IOP Conf. Series: Materials Science and Engineering **190** (2017) 012019 doi:10.1088/1757-899X/190/1/012019

Investigation of Passive Filter for LED Lamp

Edi Sarwono[1,2], Mochammad Facta[2], Susatyo Handoko[2]
[1]Vocational High School 1 Semarang, Indonesia
[2]Electrical Engineering Department, Diponegoro University, Semarang, Indonesia

edisarwonono@gmail.com; facta@elektro.undip.ac.id; susatyo@elektro.undip.ac.id

Abstract. Light Emitting Diode lamp or LED lamp is one of the energy saving lamps nowadays widely used by consumers. However, LED lamp has contained harmonics caused by the rectifier circuit inside the lamp. Harmonics cause a quality problem in power system. As the harmonics present in current or voltage, the waveforms are distorted. Harmonics can lead to overheating in magnetic core of electrical equipments. In this paper, several tests are carried out to investigate the harmonic content of voltage and currents, and also the level of light intensity of the two brands of LED lamps. Measurements in this study are conducted by using HIOKI Power Quality Analyzer 3197. The test results show that the total harmonic distortion or THD of voltage on various brands of LED lamps did not exceed 5% as in compliance to the limit of IEEE standard 519-1992. The largest harmonic voltage is 2.9%, while maximum harmonic current for tested brands of LED lamp is 170.6%. The use of *low pass filter* in the form of LC filter was proposed. Based on experimental results, the application of LC filter at input side of LED lamp has successfully reduced THD current in the range of 85%-88%.

Keyword: LED lamp, harmonic distortion, power quality, THD current, THD voltage, lighting intensity

1. Introduction

Light Emitting Diode lamp or LED lamp is one of the energy saving lamps used currently widely by consumers such as households, offices and industry [1]. However, LED lamp contains harmonics caused by the rectifier circuit attached inside the lamp [2]. Harmonics can cause interference on the electrical system, overheating in magnetic core of electrical equipments and it can be detrimental in terms of both producers and consumers [3]. To reduce harmonics, many references suggest the use of filter [4,5,6]. In this work passive filter has been proposed to reduce harmonics in the two selected brands of LED lamps. In this work passive filter is proposed to reduce harmonics in the two selected brands of LED lamps. These two brands represent the LED lamps commercialized in Indonesia. Passive filter is chosen to be applied because this circuit required no additional power supply to work [7]. Small dimension of passive filter can be obtained by selected the appropriate components.

The work in this paper starts with investigation of harmonics in the two selected brands of LED lamps. The early investigation is required to get harmonics spectrum and to find out the most dominant harmonics order. The most dominant order becomes a target to be eliminated by choosing a suitable component for passive filter. According to several references passive filter can be constructed by combining two or more components of inductor (L) and capacitor (C) [8]. In this work, LC filter is selected to be applied as additional circuit to eliminate the most dominant harmonics of selected LED lamps.

2. Led Lamp Specification

In this paper, two brands of LED lamps with three different rating power are investigated. Their specifications are:

- Brand-A (3, 4, and 7 Watt)
- Brand-B (3, 5, and 9 Watt)

Both LED lamps required alternating current (AC) 220 volt and 50 Hz to turn on [9].

3. Experiments and Results

To find the dominant parameters of LED lamps such as voltage, current, power factor, real power factor, percentage of total harmonics distortion for voltage and current, the power quality analyzer (PQA) HIOKI 3197 is used in this work. The lighting intensity of the LED lamps in the value of lux is measured by using lux meter. The illustration of experimental circuit in general is shown in Figure 1. The values of electrical parameters as the dominant parameters of LED lamps is read and recorded directly from PQA to personal computer by using USB.

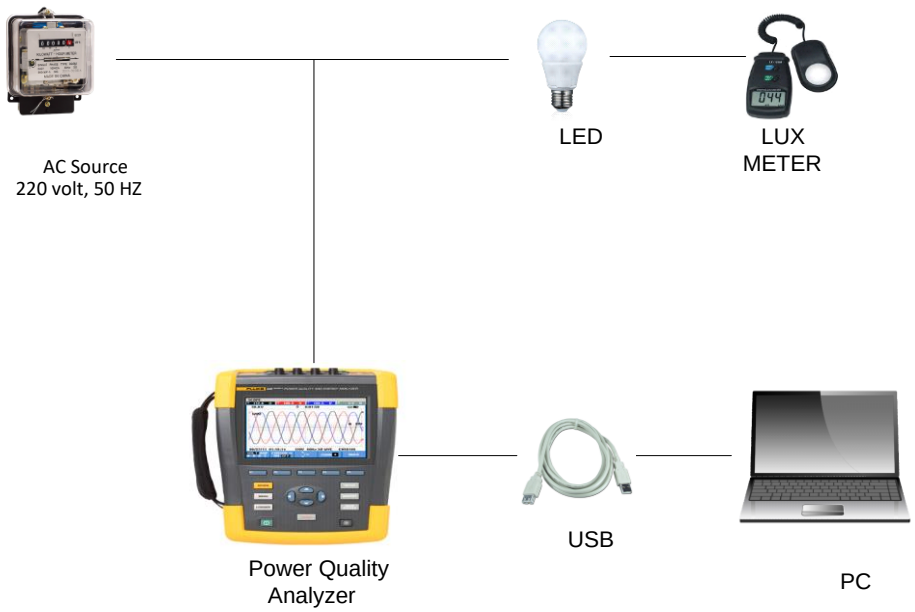


Figure 1. Harmonics & Lumen measurement LED lamps

Table 1 and 2 show the result of measurement for every brand of LED lamps. Every lamp is measured separately to get the value of voltage and current harmonics. It is shown that the largest harmonics of voltage is 2.9% and the largest of harmonics of current is 170.6%. In this experiment the highest light intensity 1007 lux is given by 9 watt of LED lamps brand-B.

Table 1. Percentage Of Total Harmonic Distortion Of Current (THD_I) LED Lamp Brand-A

No	Rating Power	THD_V (%)	THD_I (%)	Lumen
1	3W	2.7	154	288
2	4W	2.8	148.6	365
3	7W	2.8	128.9	787

Table 2. Percentage Of Total Harmonic Distortion Of Current (THD_I) LED Lamp Brand-B

No	Power	THD_V (%)	THD_I (%)	Lumen
1	3W	2.9	163.7	398
2	5W	2.9	170.6	514
3	9W	2.8	158.7	1007

Table 3. Harmonics order of LED Lamp Brand-A and Brand-B

Order	U [V]	I [A]
1	223.0	14.0m
2	0.8	0.3m
3	4.8	11.8m
4	0.2	0.2m
5	0.9	8.8m
6	0.1	0.1m
7	1.5	6.6m
8	0.1	0.2m
9	2.4	6.4m
10	0.1	0.2m
11	1.4	6.5m
12	0.1	0.2m
13	0.5	5.9m
14	0.1	0.2m
15	0.9	4.9m
16	0.1	0.3m
17	0.2	4.2m

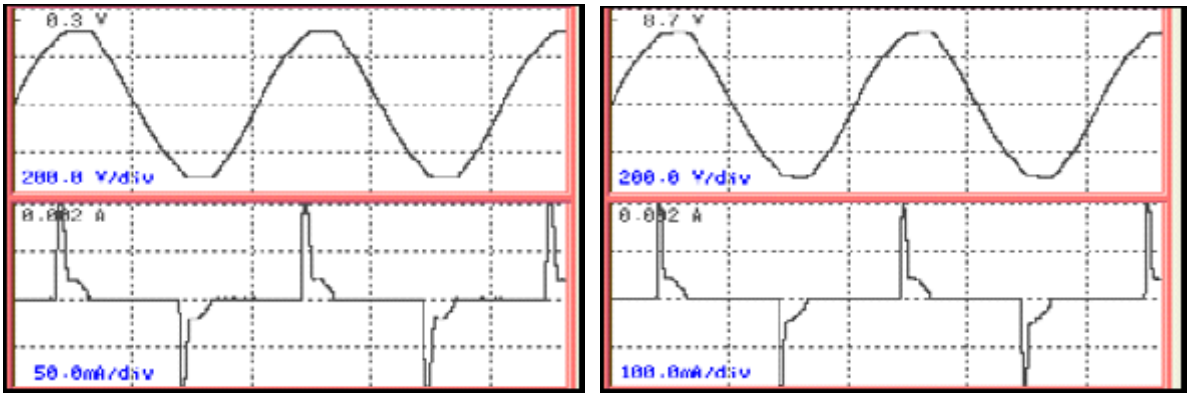
Harmonic order Brand-A

Order	U [V]	I [A]
1	220.6	22.2m
2	0.3	0.2m
3	5.2	19.2m
4	0.1	0.2m
5	0.8	14.5m
6	0.1	0.2m
7	1.8	10.5m
8	0.1	0.1m
9	2.4	9.6m
10	0.1	0.2m
11	1.2	10.3m
12	0.1	0.3m
13	0.5	10.3m
14	0.1	0.3m
15	0.9	9.3m
16	0.0	0.3m
17	0.2	8.2m

Harmonic order Brand-B

Table 3 shows the order of current harmonics for LED lamps brands A and B consecutively as they are displyaed in PQA. The highest current harmonics for brand-A is 11.8 mA and it is present in the 3rd order of harmonics. For brand-B, the highest order also present in the 3rd order with magnitude of current 19.2 mA.

The shapes of waveform of voltage and current for brand-A and brand-B LED lamps are shown in Figure 2. It is clearly seen that current waveform for both lamps is close to impulse rather than sinusoid. These shapes imply the content of harmonics mostly dominant in current due to voltage waveform for both lamps remain sinusoid.



(a) Waveform LED lamp brand-A (b) Waveform LED lamp brand-B

Figure 2. Waveform voltage and current

According to the results above, it is found that both of LED lamp of brand-A and Brand-B have dominant high harmonics distortion for current, so that the work is continued to eliminate the highest harmonics in the current. It is also discovered that the highest magnitude of current was presented in the fundamental and 3rd order. To reduce harmonics significantly the 3rd order harmonics should be eliminated by applying the suitable filter for 3rd order.

4. Design of LC Filter

Passive filter is most commonly used as filtering techniques for mitigation of harmonics, because it offers low impedance path to divert harmonic current caused by non-linear load [5].

In this work, the passive filter is simply composed of one inductor in series with one capacitor to form LC filter because this topology require no power supply to eliminate harmonics. No additional power supply gives advantage to the small dimension of filter. This LC filter only passes low frequency and reduce high frequency so that this circuit is also none as low pass filter [8].

Based on finding in the previous chapter, the 3rd harmonics has the highest magnitude of current, then the filter was designed to eliminate the 3rd order. By using the resonance principle in [5,8], the value of inductor (L) in Henry and capacitor (C) in Farad is determined by equation (1).

$$C = \frac{1}{(2\pi f)^2 h_o{}^2 L} \tag{1}$$

Where, h_o is order of harmonic to which filter is designed to tune. In this paper, the cut-off frequency of harmonic filter is fixed at 3rd order or 150 Hz because fundamental frequency is 50 Hz.

Based on equation (1), the value of inductor is 115 mH and the value of capacitor is 9.8μF. the inductor and capacitor is connected in series as it is shown in Figure 3.

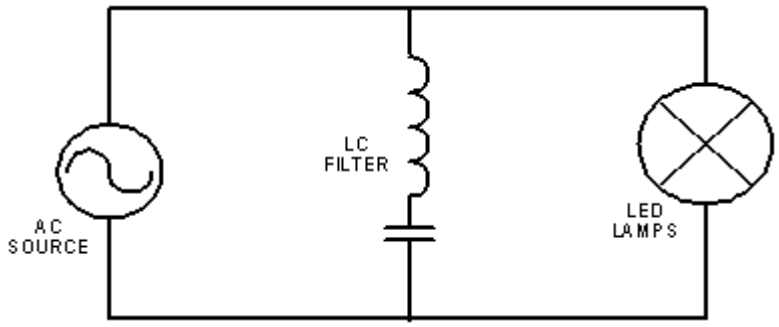
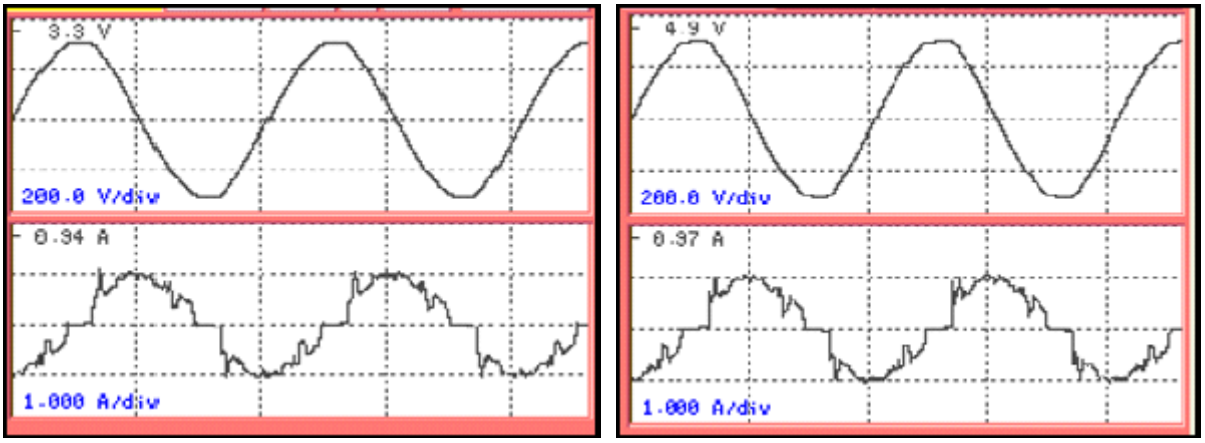


Figure 3. LED lamps with LC filter and AC source

The next experiment is carried out by using circuit in Figure 3 for every lamps of brand-A and brand-B. The measurement result show that after LC filter attached to LED lamps than the voltage waveform remain sinusoid and the current waveform becomes more sinusoidal as shown in Figure 4.



(a) Waveform LED lamp brand-A (b) Waveform LED lamp brand-B

Figure 4. Waveform voltage and current after filtering

Table 4. Percentage Of THD_I LED Lamp Brand-A after filtering

No	Power	THD_V (%)	THD_I (%)	Lumen
1	3W	2.8	19.1	293
2	4W	2.8	18	367
3	7W	2.7	19.2	808

Table 5. Percentage Of THD_I LED Lamp Brand-B after filtering

No	Power	THD_V (%)	THD_I (%)	Lumen
1	3W	2.8	19	403
2	5W	2.8	19.1	529
3	9W	2.9	19	1024

The use of LC filter in LED lamps for both brands-a and brand-B has significantly reduced the value of THDi as it is shown in table 4 and table 5. For example, THD_i decrease from 154 % to 19.1 % for brand-A 3 watt and from 170.6% to 19.1% for brand-B 5 watt. Based on the results in same tables, the lighting intensity for every lamp was found to increase as the current shape become more sinusoid.

5. Conclusion

The harmonics issued in the power system due to the presence of nonlinear loads like LED lamps has been presented in this paper. Harmonics arefound more dominant in current than voltage because THD_i is found greater than THD_v.

The use of LC filter to reduce the dominant order in harmonics is successfully decreased the value of THD_i for every sample of LED lamps without affecting the shape of voltage waveform. The voltage remains sinusoid with lowest THD_v as it was required by standard.

References

[1] Kshitu S, Arti N, Neelam S, and Raghuvir S 2010 *International Journal of Engineering Science and Technology*, **2** 8 pp 3955-3963.
[2] Chaudhary D D, Nayse S P, and Waghmare L M 2011 *Journal of Wireless & Mobile Networks (IJWMN)* **3** 10 pp 140-149.
[3] Syed D, Masood U, Farwa U and Khurram M 2015 *Journal of Computer Engineering and*

Applications **4** 3 pp 153-163.
[4] Jiao J, Ma H, Qiao Y, Du Y, Kong W, and Wu Z-C 2014 *Advance Journal of Food Science and Technology* **6** 3 pp 368-373.
[5] Kaloxylosa A, Groumasb A, Sarrisb V, Katsikasb L, Magdalinosb P, Antoniouc E, Politopoulouc Z, Wolfertd S, Brewstere C, Eigenmannf R and Tero C-M, *Journal of Computers and Electronics in Agriculture* 100 pp 168–179.
[6] Malik R F, Hafiz M, Nopransyah A, Zalbina MR and Septian L M, 2015 *Proc. of Int. Conf. on Electrical Engineering, Computer Science and* Informatics (*Palembang, Indonesia*).
[7] Lindsey S and Raghavendra C S, 2002 *IEEE Aerospace Conference* (*Montana, USA*) **3** 3 p 1125.
[8] Perera T A and Collins J 2010 *Auckland: Auckland University of Technology. Thesis*.
[9] Mohanan V, Budiarto R, Zainon W M N W 2012 *Proc. 18th Asia-Pacific Conference on Communications (Jeju island, Korea)* pp 53-58.
[10] Mohanan V, Budiarto R 2013 *Proc. 19th Asia-Pacific Conference on Communications (Bali, Indonesia)* pp 196-201.