sources of Harmonic Currents. *American Journal of Electrical Power and Energy Systems*. Special Issue: Improvement of Energy Efficiency in the Conversion of Electrical Energy by Means of Electronic Converters. Vol. 4, No. 6-1, 2015, pp. 13-18. doi: 10.11648/j.epes.s.2015040601.13

Abstract: This paper presents the results from the research of the indexes in regard to the power supply network, when a change is applied to the power supply tension of the Compact Fluorescent Lamps and LED Lamps with power up to 30W of different manufacturers. Comparision data is presented for the power factor, the displacement factor and the total harmonic distortion of the current, and the relevant conclusions have been made.

Keywords: Compact Fluoroscent Lamps, Light-Emitting Diodes, Harmonic Distortion

1. Introduction

In the past years, on a worldwide scale is being conducted the replacement of lamps with incandescent light bulbs with new, energy saving lamps - Compact Fluorescent Lamps and LED Lamps. These new light sources require an electrical converter, connected to the power supply network. It influences the indexes of the light source in regard to this network - power factor, the displacement factor and the total harmonic distortion of the current. These indexes are subject to research at different power levels of the lamps by different authors, such as [1, 2, 3, 4]. Fot his purpose some of them have developed special generators [5]. The matter with the influence of the powersaving lamps on the power supply network becomes even more topical in relation to the creation of smart grids and the use of renewable energy sources [6].

Based on their research, some authors offer shunt active power filters for compensating the harmonic distortions of the Compact Fluorescent Lamps [7]. It must be noted, that the more common approach is the use of active correction of the power factor in the electrical converter itself [8, 9]. Usually this is done when the power input is more than 25W.

The goal of this work is to conduct a research of the indexes in relation to the power supply network of Compact Fluorescent Lamps and LED Lamps with different power inputs - less than 25W and more than 25W. Based on this, conclusions will be made about their influence over the power supply network in conjunction with the international standards. In Part 2 are presented the main indexes against the network, as well and the standard requirements. In Part 3 are given the results of the experimental research. In Part 4 are presented the relevant conclusions based on the conducted research.

2. Main Indexes and Standards

Main index of the influence of the connected to the network consumers (in the case of light sources) is the power factor PF, representing the relation between active $P$and total Spower:

$$\mathrm{PF} = \frac{\mathrm{P}}{S} = cos\varphi_1.\nu \tag{1}$$

It has to be noted, that for power factor in literature different designations are used, such as K_p, and often in relation to light sources – λ.

The power factor is the product of the displacement factor $\cos\varphi_1$, defined by the phase shift between the tension of the power supply network and the first harmonic of its current - I_1, and distortion factor - ν. This last one represents the relation between the efective value of the first harmonic of the current from the power supply network I_1 and the effective value of its current I:

$$\nu = \frac{I_1}{I} = \frac{I_1}{\sqrt{\sum_{k=1}^{n} I_k^2}} \tag{2}$$

Except with the distortion factor , the distortion of the current is characterized as well with total harmonic distortion – THD:

$$\mathrm{THD} = \frac{\sqrt{\sum_{k=2}^{n} I_k^2}}{I_1} \tag{3}$$

The connection between ν and THD is:

$$\nu = \frac{1}{\sqrt{1+THD^2}} \tag{4}$$

The requirements fo the harmonic constitution of the current in relation to the power supply network with current <16A on phase are defined by: IEC 6100-3-2 [10, 11]. In relation to this the lihgting equipment falls into class C equipment, in regards to which the requirements for harmonic constitution of the current are presented in table 1 [11]. It has to be noted that the standard enforces these requirements on powers greater than 25 W.

On some converters with uncontrollable rectifier at the entry of the Compact Fluorescent Lamps and LED Lamps, the form of the current could be related to the one, presented in the standard for lighting equipment class D. The requirements for this class, though, are for powers greater than 75 W.

Due to the abovementioned peculiarities of the standard, the requirements for the harmonic constitution of the current are violated by some of the manufacturers on power outputs lesser than 25W.

In regards to the form of the current, the crest factor K, is also defined, representing the relation between the maximal I_M and effective I_{RMS} values:

$$K = \frac{I_M}{I_{RMS}} \tag{5}$$

Table 1. *Limits for Clas C Equipment.*

Harmonic order, n	Maximum permessible harmonic current, (% of fundamental)
2	2
3	30xcircuit power factor
5	10
7	7
9	5
$11 \le n \le 39$	3

Sinusoidal current form: $K = \sqrt{2}$.

In regards to the displacement factor $\cos\varphi_1$ another standard exists, in which are enforced restrictions on the lesser power lamps as well. In table 2 are presented the requirements regarding the displacement factor $\cos\varphi_1$ for different powers, in accordance with [12].

Table 2. *Recommendet values for displacement factor.*

Metric	Limit			
Kdisplacement	P≤2W	2W<P≤5W	5W<P≤25W	P>25W
($\cos\varphi_1$)	No limit	≥0.4	≥0.7	≥0.9

3. Results of the Investigations

For the experimental research, 10 lamps with different powers have been used, taken randomly. In order to avoid eventual misunderstandings with the companies-manufacturers, in the below presented data, the lamps are given names from 1 to 10 and only the type and power of the lamp are indicated – Compact Fluorescent Lamp (CFL) or LED Lamp. Lamp 7 is induction, non-electrode. Research has been made using three different values of the power supply network voltage – normal 230V, 230V-10% and 230V+10%. The results for the main indexes - $PF, \cos\varphi_1, THD, K$ are presented in Table 3. Fluke Power Quality Analyzer 434 has been used.

Table 3. *Indexes in accordance with the power supply network for the researched lamps.*

Lamp№	Type, Power W	Supply Voltage, Urms, V	PF	$\cos\varphi_1$	THD,%	K
1	CFL, 15	207	0.51	-	80.8	152.4
		230	0.51	-	80.8	140.2
		253	0.51	-	81.6	104.8
2	CFL, 30	207	0.54	0.89	79.5	54.5
		230	0.54	0.89	80.9	60.5
		253	0.51	0.91	82.6	55.6
3	CFL, 15	207	-	-	49.3	29.7
		230	-	-	46.6	24.1
		253	-	-	44.3	20.6
4	CFL, 15	207	0.52	0.89	82.8	80.5
		230	0.51	0.88	80.4	92.9
		253	0.48	0.89	84.2	85.4
5	CFL, 20	207	0.47	0.89	84.4	79.1
		230	0.45	0.9	86	95.5
		253	0.45	0.91	86.5	85.6
6	CFL, 8	207	0.48	-	80.6	116.3
		230	0.47	-	81.4	119.3
		253	0.47	-	82.2	91.4
7	Induction L, 23	207	0.49	0.91	84.6	64.3
		230	0.47	0.91	84.7	58.1
		253	0.49	0.92	84.7	
8	LED lamp,15	207	0.54	-	76.7	110.6
		230	0.52	-	77.5	134.1
		253	0.53	-	79.1	120.4
9	LED lamp,30	207	0.71	0.99	67.1	11.8
		230	0.69	0.98	70.1	12.8
		253	0.67	0.98	70.5	14
10	LED lamp,15	207	-	0.98	22.5	10.9
		230	-	0.98	24.5	12.5
		253	-	0.98	27.3	15.5

No strict dependence exists between THD and the value of the power supply network voltage. In most cases THD grows with the growth of the voltage. Table 3 and fig. 10 show the significantly better indexes of lamp 10, despite its power of 15W. On the other hand, from fig.9 we see that lamp 9, with power of 30W, also does not cover the requirement of the standard in regards to the harmonic constitution of the current.

The waveforms from the experiments for each of the lamps and with tension of the power supply network are presented in fig. 1 to 10. Oscilloscope Tektronix 2012 has been used.

CH1 is a waveform of the tension of the power supply network, while CH2- its current. The waveform of the current is with ratio 100mV/A.

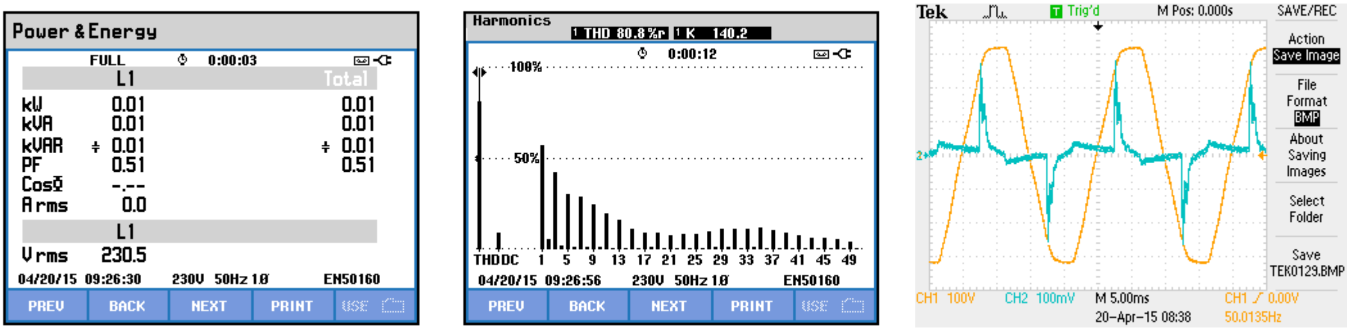

Figure 1. *Wavwforms for lamp 1.*

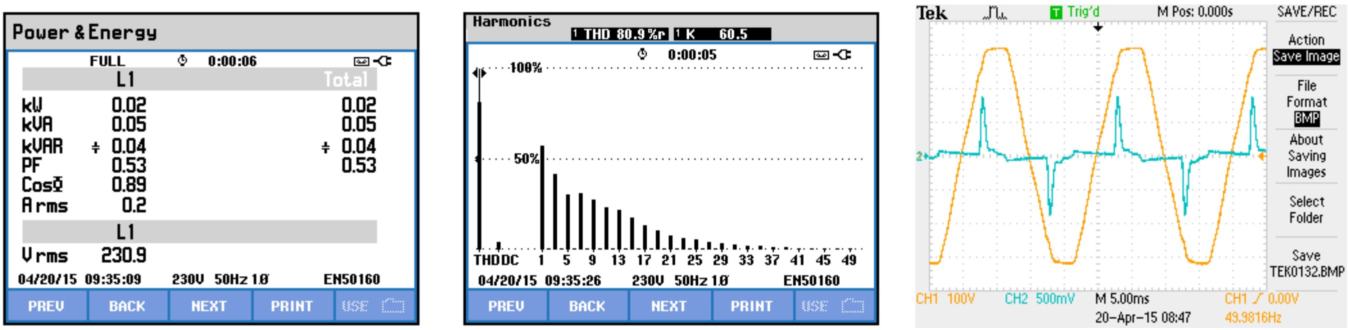

Figure 2. *Wavwforms for lamp 2.*

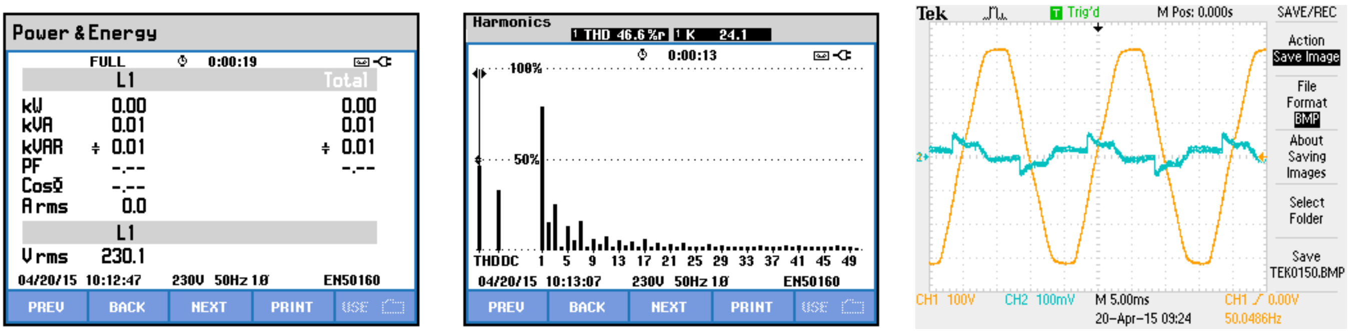

Figure 3. *Wavwforms for lamp 3.*

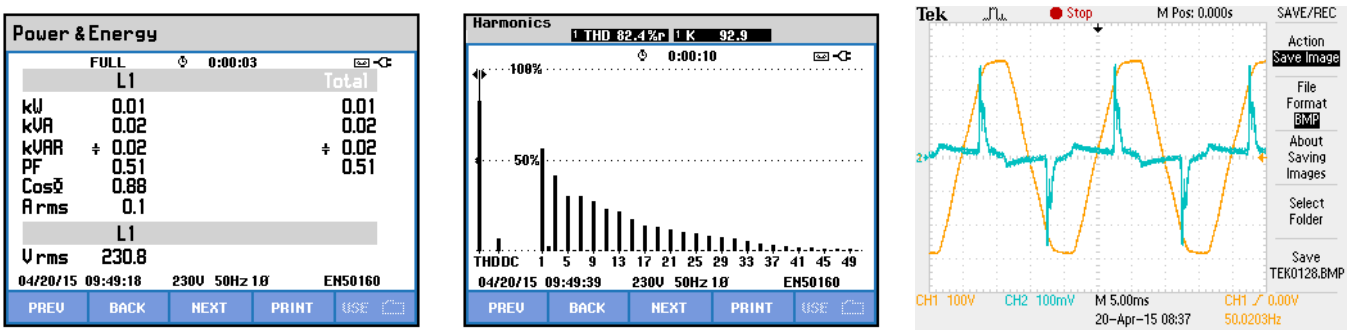

Figure 4. *Wavwforms for lamp 4.*

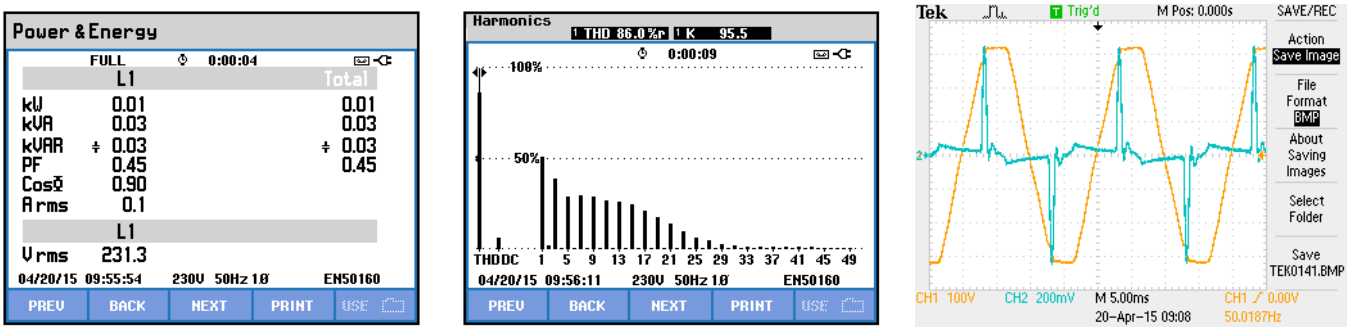

Figure 5. *Wavwforms for lamp 5.*

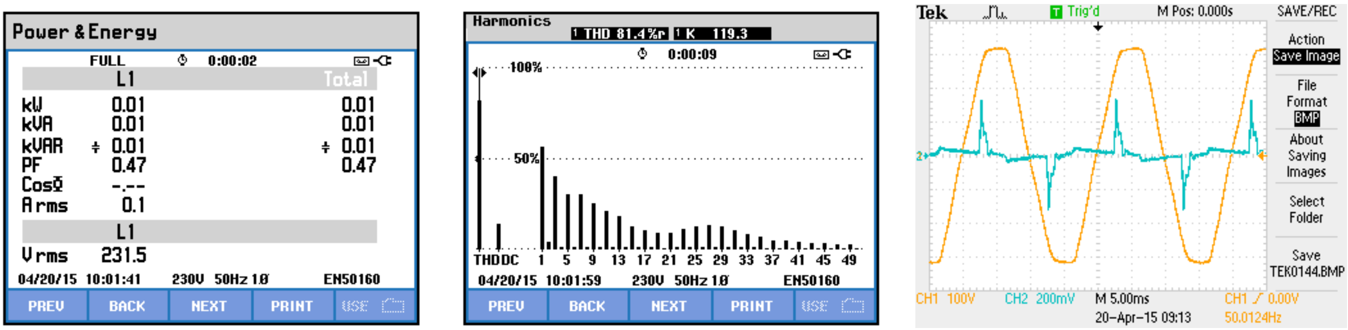

Figure 6. *Wavwforms for lamp 6.*

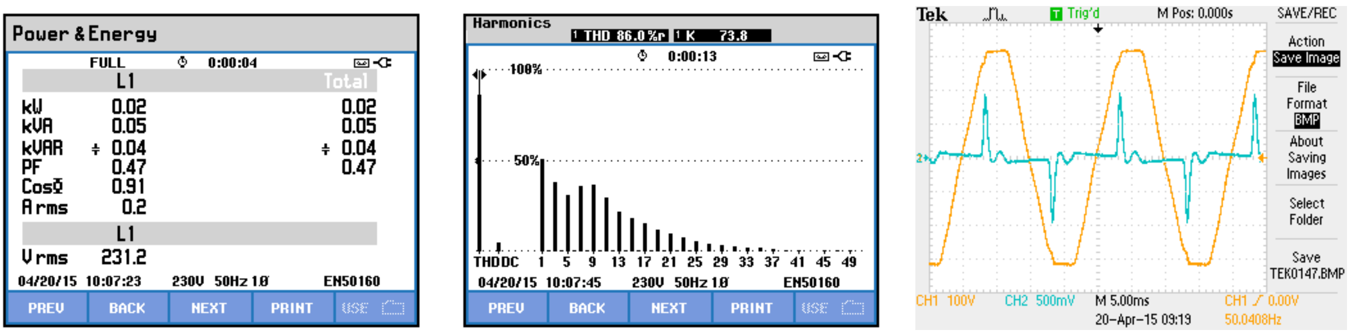

Figure 7. *Wavwforms for lamp 7.*

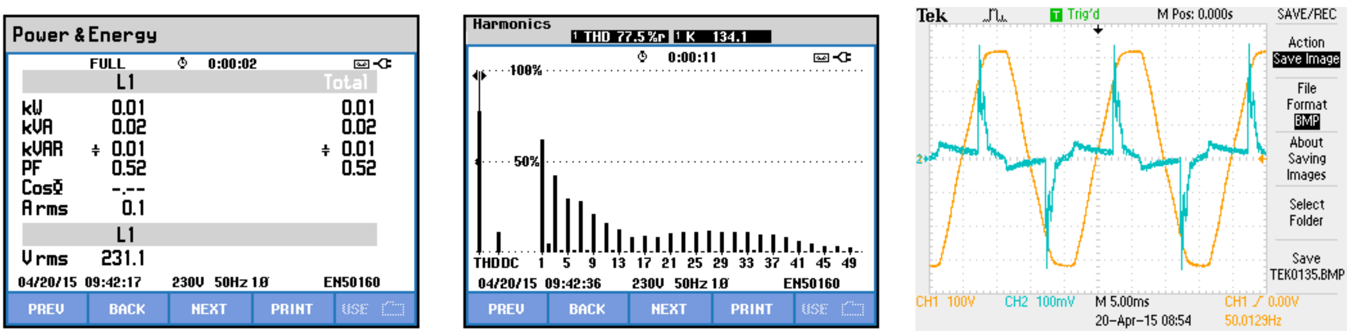

Figure 8. *Wavwforms for lamp 8.*

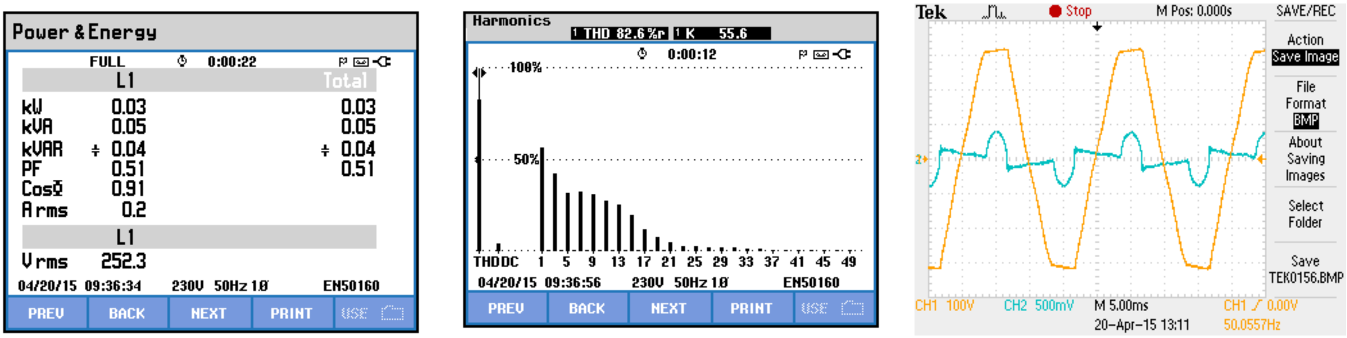

Figure 9. *Wavwforms for lamp 9.*

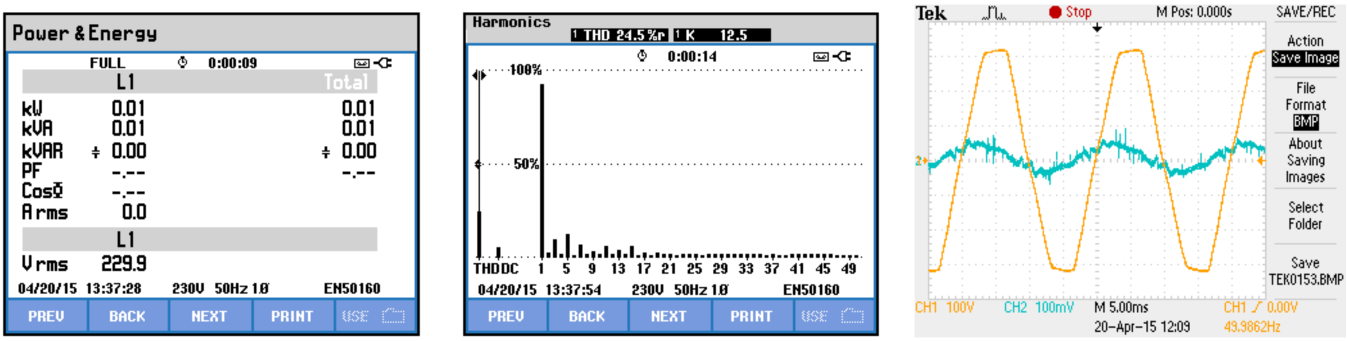

Figure 10. *Wavwforms for lamp10.*

4. Conclusion

The results of the conducted experimental research show a bad harmonic constitution in most lamps with a power of less than 25 W – high THD and K. For the resolution of this matter, there are enough technical means at hand – active or passive correction of the power factor. A comprehensive evaluation might be necessary and eventually correction in the standard with restrictions in respect to the harmonic constitution of the current and with power under 25 W. This matter is also connected to a particular economic evaluation, with which to be registered the increased costs of a separate lamp when entering a means of correction from one side and the cumulative negative effect on the supply network at bad harmonic constitution.

References

[1] Nassar A., M.Mednik, “Introductory physics of harmonic distortion in fluorescent lamps”, American Journal of Physic., Vol.71, No6, pp.577-579, June, 2003.

[2] George V., Bagaria A., Rampattiwar S. R., “Comparision of CFL and LED lamps – harmonic disturbances, economics (cost and power quality), and maximum possible loading in a power system”, International Conference and Utility Exhibition, 2011, pp.1-5.

[3] Dolara A., S.Leva, “Power Quality and Harmonic Analysis of End User Devices”, Energies, No 5, 2012, pp.5453-5466, ISSN 1996-1073.

[4] F. V. Topalis F. V., I. F Gonos, M. B. Kostic, “Effects of changing line voltage on the harmonic current of compact fluorescent lamps”, Proceedings of the IASTED International Conference Power and Energy Systems, November 8-10, Las Vegas, USA, pp.1-4.,1999.

[5] F. V. Topalis F. V., I. F Gonos, M. G.A.Vokas,” Arbitrary wavwform generator for harmonic distortion tests on compact fluorescent lamps, Measurement, Elsevier, no.30, pp.257-267, 2001.

[6] Islam M. S., Chowdhury N. A. Sakil A. K., Khandakar A., “Power Quality Effect of using Incandescent, Fluorescent CFL and LED Lamps”, First Workshop on Smart Grid and Renewable Energy, Qatar, 2015, pp.1-5.

[7] Moulahoum S., Houassine H., N. Kabahe, “Shunt Active Power Filter to Mitigate Harmonics Generated by Compact fluorescent lights ”, 18th International Conference of Methods and Models in Automation and Robotics, 2013, pp.496-501.

[8] Chun C., H.L.Cheng, T.Y. Chung, “A Novel Single-State High-Power-Factor LED Street-Lighting Driver With Coupled Inductors” IEEE Transactions on Industry Applications, Vol.50, Issue 5, 2014, pp.3037-3045.

[9] Lam J. C. W., Shangzhi P., Jain P. K., “A Single-Switch Valley-Fill Power –Factor-Corrected Electronic Ballast for Compact Fluorescent Lightings With Improved Lap Current Crest Factor”, IEEE Transactions on Industrial Electronics, Vol.61, Issue 9, 2014, pp.4654-4664.

[10] IEC 6100-3-2, Electromagnetic compatibility (EMC), Part3: Limits-Section 2: Limits for harmonic current emissions (equipment current < 16A per phase).

[11] European Power Supply Manufacturers Association, Harmonic Current Emissions, Guidelines to the Standart EN 6100-3-2, Revision data 2010-11-08.

[12] IEC 60969, Self-ballasted compact fluorescent lamps for general lighting services – performance requirements.