REDUCTION OF CURRENT HARMONIC CAUSED BY AC-DC RECTIFICATION WITH HYBRID FILTER FOR ENERGY SAVING LAMP ELECTRONIC BALLAST

Wiwik Hadajadi, F. Danang Wijaya, Sarjiya

[1] Jurusan Teknik Elektro dan Teknologi Informasi, Fakultas Teknik, Universitas Gadjah Mada, Jl.Grafika 2 Yogyakart
55281, INDONESIA. (e-mail: wiwikhandajadi@gmail.com)

[2), 3)] *Jurusan Teknik Elektro dan Teknologi Informasi, F*
Fakultas Teknik, Universitas Gadjah Mada, Jl. Grafika 2 Yogyakarta
55281, INDONESIA. (e − mail: f. danangwijaya@teti gadjahmada. edu)

ABSTRACT

Use LHE (Energy Saving Lamp) that use electronic ballasts will cause harmonics, both current and voltage harmonics and the harmonics will result in a poor electric power quality. On the other hand LHE that uses electronic ballasts have good properties in converting electrical energy into light, because it has an efficiency of above 80%. This research aims to analyze the activity electric power quality in the distribution network due to load LHE with electronic ballast. We then measured with a laboratory scale and continued analysis using the program, for the issues analyzed include: the use of electronic ballasts will cause harmonic currents and voltage, harmonics and odd harmonics influential 3rd harmonic dominant, harmonics will affect the quality of electric power . thus will follow up effort to minimize the presence of harmonics in particular harmonic currents and harmonic influence further analyzed for capacity LHE group with large-capacity load on the distribution network.

In order to save electrical energy, mainly for lighting, energy-saving lamps can be used. Those lamps, which use electronic ballast and added by hybrid filter, can reduce negative effect due to harmonic, so that efficient condition in load and optimal condition in distribution network can be obtained. This study was carried out by a simulation with PSIM program version 9.0 and a reference to minimize current harmonics in such energy-saving lamps using electronic ballast to increase the quality of electrical power.

Results of the study show that reduction in large current harmonics of 10% due to AC-DC rectification was because of electronic ballast use. Moreover, some efforts were found reducing the harmonic effect by using hybrid filter to meet the standards of IEC 61000-3-2 in Class C.

Key Words : Harmonics, hybrid filter, electronic ballast

INTISARI

Penggunaan LHE (Lampu Hemat Energi) yang menggunakan ballast elektronik akan menimbulkan harmonik, baik harmonik arus maupun tegangan dan adanya harmonik akan berakibat kualitas daya listrik menjadi buruk. Disisi lain LHE yang menggunakan ballast elektronik mempunyai sifat- sifat yang baik dalam mengkonversikanenergi listrik menjadi cahaya, karena mempunyai efisiensi diatas 80%. Riset ini melakukan kegiatan yang bertujuan menganalisis kualitas daya listrik pada jaringan distribusi akibat beban LHE dengan ballast elektronik. Selanjutnya dilakukan pengukuran dengan skala laboratorium dan dilanjutkan analisis dengan menggunakan program, untuk itu dianalisis permasalahan yang meliputi: penggunaan ballast elektronik akan menimbulkan harmonik arus maupun tegangan, harmonik yang berpengaruh harmonik ganjil dan harmonik ke-3 paling dominan, harmonik akan berpengaruh pada kualitas daya listrik.Dengan demikian akan ditindak lanjuti upaya untuk memperkecil adanya harmonik khususnya harmonik arus dan selanjutnya dianalisis pengaruh harmonik untuk kapasitas kelompok beban dengan LHE berkapasitas besar pada jaringan distribusi.

Untuk penghematan penggunaan energi listrik, khususnya kebutuhan penerangan harus diupayakan adanya konversi energi listrik yang optimal dan efisien, maka dapat digunakan LHE yang menggunakan ballast elektronik dan ditambahkan filter hybrid dapat mengurangi efek negatif yaitu adanya harmonik, sehingga dapat diperoleh kondisi yang efisien pada beban dan optimal pada jaringan distribusi.

Dalam penelitian ini dilakukan simulasi dengan program PSIM versi 9.0 dan menggunakan acuan, untuk meminimalkan adanya harmonik arus pada LHE dengan ballast elektronik agar dapat

meningkatkan kualitas daya listrik.
Dari hasil penelitian ini dapat diperoleh pengurangan besarnya harmonik arus sebesar 10 % akibat penyearahan AC- DC, akibat penggunaan ballast elektronik. Selain itu juga dapat diperoleh cara mengurangi adanya harmonik dengan menggunakan filter hybrid tersebut agar LHE memenuhi standar IEC 61000-3-2. Class C.

Kata- kata kunci : Harmonik; filter hybrid; ballast elektronik.

INTRODUCTION

Electric power is an energy having useful characteristic compared to other energy; easy to generate (generation), easy to transmit (transmition), easy to distribute (distribution), and easy to transform into other energy by high efficiency. To generate electric power it needs other energy as primeover energy; the existing currently is mostly using fossil energy. Energy conservation sources from fossil energy nowadays have been decreased, whereas to generate electric energy it still mostly base on this energy. Although the effort to generate electric energy is being strived by various ways which use other energy beside of fossil and is an environment-friendly process (reversible).

On the other hand, it needs the effort of energy saving for fullfiling energy necessity, either for industrial use and domestic use. In saving electric energy it can be strived the increase of electric power quality (EPQ).

For saving the use of electric energy, especially the enlighment use should be strived the existence of conversion from electric energy into light optimally and efficiently, thus it is used LHE (Energy Saving Lamp). It based on the energy necessity for enlighment in generally is 25-50% (Muhammad WNWZ,2010: 282-286) from total of electric energy for a building.

Nowadays, the enlightment of a building is dominated by using fluorescent lamp and in generally energy saving lamp (LHE). In LHE, there is electronic ballast used in converting from *Alternating Current to Direct Current* (AC-DC) and the existence of this converter will emerge current harmonic of which will decrease the quality of electric power. Thus, it needs to strive the decrease of current harmonic emerged as the result of transformation of AC-DC and the existence of converter (*Direct Current to Alternating Current* = DC-AC) on electronic ballast in LHE, thus it gains EPQ optimally and by minimizing the cost in decreasing the harmonic; it aims to save relatively cheap price of LHE compared to previous price.

BASIC THEORETICAL

A. Harmonic

Variant of basic wave of a voltage source or A.C. electric current by shape of sinus, as the effect of certain load for example nonlinear load will result this variant wave is not a pure sinus. However by Fourier's method it can be explained that the variant of this wave is a component of pure sinus having multiple frequency of its fundamental frequency, by the smaller amplitude than its fundamental amplitude. It is so-called harmonic. Harmonic meant in this matter is the orders of current wave or voltage whose frequency is the multiplication of cardinal number from the base frequency of voltage or the current itself. Multiplying cardinal number on harmonic frequency is orders (n) of this harmonic. For example, base frequency of electric system in Indonesia is 50 Hz, thus the second harmonic is 2 x 50 Hz (100 Hz), the third is 3 x 50 Hz (150 Hz), et cetera, thus n^{th} harmonic has frequency n x 50 Hz..(Subuh Isnur Haryudo, 2007).

Distortion of the shape of harmonic wave is second, third and so on is total by base wave, thus the shape of voltage or current wave will be distorted.

Figure 1 shows a perfect base wave by nominal 3 Ampere at frequency of 50 Hz or 20 mili second per cycle. Meanwhile Figure 2.7 shows a 3^{rd} harmonic wave. Thus at this figure, the amount of current is 1/3 of base current wave, i.e. 1 ampere by frequency of 150 Hz, or 3 times from frequency of base wave.

For the first signal is stated as function of period and frequency is stated in equation (1) [5]

$$I = I\sin(\omega t) \quad (1)$$

second signal is:

$$I_2 = \left(\frac{1}{3}\right) I\sin(\omega t) \quad (2)$$

The join of signal i_1 and i_2 by superposition, thus the result is signal stated as follow:

$$I_3 = I_1 + I_2 \quad (3)$$
$$= I\left[\sin(\omega t) + \left(\frac{1}{3}\right)\sin(\omega t)\right]$$

and the variant of this signal can be seen in Figure 1.

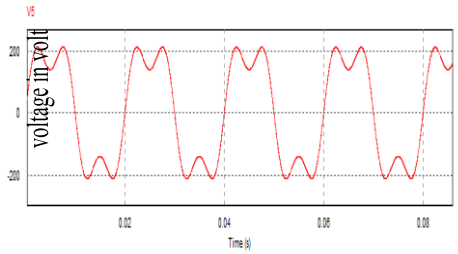


Figure 1 The shape of current wave distorted 3rd harmonic

Total amount of disturbance of harmonic in a electric power system is stated by Total Harmonic Distortion (THD), defined in equation (4). (Subuh Isnur Haryudo, 2007).

$$THD = 100 \times \frac{\sqrt{\sum_2^x V_n^2}}{V_1} \quad (4)$$

by:
Vn : harmonic voltage in nth order
V1 : fundamental voltage (V ms)

By the similar formulation, total harmonic disturbance for current can be also calculated, i.e. substituting the component V by I.

The existence of harmonic in electric power system will result various effect, below are influences of harmonic in electric power system. One of the examples of observation seems in Figure 5, that 3rd harmonic has biggest percent compared to uneven harmonic from bigger order.

B. Filter Hybrid

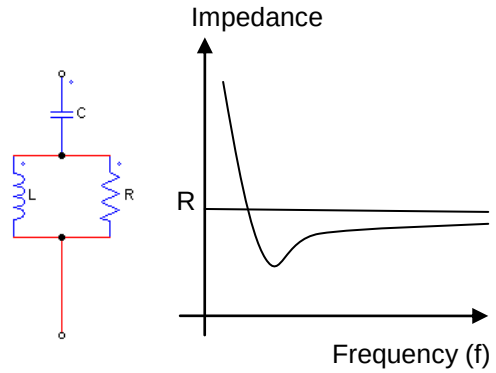
Passive High Pass Filter Damped, is very influential filter to hybrid filter by reason of it has either simple structure or characteristic of harmonic compensation.

The series of second order passive high pass filter damped in Figure 2 can be substituted by a second ordered leg-tuned high pass filter damped on appropriate frequency, i.e. a single-tuned passive filter. By this join structure, a capacitor is added compared to pure active filter. Voltage of small DC capacitor can be also determined through appropriate design of single-tuned filter for specific application by considering either simple structure or characteristic of harmonic compensation, the simple hybrid single tuned is a better assortment in various situations.

Second ordered High pass filter damped comprises of resistance paralleled by inductor and series to capacitor.
Impedance of

Impedance of the series can be written in equation (5) – (6). (Shui Qiang Liu, Shao Jie Wang, 2011)

$$Z = \frac{1}{j\omega C} + \frac{R\, j\omega L}{R + j\omega L} \quad (5)$$



(a) (b)

Figure 2a. Second ordered High pass filter damped
b. Curve of impedance of frequency function of second ordered high pass filter damped

During resonance of imaginer part = 0 and ω = ω_o, thus the equation will be as follow:

$$R^2 {\omega_0}^2 LC = R^2 + {\omega_0}^2 L^2 \quad (6)$$

thus it gains L value:

$$L_{1.2} = \frac{-R^2 \omega_o\, C \pm \sqrt{[R^2\ \omega_0^2\, C - 4\ \omega_0^2)}}{2\omega_0^2} \quad (7)$$

To gain real L, thus value under the root is positive, thus:

$$R^2 \omega_0^2\, C - 4\omega_0^2 \geq 0$$

and it gained

$$R \geq \frac{2}{C \omega_O} \quad (8)$$

From the ground of this discussion it will develop the use of Passive High Pass Filter Damped on hybrid filter by intended condition.

RESEARCH METHOD

In this research it conducted some steps, as follow:

1. Problem formulation.
2. Find out any literatures, magazine, journal, program package and standard referred in the connection to research.
3. Select the type and capacity of LHE will be study, based on problem selected in this research.
4. Create modeling and conduct activity of measurement in laboratory.
5. Conduct the selection of program package used in analysis.
6. Analyze by using selected program package, and then conduct simulation by comparing to standard.
7. Analyze the existence of harmonic from result of measurement and find out simulation by program.
8. Conduct analysis and effort to decrease the amount of THD existing in LHE electronic ballasted, by using hybrid filter as simulation by program package.
9. Conduct analysis by using program package, to find capacity influence n-LHE towards source voltage/distribution network.
10. Remark and suggestion.

Flowchart of the research can seen in Figure 5.

ANALYSIS AND DISCUSSION

Result of study in this research is differentiated into two, i.e.: using simulation program and conduct measurement on LHE in laboratory. It aims to gain trust worthiness and appropriateness theoretically to practically, in addition to gain optimal result.

A. Measurement of LHE harmonic by electronic ballast in Laboratory

Harmonic of voltage in source in the shape of FFT is shown in Figure 3.

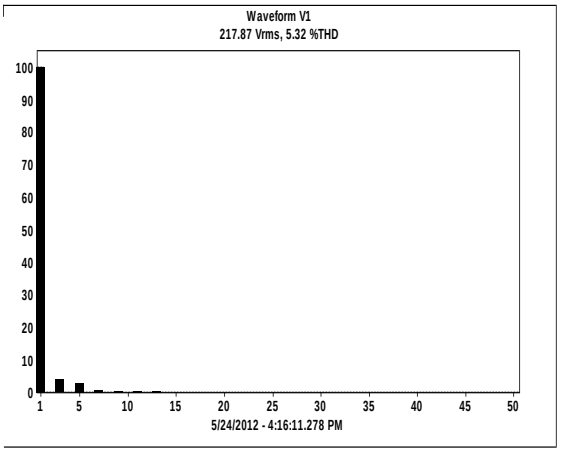


Figure 3. Variant of harmonic wave of voltage in FFT.

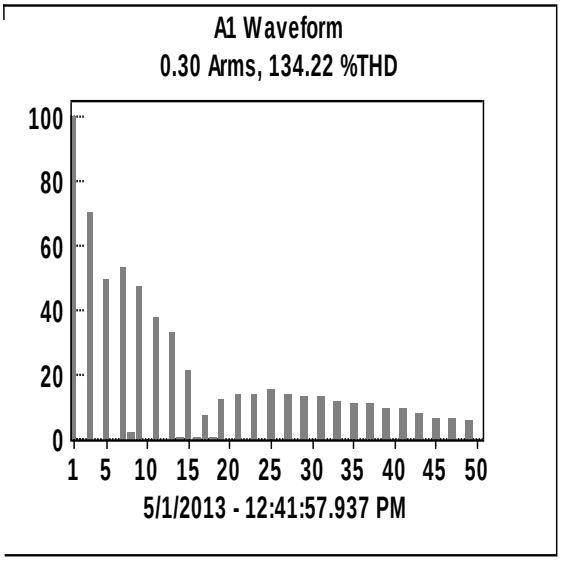


Figure 4. Variant of current harmonic wave in FFT.

Meanwhile for current of observation result of LHE, the amount of current harmonic can seen in Figure 4.

B. Simulation by PSIM version 9.0

In analysis it used LHE model by electronic ballast gained was then conducted simulation by using program PSIM version 9.0. In simulation it conducted for two condition, i.e. before the installment of filter (SB) and after installment of filter (SS).

For process of simulation by PSIM used series of model described in Figure 6.

This simulation aimed to find way to decrease the existence of harmonic by using hybrid filter using mixed component and by selecting simple component, however has cheap price value.

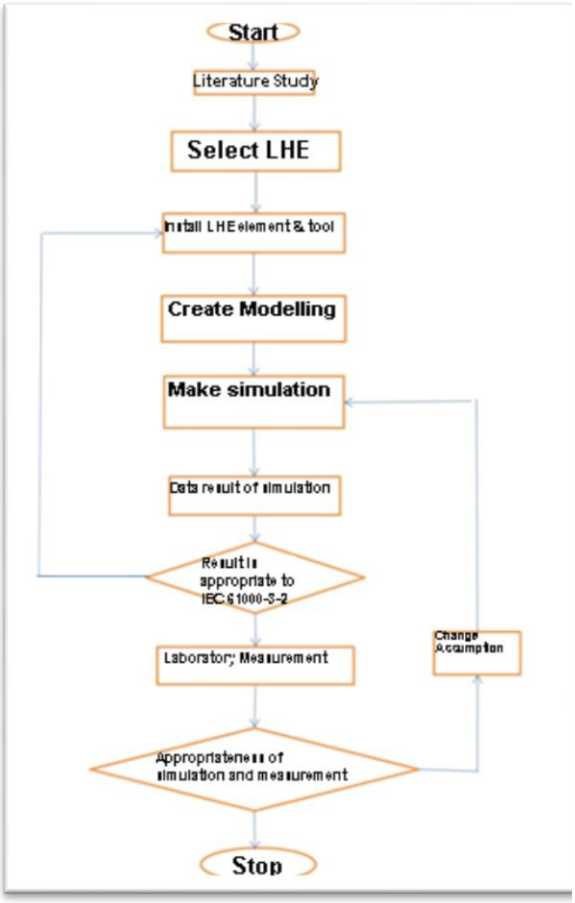


Figure 5. Flowchart of the research

B. Simulation by PSIM version 9.0

In analysis it used LHE model by electronic ballast gained was then conducted simulation by using program PSIM version 9.0. In simulation it conducted for two condition, i.e. before the installment of filter (SB) and after installment of filter (SS).
For process of simulation by PSIM used series of model described in Figure 6.

This simulation aimed to find way to decrease the existence of harmonic by using hybrid filter using mixed component and by selecting simple component, however has cheap price value.

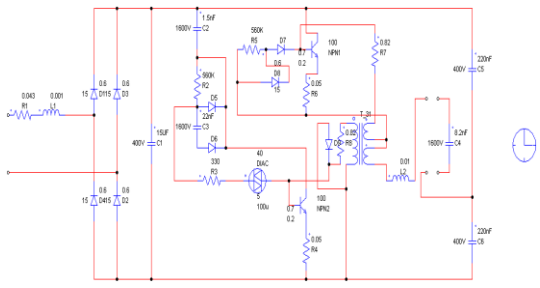


Figure 6. LHE model by electronic ballast

Meanwhile in determining the amount of component used to gain result for decreasing harmonic optimally. After gained way and amount resulted in effort appropriate to its purpose, thus it conducted converting or adding of component on pure LHE. Then it was conducted measurement of amounts of which determines EPQ of LHE in increase the full filment of any given standard.

From the result of simulation it will gain data of which can be used as calculation base/ analysis of observed LHE and finally can be measured the existence of amount used in calculating the quality of EPQ. Thus it can be compared better for initial condition to final condition of analysis, if compared to valid standard IEC 61000-3-2. Class C .

From analysis as result of the existence of current harmonic on distribution network of which can influence the quality of electric power, the effect of the use of load by shape of LHE by capacity appropriate to IEC 61000-3-2. Class C , thus it made load gride of which is a join of n item LHE for capacity by smaller current or similar to 16 A. The analysis was conducted by program PSIM 9.0.

Using program PSIM version 9.0 by simulation in measurement of harmonic it gained variant of wave from source current (=I_s) and source voltage (= V_1) can be shown in Figure 6, for condition before existing and after existing of filter.

A. Before existing filter

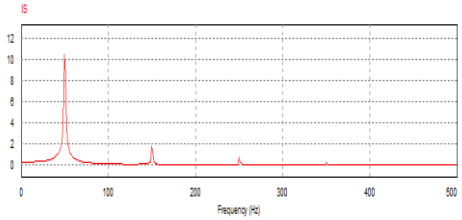


Figure 7. Graphic of source current (I_s) (FFT)

(SB)

B. After adding filter

Meanwhile the result of measurement as simulation after adding filter (SS) can be seen in Figure 8.

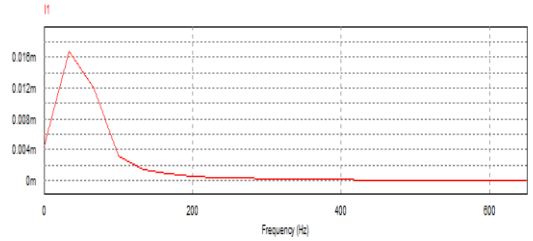


Figure 8. Graphic of source current (I_s) (FFT)

From Figure 7 can be gained the amount of current harmonic before the existing of hybrid filter, the data can be drawn into Graphic 7.

From the result of simulation shown it drawn graphic on the relation of current amount and voltage with the harmonic emerged before (SB) and after (SS) the existence of hybrid filter. This relation is seen in Figure 6 and 7, and from these figures it can be known the decrease on the existence of adding hybrid filter installed on LHE ballast for current amount.

From the data as result of measurement and result of simulation that harmonic is good for current amount seems the 3rd harmonic shows the biggest, by range for current harmonic has percentage of 10%.

To comprehend how the result of comparison of THD before (SB) and after (SS) the installment of hybrid filter in LHE ballast towards standard IEC 61000-3-2, Class-C (STD), it is shown in Figure 9.

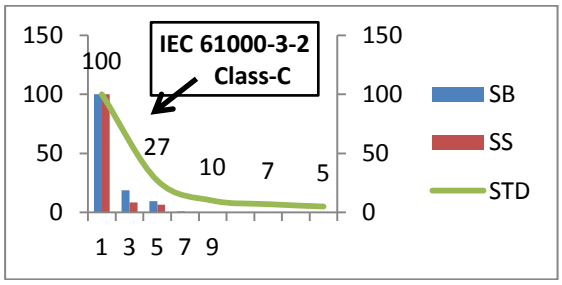


Figure 9. Graphic on comparison of current THD SB and SS the installment of filter by standard IEC 61000-3-2, Class-C.

Analysis of harmonic on LHE by electronic ballast was merely conducted as simulation by using PSIM version 9.0 and the filter used was hybrid filter. In designing filter it used result of research; that dominant harmonic is the third harmonic, thus ω_o taken 150 Hz and by the existence of hybrid filter it will be able to increase Cos φ, from 0,86 into 0,88 and fulfill standard IEC 61000-3-2, Class-C.

A. Measurement by simulation

Result of test of n – load group of LHE by electronic ballast in giving distribution of harmonic on source/distribution network.

The influence of current harmonic for load n LHE can be seen in the result of simulation and Figure 9.

B. Measurement in laboratory

From the measurement in laboratory from n group LHE by electronic ballast, thus it gained data thus it will gain graphic on relation of load amount to THD. The influence of this load can be seen in figure of graphic drawn in Figure 11, 12, 13 the amount of current n group and also current THD.

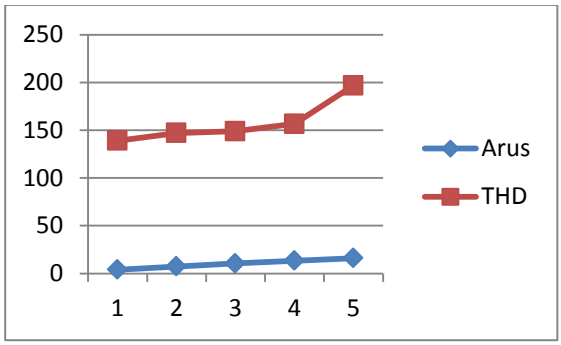


Figure10. Graphic on relation between current
(load) to THD for big capacity.

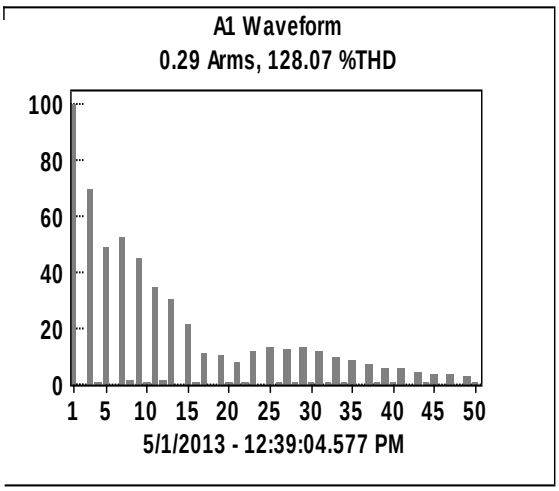


Figure 11. Wave harmonic in FFT for n-1

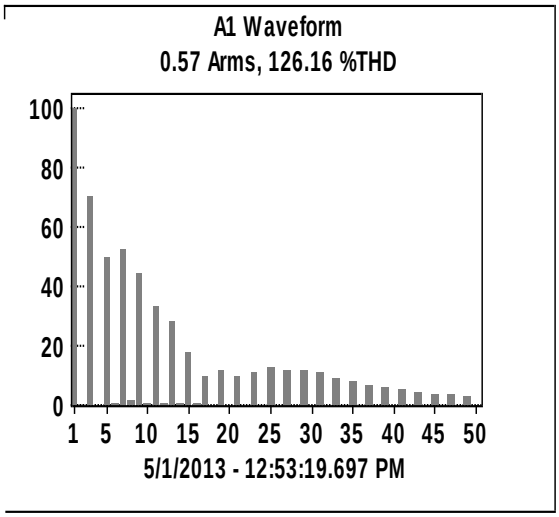


Figure 12. Current harmonic in FFT for n=2

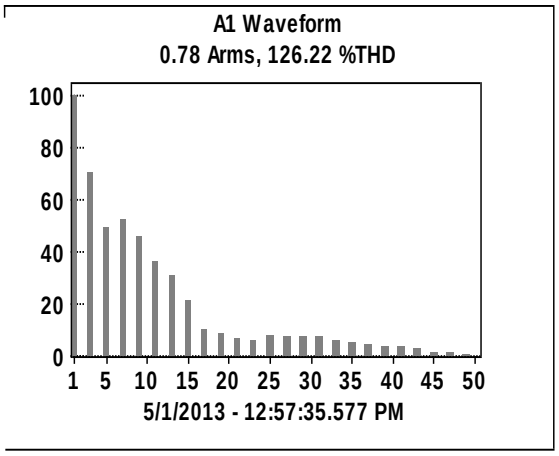


Figure 13. Current harmonic in FFT for n=3

From data of result of measurement seen in Figure 11, 12 and 13, it can be drawn a graphic stating the relation of load group by THD from current, of which shown in Figure 14.

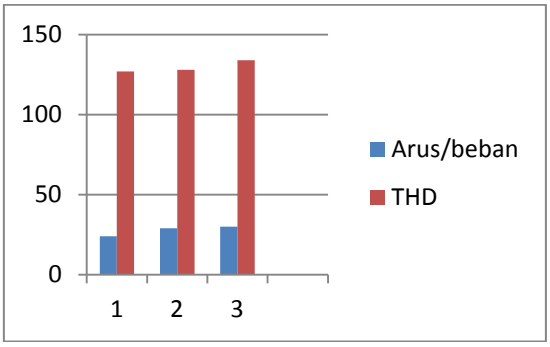


Figure 14. Graphic on the relation of amount of load group towards the measurement in laboratory

From data listed in table and graphic can be seen that the existence of harmonic emerged as the result of the use of LHE by electronic ballast will influence electrical amount, i.e. PDF, active power, apparent power or so-called quality of electrical power. In addition the amount of power of which is the source also influence the amount of harmonic emerged of 1.24%.

CONCLUSION

A. Conclusion

From the result of research and discussion had been conducted in testing LHE by electronic ballast and conducted simulation of LHE model it can be withdrawn some conclusion relating to harmonic and quality of electric power, as follow:

- The use of electronic ballast in LHE will result harmonic of load and current, of which most dominant is 3rd harmonic.
- By using hybrid filter it can decrease the existence of current harmonic, thus THD will decrease 10% and will increase cos φ (DF = Derating Factor) of 0.02.
- The existence of harmonic will influence the quality of electric power, i.e. bigger capacity of LHE use by electronic ballast will give effect to current harmonic and bigger load and bigger factor cos φ (DF) reach 0.99 and has leading characteristic.

B.

For further research can be conducted study on the influence of the existence of harmonic and in particularly current harmonic as result of use of n-LHE by electronic ballast, by big capacity on distribution network, in particularly transformer used.

REFERENCES

Eka Firmansah,VSatoshi TOMIOKA, 2010, *Totem-Pole-Factor – Correction Converter under Critical-Conduction-Mode Interval Operation*, IEICE transactions on Comunication, Vol.E93-B No.9.

Fathurohman, Arief, dan Jusanto Gusman, 2000, Metode CPPFC (*Charge Pump Power Factor Corection*) Sebagai Ballast Ellectronik Pada Lampu Tabung.

J. F. Hernández-Pérez, dkk., 2007, *A Morlet Wavelet Signal Analysis with a Daubechies Filter for Power Quality Disturbances*, IEEE.

Liem Ek Bien ; Sudarno, 2004, Pengujian harmonisa dan upaya pengurangan gangguan harmonisa pada lampu hemat energy, JETri, Volume 4, Nomor 1.

LV Zhaorui, XIA Li, WU Zhengguo, 2008, *A New Harmonic Analysis Method* [9] Hui Ding, dkk., 2006, A *Method Combining LPC-Based Cepstrum and Harmonic Product Spectrum for Pitch Detection*, IEEE.

Mujiman, 2007, Unjuk Kerja Lampu Flourescen Ballast Elektronik dibanding Lampu Flourescen Ballast Induktor, UGM.

Muhammad WNWZ, Zain MYM,Wahab N Aziz NHA, Kadir RA. Energi EffisienSystem Lighting System Design for Building.IEEE Intl. Coference on Inteliget System, Modelling and Simullation (ISMS) Liverpool. 2010: 282-286.,

Qiang Jiang, dkk., 2008, *Measurement of Harmonics and Inter-harmonics Based on DWFFT,* IEEE.

Subuh Isnur Haryudo, 2007, Peredaman Harmonik Sistem Tenaga Menggunakan Filter Aktif *Hybrid,* Electrical Engineering, Faculty of Technology, Hang Tuah University, ,Indonesia

Shui Qiang Liu, Shao Jie Wang, 2011, *Improved method for detecting currents with harmonics and reactive power in the injection active power filter*, Jurnal IEEE .

Sumani, Sambodho, 2002, Pengenalan Mutu Listrik, Prosiding Seminar *for AC/DC/AC ,* IEEE Elektric Power Quality, STT-PLN, Jakarta

The WEEE website. [Online]. Available: http://www.aemc.com], 2002.