Analytical Study of Harmonics Issued from LED Lamp Driver

Chaiyan Jettanasen
Department of Electrical Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand
kjchaiya@kmitl.ac.th

Atthapol Ngaopitakkul
Department of Electrical Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand
knatthap@kmitl.ac.th

***Abstract*—Harmonics are always generated in any non-linear electrical/electronic systems, and cause severe problems in terms of performance and operation. This paper focuses on analytical study of harmonics originated from LED lamps usually functioning using a driver. Since the driver is a switching device, it will be thus a direct harmonic and/or electromagnetic interference (EMI) source of the system. In order to suppress or reduce produced harmonics, a low-pass harmonic filtering technique is proposed and applied. The experimental results can reveal harmonic reduction effectiveness by comparing with lighting standard, which is herein IEC 1000-3-2 (or EN 61000-3-2); this confirms finally the Electromagnetic Compatibility (EMC) of the system.**

Keywords—EMI/EMC; harmonics; LED driver; low-pass filter

I. Introduction

Nowadays, Light Emitting Diode (LED) lamps become increasingly popular to be used in many applications, for example, inside and outside of the residence or office, street lights, building decoration, and vehicle application. The main purposes of using LED lamp are energy savings because of low energy consumption and overall efficiency augmentation. Moreover, it has long lifetime, and is environmentally friendly because there is no composition of the toxic substance comparing to other types of lamps. As a result, in the buildings, LEDs have replaced incandescent lamps and fluorescent lamps, which have been usually used for many decades. Even though LED lamp has many advantages, it also has some disadvantages such as generation of harmonics or EMI in the system due to the functioning of switching devices of the LED driver. The driver is essential for lightening the lamp.

Many research papers have focused on development of performance of LED lamps, lighting control, and illumination on the work surface [1-4], but there are few papers concerning side effects [5-6] when employing this kind of lamp.

To reduce or suppress harmonics generated in any electrical/electronic system, there are a number of traditional and innovative techniques [7-11]. However, in this paper, low-pass harmonic filtering approach will be studied and discussed.

In this paper, the studied system and its experimental setup are first presented. Second, the harmonics measurement and its results are illustrated. Harmonic filter design is next carried out in order to overcome harmonics problem. Finally, the results when inserting harmonic filter at the input of LED lamp's driver are shown and compared with the lighting standard to reveal the effectiveness of passive filtering technique implemented in the studied system. This will further confirm the electromagnetic compatibility (EMC) of the considered system.

II. Studied System and Experimental Setup

The studied system composed of an ac power source, and LED lamp and its driver set of different commercial brands. Three brands are studied in this paper; two brands (A and B) are constant voltage LED driver and one brand (C) is constant current LED driver. Various configurations are considered and carried out for each brand as presented below:

- 1 driver for 1 LED lamp
- 1 driver for 9 LED lamps
- 9 drivers for 9 LED lamps

The purpose is to know the effect of number of driver and number of LED lamp to generation of harmonics and/or EMI.

(a)

(b)

Fig. 1. LED lamps (a) and driver (b)

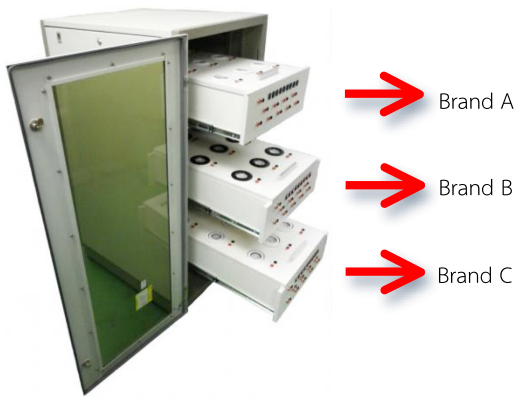


Fig. 2. Experimental setup of LED lamps

The example of LED lamp and its driver used in this study is shown in Fig. 1 and the overall experimental setup is illustrated in Fig. 2.

III. Harmonics Measurement and Results

For each configuration, the harmonic measurement is carried out at the input of LED lamp using a power quality analyzer as depicted in Fig. 3. This measuring instrument can provide a number of electrical quantities, such as values of power, power factor, and total harmonic distortion percentage.

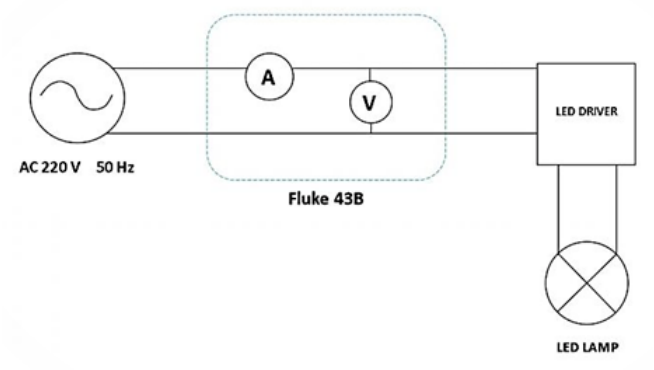


Fig. 3. Harmonics measurment in LED lamps system

The percentage of total harmonic distortion of current (%THD_i) is compared for different configurations as presented in Table I.

TABLE I. Percentage of Total Harmonic Distortion of Current for Different Configurations

LED lamps and Drivers	%THD_i	
	1 driver	9 drivers
LED lamp with driver of brand A	141.4	174.6
LED lamp with driver of brand B	75.6	76.3
LED lamp with driver of brand C	56.0	23.5

Note that LED lamp of brand C produces less harmonics than that of brand A and B because the current waveform is less distorted. Fig. 4 and Fig. 5 show the current waveform of brand A and C, in time domain, respectively. However, it is clearly seen that these waveforms contain harmonic components by using Fast Fourier Transform (FFT) function of oscilloscope.

Moreover, harmonics magnitude (%f) of each harmonics order is compared for each LED lamp brand and shown in Fig. 6.

According to the results, it is found that LED lamp of brand A has high %THD_i; that is why, this study will focus on this brand, and the low-pass harmonic filtering technique will be applied to improve power quality of current signal.

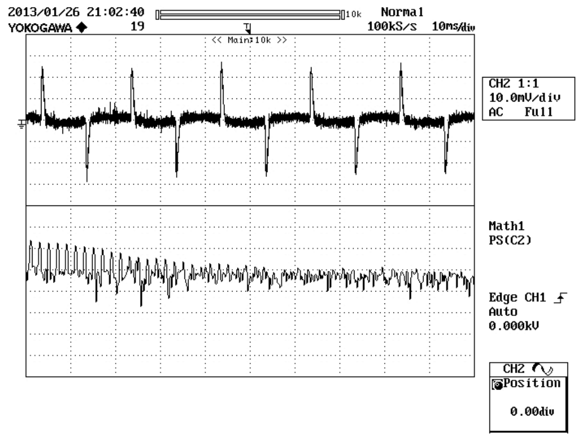


Fig. 4. Waveform of current in LED lamp with 1 driver of brand A

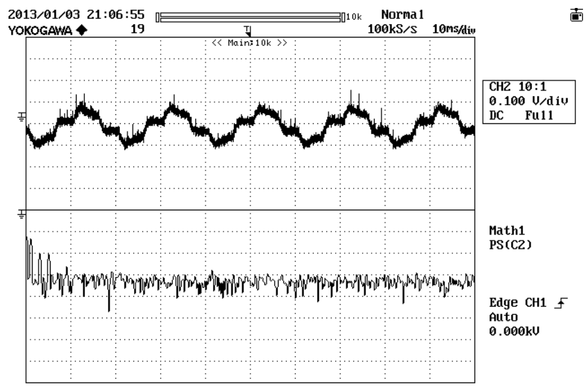


Fig. 5. Waveform of current in LED lamp with 1 driver of brand C

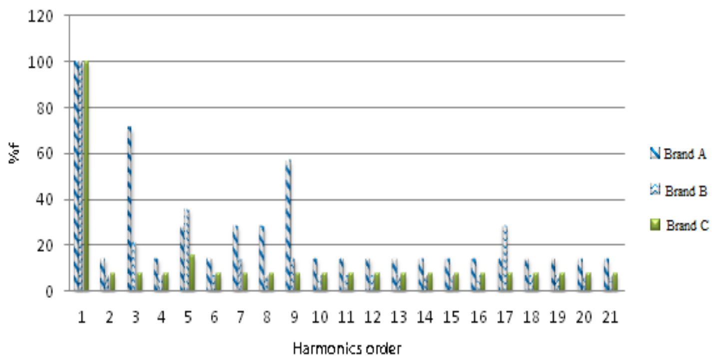


Fig. 6. Comparison of harmonics magnitude at different harmonics order for each brand (1 lamp & 1 driver)

IV. Design of Low-Pass Harmonic Filter

LED lamp functioning with driver of brand A is chosen for harmonic filter design owing to its highest harmonics generation. The acceptable level of harmonics is normally defined by a standard, which is herein IEC Std. 1000-3-2 (Group C); this ensures that the sensitive nearby electrical/electronic equipments or itself will be not affected by generated harmonics. Table II shows the limited harmonic current of lighting equipments according to the mentioned standard.

TABLE II. LIMIT OF HARMONIC CURRENT OF LIGHTING EQUIPMENTS (GROUP C) ACCORDING TO IEC 1000-3-2 STANDARD

Harmonics Order (n)	Maximum harmonic current permitted (calculated in percentage by comparing to the fundamental magnitude)
2	2
3	30*(power factor)
5	10
7	7
9	5
11≤n≤39 (only odd order)	3

Note that for brand A and B, the harmonics level exceeds the maximum harmonic current permitted by the applied standard, whereas brand C rather respects to the standard.

The generated harmonics issued from LED lamp of brand A will be reduced by adding the harmonic filter at the input of the LED lamp. This filter is simply composed of one series inductor and one parallel capacitor. The resistor of the order of MΩ can be added in parallel with the capacitor in order to discharge its electric charge and also for a reason of mechanical structure.

To reduce the harmonics magnitude, the cut-off frequency is a key parameter to be considered. Here, the cut-off frequency of harmonic filter is fixed at 150 Hz, and the value of capacitor is 11 μF, thus by using (1), the value of inductor will be 102.34 mH.

$$f_c = \frac{1}{2\pi\sqrt{LC}} \quad (1)$$

After inserting the experimentally designed filter as depicted in Fig. 7, the current waveform becomes more sinusoidal as shown in Fig. 8. Furthermore, the $\%THD_i$ is improved, it is presently equal to 10.2 % (before insertion of harmonic filter, it was equal to 141.4%)

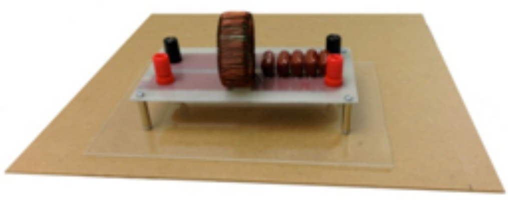
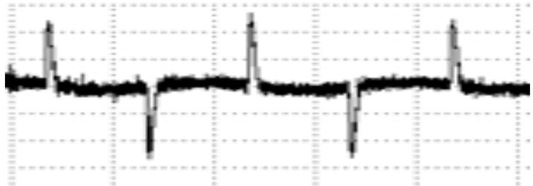
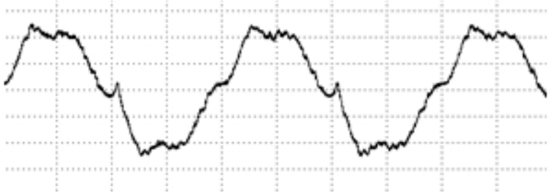


Fig. 7. Experimentally designed filter used in this study



(a)



(b)

Fig. 8. Current waveform without harmonic filter (a), and with harmonic filter (b)

The spectrum of current waveform with harmonic filter is also determined. The result is shown in Fig. 9.

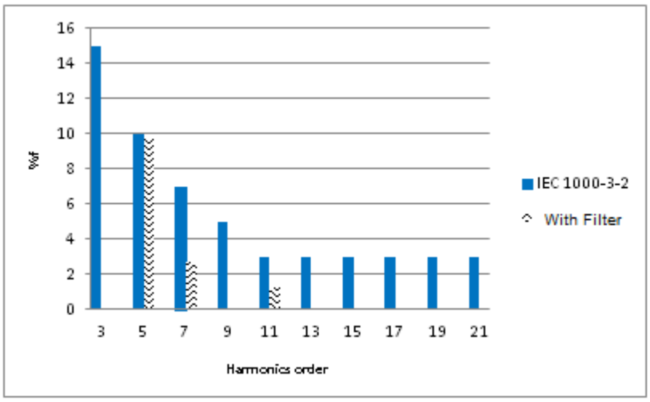


Fig. 9. Harmonics magnitude, obtained after insertion of harmonic filter, at different orders compared with IEC standard

The results are obviously shown that the harmonics level is now conformed to the lighting equipment standard.

V. CONCLUSION

The analytical study of harmonics generated by LED lamp driver for lighting applications has been conducted in this paper. Since the harmonics level exceeds the applied IEC 1000-3-2 standard, it must be reduced by an attenuation approach. The passive low-pass harmonic filtering technique was proposed in this study, and with this filter, the level of harmonics respects satisfactorily to the standard. Finally, this shows the Electromagnetic Compatibility of the overall system.

ACKNOWLEDGMENT

This work is supported by Research Fund of Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang (KMITL), Thailand, the authors would like to thank for this financial support. The authors also gratefully acknowledge the helpful comments and suggestions of the reviewers, which have improved the presentation.

REFERENCES

[1] Ashish Pandharipande and David Caicedo, "Daylight integrated illumination control of LED systems based on enhanced presence sensing," 2011, pp. 944 - 950.

[2] W.R.Ryckaert, K.A.G.Smet, I.A.A.Roelandts, M.VanGils and P.Hanselaer, "Linear LED tubes versus fluorescent lamps: An evaluation," 2012, pp. 429 - 436.

[3] Mokhtar Ali, Mohamed Orabi, Mahrous E. Ahmed and Abdelali El Aroudi, "Design Considerations of a Single-Stage LED Lamp Driver with Power Factor Correction".

[4] T. M. Roffi, I. Idris, K. Uchida, S. Nozaki, N. Sugiyama, H. Morisaki, F. X. N. Soelami, "Improvement of High-Power-White-LED Lamp Performance by Liquid Injection," 2011 International Conference on Electrical Engineering and Informatics 17-19 July 2011, Bandung, Indonesia.

[5] Sohel Uddin, Hussain Shareef, Azah Mohamed, M A Hannan, "An Analysis of Harmonics from LED Lamps," 2012, pp. 837 - 840.

[6] Sohel Uddin, Hussain Shareef, Member, IEEE, Azah Mohamed, Senior Member, IEEE, and M A Hannan, Member, IEEE, "An Analysis of Harmonics from Dimmable LED Lamps," 2012 IEEE International Power Engineering and Optimization Conference (PEOCO2012), Melaka, Malaysia: 6-7 June 2012, pp. 182 - 186.

[7] Harpreet kaur Channi, and Harwinder Singh Sohal, "Power Quality Innovation in Harmonic Filtering," International Journal of Research in Engineering & Applied Sciences (IJREAS), Vol. 2, Issue 2, February 2012, pp. 518-528.

[8] Manuel Arias, Diego G. Lamar, Francisco F. Linera, Didier Balocco, Almadidi Aguissa Diallo, and Javier Sebastián, "Design of a Soft-Switching Asymmetrical Half-Bridge Converter as Second Stage of an LED Driver for Street Lighting Application," IEEE Transactions on Power Electronics, Vol. 27, No. 3, March 2012, pp. 1608-1621.

[9] S. Y. Ron Hui, Leung Ming Lee, Henry Shu-Hung Chung, and Y.K. Ho, "An Electronic Ballast with Wide Dimming Range, High PF, and Low EMI," IEEE Transactions on Power Electronics, Vol. 16, No. 4, July 2001, pp. 465-472.

[10] Fabio Luis Tomm, Álysson Raniere Seidel, Alexandre Campos, Marco A. Dalla Costa, and Rocardo Nederson do Prado, "HID Lamp Electronic Ballast Based on Chopper Converters," IEEE Transactions on Industrial Electronics, Vol. 59, No. 4, April 2012, pp. 1799-1807.

[11] Liang, and Tsorng-Juu, "A two-stage electronic ballast for HID lamp with flyback PFC," 7th International Power Electronics and Motion Control Conference (IPEMC) 2012, Vol. 1, 2–5 June 2012, China, pp. 192-198.