# Comparative Performance Analysis of Shunt and Series Passive Filter for LED Lamp

*by* Susatyo Handoko

# Comparative Performance Analysis of Shunt and Series Passive Filter for LED Lamp

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**Abstract.** Light Emitting Diode lamp or LED lamp nowadays is widely used by consumers as a new innovation in the lighting technologies due to its energy saving for low power consumption lamps for brighter light intensity. How ever, the LED lamp produce an electric pollutant known as harmonics. The harmonics is generated by rectifier as part of LED lamp circuit. The present of harmonics in current or voltage has made the source waveform from the grid is distorted. This distortion may cause inacurrate measurement, mall function, and excessive heating for any element at the grid. This paper present an analysis work of shunt and series filters to suppress the harmonics generated by the LED lamp circuit. The work was initiated by conducting several tests to investigate the harmonic content of voltage and currents. The measurements in this work were carried out by using HIOKI Power Quality Analyzer 3197. The measurement results showed that the harmonics current of tested LED lamps were above the limit of IEEE standard 519-2014. Based on the measurement results shunt and series filters were constructed as low pass filters. The bode analysis were appled during construction and prediction of the filters performance. Based on experimental results, the application of shunt filter at input side of LED lamp has reduced THD current up to 88%. On the other hand, the series filter has significantly reduced THD current up to 92%.

## INTRODUCTION

Light Emitting Diode lamp or LED lamp nowadays is widely used by consumers as a new innovation in the lighting technologies due to its energy saving for low power consumption lamps for brighter light intensity. How ever, the LED lamp produce an electric pollutant known as harmonics. The harmonics is generated by rectifier as part of LED lamp circuit[1].

Harmonics are a major cause of power supply pollution lowering the power factor and increasing electrical losses. The effect of harmonic results in premature equipment failure and also cause of requirement of equipment of high rating. The voltage distortion produced in the system is the major issue with the harmonics distribution[2].

The present of harmonics in current or voltage has made the source waveform from the grid is distorted. This distortion may cause inacurrate measurement, mall function, and excessive heating for any element at the grid. In this work passive filter was proposed to reduce harmonics in the two selected brands of LED lamps commercialized in Indonesia. Passive filter was chosen to be applied because this circuit required no additional power supply to work, small dimension can be obtained by selected the appropriate components[3].

Several research were carried out to reduce of THD in LED lamp, such as the efforts to investigate the impact of LED lamp on power quality on distribution systems by using Matlab Simulink[4] and the work to use a single tuned passive filter and double tuned passive filter to eliminate harmonic distortion caused by non-linear loads[5]. How ever, in the first work, no validation to real experiment provided. In the second reference, the mechanism to determined the value of component in the filter was not detailed and explainned.

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According to several references passive filter can be constructed by combining two or more components of inductor (L) and capacitor (C)[5]. In this work, Shunt and series performances passive filter compared to reduce harmonic of LED lamps. LC filter was chosen to be applied as additional circuit to eliminate the most dominant harmonics of selected LED lamps.

## PASSIVE FILTER

Passive filter is most commonly used filtering techniques for mitigation of harmonics, it offers low impedance path to divert harmonic current caused by non-linear load. Passive filter has two types, series passive filter and shunt passive filter as connection based, a series filter should carry full load current while shunt type filter takes only a part of full load current. The shunt passive filter can able to deliver reactive power at fundamental line frequency and due to lower cost, it is best suited to practical use for harmonic filters[5].

## EXPERIMENTS AND RESULTS

The illustration of experimental circuit in general is shown in Fig. 1. The values of electrical parameters as the dominant parameters of LED lamps was read and recorded directly from PQA to personal computer by using USB.

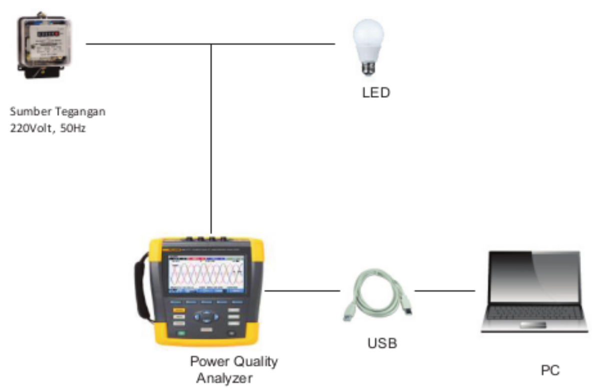



**FIGURE 1.** Harmonics measurement LED lamps

Every LED lamps measured separately to get the value of voltage and current harmonics. The result of measurement for every brand of LED lamps shown in Table 1 and Table 2.

**TABLE 1**. Percentage of Total Harmonic Distortion of Current ($THD_I$) LED Lamp Brand-X

| No | Rating Power | $THD_V$ (%) | $THD_I$ (%) |
|---|---|---|---|
| 1 | 3W | 1.6 | 144.8 |
| 2 | 4W | 1.1 | 145 |
| 3 | 7W | 1.4 | 130 |
| 4 | 14W | 1.4 | 125.4 |

Table 2 shown that the largest harmonics of voltage is 1.6 % and the largest of harmonics of current is 155%.

**TABLE 2.** Percentage of Total Harmonic Distortion of Current ($THD_I$) LED Lamp Brand-Y

| No | Power | $THD_V$ (%) | $THD_I$ (%) |
|---|---|---|---|
| 1 | 3W | 1.3 | 155 |
| 2 | 5W | 1.3 | 151.4 |
| 3 | 9W | 1.4 | 148.5 |
| 4 | 17W | 1.3 | 150 |

Table 3 show the highest current harmonics for brand-X is 11.5 mA and it is present in the 3rd order of harmonics. For brand-Y, the highest order also present in the 3rd order with magnitude of current 11.4 mA.

**TABLE 3**. Harmonics order LED Lamp Brand-X and Brand-Y

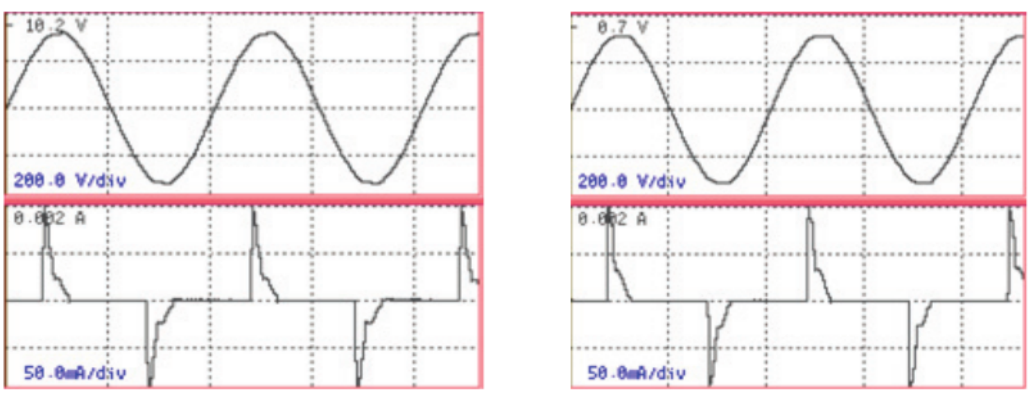
| Order | U [V] | I [A] |
|---|---|---|
| 1 | 228.8 | 13.4m |
| 2 | 1.9 | 0.3m |
| 3 | 1.9 | 11.5m |
| 4 | 0.8 | 0.4m |
| 5 | 1.2 | 8.6m |
| 6 | 0.5 | 0.4m |
| 7 | 1.0 | 6.0m |
| 8 | 0.3 | 0.4m |
| 9 | 1.0 | 5.1m |
| 10 | 0.3 | 0.4m |
| 11 | 1.0 | 5.0m |
| 12 | 0.3 | 0.4m |
| 13 | 0.4 | 4.6m |
| 14 | 0.2 | 0.4m |
| 15 | 0.2 | 3.8m |
| 16 | 0.2 | 0.3m |
| 17 | 0.4 | 3.2m |

(a) Harmonik order Brand-X

| Order | U [V] | I [A] |
|---|---|---|
| 1 | 227.6 | 12.9m |
| 2 | 0.9 | 0.8m |
| 3 | 1.9 | 11.4m |
| 4 | 0.1 | 0.7m |
| 5 | 0.4 | 9.0m |
| 6 | 0.2 | 0.5m |
| 7 | 1.1 | 6.4m |
| 8 | 0.2 | 0.6m |
| 9 | 1.2 | 4.9m |
| 10 | 0.1 | 0.8m |
| 11 | 1.0 | 4.5m |
| 12 | 0.1 | 0.9m |
| 13 | 0.1 | 4.5m |
| 14 | 0.1 | 1.0m |
| 15 | 0.4 | 4.2m |
| 16 | 0.0 | 1.0m |
| 17 | 0.3 | 3.6m |

(b) Harmonik order Brand-Y

The shapes of waveform of voltage and current for brand-X and brand-Y LED lamps are shown in Fig. 2




(a) Waveform LED lamp brand-X (b) Waveform LED lamp brand-Y

**FIGURE 2.** Waveform voltage and current

According to the results in Fig. 2, it is found that both of LED lamp have dominant high harmonics distortion for current presented in the fundamental and 3rd order.

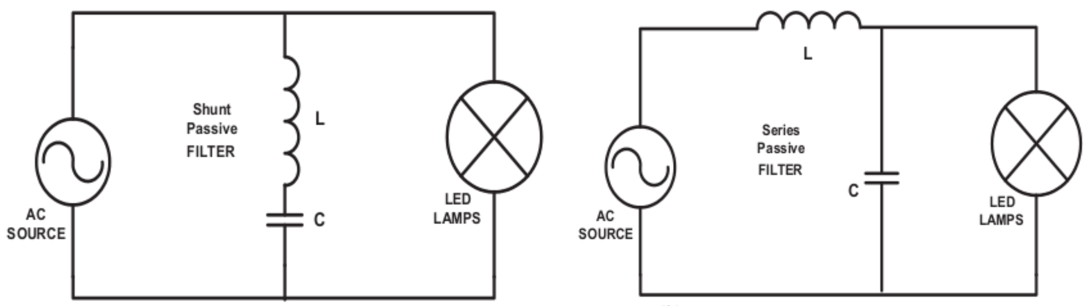
## DESIGN OF LC FILTER

Passive filter is most commonly used as filtering techniques for mitigation of harmonics. Passive filters are combination of inductance, capacitance and resistance elements configured and tuned to reduce the impact of harmonics in the power systems[6].

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[7], the value of inductor (L) in Henry and capacitor (C) in Farad may determine by equation (1).

$$C = \frac{1}{(2\pi f)^2 {h_0}^2 L} \tag{1}$$

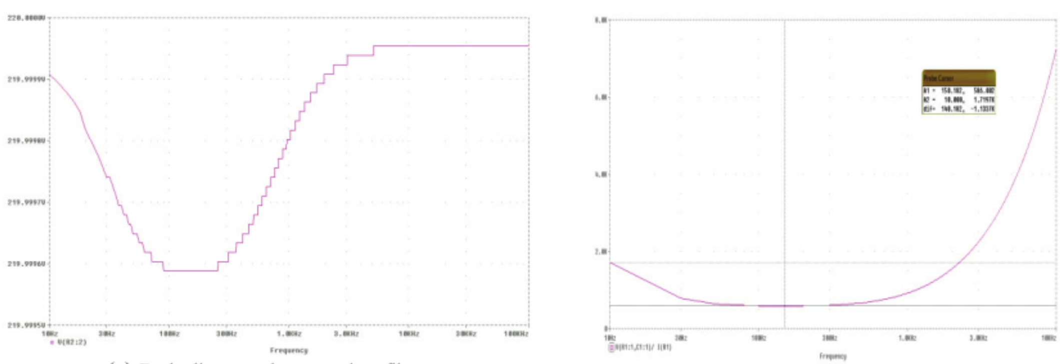
Here, the cut-off frequency of harmonic filter is fixed at 150 Hz ( $h_0$ ). From equal (1), the value of inductor is 115 mH and the value of capacitor is 9.8μF.




(a) LED lamps with shunt passive filter (b) LED lamps with series passive filter

**FIGURE 3**. LED lamps with LC filter

Bode diagram at Fig. 6 that shown cut off frequency in 150 Hz. The highest harmonics are in the third order so that the filters are designed to reduce harmonics in this order.

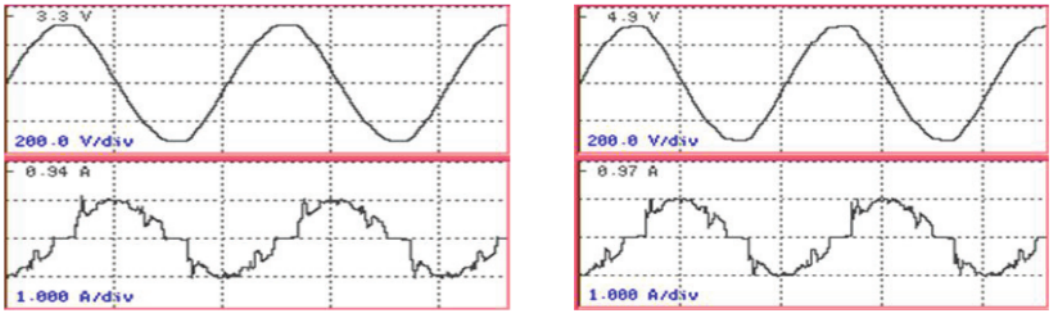


(a) Bode diagram shunt passive filter (b) Bode diagram series passive filter

**FIGURE 4**. Bode diagram

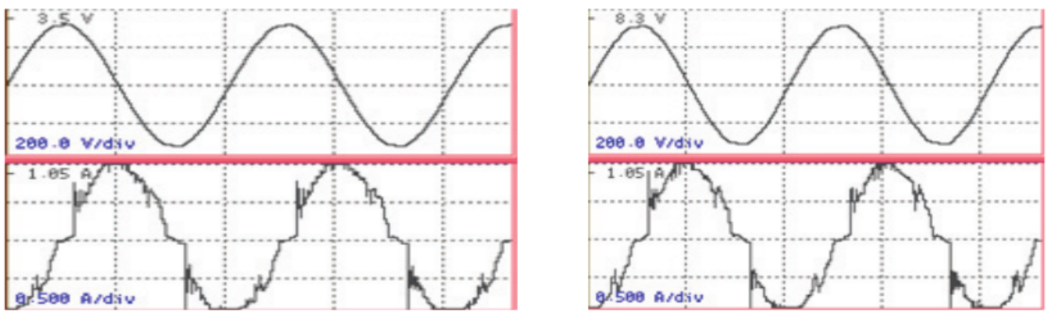
## RESULT AND DISCUSSION

Circuit in Fig. 3 was carry out for every lamps of brand-X and brand-Y. The result after shunt and series passive filter attached to LED lamps shown in Figs. 5 and 6.




(a) Waveform LED lamp brand-X (b) Waveform LED lamp brand-Y

**FIGURE 5.** Waveform voltage and current after shunt filtering




(a) Waveform LED lamp brand-X (b) Waveform LED lamp brand-Y

**FIGURE 6**. Waveform voltage and current after series filtering

Shunt passive filter in LED lamps for both brands-X and brand-Y has significantly reduce the value of THDi as it is shown in Table 4 and 5, and for series passive filter shown in Table 6 and 7.

The use of passive filter in LED lamps for both brands-X and brand-Y has significantly reduced the value of THDi as it is shown in Table 4,5,6 and 7. For example, $THD_i$ decrease from 144.8 % to 19.1 % with shunt passive filter for brand-X 3 watt and from 155% to 19% for brand-Y 3 watt with series passive filter. Based on the results in same tables, the current shape becomes more sinusoid.

**TABLE 4**. Percentage of $THD_I$ LED Lamp Brand-X after filtering using shunt passive filter

| No | Power | $THD_V$ (%) | $THD_I$ (%) |
|---|---|---|---|
| 1 | 3W | 2.1 | 19.1 |
| 2 | 4W | 2 | 18 |
| 3 | 7W | 2.1 | 19.2 |
| 4 | 14W | 2.1 | 19.4 |

**TABLE 5**. Percentage of $THD_I$ LED Lamp Brand-Y after filtering using shunt passive filter

| No | Power | $THD_V$ (%) | $THD_I$ (%) |
|---|---|---|---|
| 1 | 3W | 2 | 19 |
| 2 | 5W | 2 | 19.1 |
| 3 | 9W | 2.1 | 19 |
| 4 | 17W | 2.1 | 20.6 |

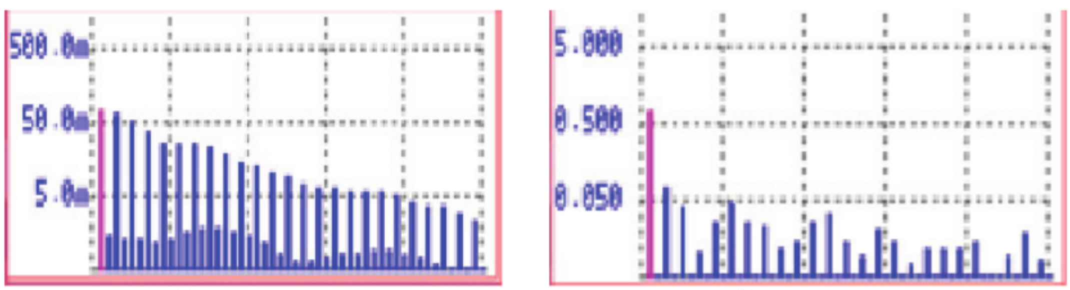
**TABLE 6**. Percentage of $THD_I$ LED Lamp Brand-X after filtering using series passive filter

| No | Power | $THD_V$ (%) | $THD_I$ (%) |
|---|---|---|---|
| 1 | 3W | 1.2 | 11.4 |
| 2 | 4W | 1.3 | 12.5 |
| 3 | 7W | 1.3 | 15.8 |
| 4 | 14W | 1.3 | 17.2 |

**TABLE 7**. Percentage of $THD_I$ LED Lamp Brand-Y after filtering using shunt passive filter

| No | Power | $THD_V$ (%) | $THD_I$ (%) |
|---|---|---|---|
| 1 | 3W | 1.3 | 13.2 |
| 2 | 5W | 1.3 | 13.5 |
| 3 | 9W | 1.3 | 14.6 |
| 4. | 16W | 1.3 | 17.2 |

It was recorded that the THD voltage could exceed the 8% of IEC standard limit when 80% incandescent lamps in a distribution power network are replaced with LED lamps[4], and the investigation presented in this work shows that the THD voltage is available in every brand of LED lamp. Several LED lamps in the same netwrok may become voltage harmonics source. Although it was reported in[5] that the use of double tuned passive filter more effective in removal of harmonic distortion than single tuned passive filter, the source current amplitude showed in this work was increased from 50 mA to 500 mA, which is due to the impedance of the passive filter. More current leads to more electric power consumption.




(a) Before filtering (b) After filtering

**FIGURE 7.** Frequency spectrum before and after filtering

## CONCLUSION

Shunt and series passive filter have reduce the dominant order in harmonics was successfully decreased the value of $THD_i$ for every sample of LED lamps without affecting the shape of voltage waveform. Shunt passive filter can reduce THD current until 88 % and series passive filter can reduce THD current up to 92 %. Series passive filter has performed better than shunt passive filter.

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