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Simulation of Passive Filter Harmonic Reduction and Power Factor Improvement for Non-Linear Loads IEC 61000-3-2 Standard

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Abstract - Pure sinusoidal shape of the current or voltage waveform is distorted by the third harmonic. Harmonics based on their order are odd order harmonics 3, 5, 7, 9,11 and so on, Harmonics can also be defined as components with frequencies that are integer multiples of the fundamental frequency. The first harmonic is the fundamental frequency, namely 50 or 60 Hz, the second harmonic is a component with a frequency twice the fundamental frequency, namely 100 or 120 Hz, etc.The ability of the passive single tuned filter used in this research was able to reduce the Total Harmonic Distortion content from 78.8% to 10.72%, IEC 61000-3-2 class D harmonic standard limits, the harmonic orders generated by the Power Amplifier exceed the standard, namely orders 3, 5, 7, 9, 11, 13, 15, 17, 19, 21**,** the Total Harmonic Distortion content from 78.8% to 10.72%. According to IEC standards.

Keywords –Harmonics, Active Power, Non-linear load, THDi

1. INTRODUCTION

The phenomenon of non-sinusoidal waveforms is a phenomenon arising from the operation of non-linear electrical loads, which will form waves with a fundamental frequency of 50 Hz or 60 Hz that cause the current and voltage waveforms, which are ideally pure sinusoidal, to become non-sinusoidal, which is called harmonics. Equipment using sensitive electronics can suffer from voltage and current harmonics in the event of mis operation. Some loads with sensitive equipment rely heavily on the accuracy of sinusoidal signals, and harmonics can cause zero crossing. [1].

Non-linear loads continue to impact the quality of electrical power. Non-linear loads that generate harmonics include photostats, laptops, personal computers, freezers, amplifiers, televisions, and Harmonics are generated by non-linear loads, as well as in room lighting such as fluorescent lamps with electronic ballasts, The presence of harmonic content in non-linear loads causes the quality of electrical power to decrease and become low. It is estimated that the generation of harmonics increases with the number of non-linear loads used. These harmonics carry the risk of the power supply overheating and impairing the capacity of other electrical devices to operate together as a system, you must be using these non-linear electrical loads both at home and in the office [2].

A passive single-tuned filter is a filter consisting of components of a resistor (R), an inductor (L), and a capacitor (C) connected in series that can reduce harmonics in accordance with the provisions of IEC 61000-3-2, class D [3] [4]. A single-tuned passive filter will reduce harmonics on odd orders and can increase the power factor. To improve the quality of electric power, this research simulates non-linear loads that have harmonics and implements a harmonic reduction of 1-phase non-linear loads found in workspaces that have non-linear loads, such as personal computers, lighting, and other loads in the office space, then adjusted to the recommendations of IEC 61000 standard -3-2, class D. [5].

Measuring instruments used to determine the harmonic data on non-linear loads in this study are the single-phase Power Quality Analyzer Fluke 43B (Figure 1) and (Figure 2) to determine the harmonics of current, voltage, power factor, and frequency in electric power [6].

2. METHOD

Apparent Power is the power produced by multiplicationbetween voltage and current in a network or power which is the result of the trigonometric sum of active power and reactive power. Apparent power is the power released by an alternation current (AC) source or absorbed by the load. The unit of apparent power is the volt ampere (VA). The following is the equation for apparent poweras in figure 1.

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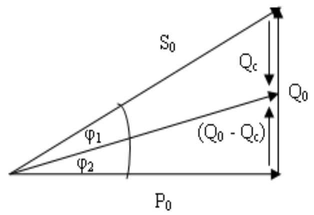

Figure 1. power triangle

Harmonic analysis, the following important indices are used to determine the influence of harmonics on electrical power system components and can be seen in total voltage harmonics and current harmonics as in equations 1 and 2.

$$THDv = \frac{\sqrt{\sum_{n=2}^{\infty}\left(\frac{Vn}{\sqrt{2}}\right)^2}}{\frac{V_1}{\sqrt{2}}} = \frac{\sqrt{\sum_{n=2}^{\infty}(V_n)^2}}{V_1} \quad (1)$$

$$THD_i = \frac{\sqrt{\sum_{n=2}^{\infty}\left(\frac{I_n}{\sqrt{2}}\right)^2}}{\frac{I_1}{\sqrt{2}}} = \frac{\sqrt{\sum_{n=2}^{\infty}(I_n)^2}}{I_1} \quad (2)$$

$$PF = Cos\ \varphi = \frac{P}{S} \quad (3)$$

The Fourier series can be expressed as equation 3:

$$f(t) = a_0 + \sum_{n=1}^{\infty}(a_n \cos n\omega t + b_n \sin n\omega t) \quad (4)$$

$$TPF = \frac{DPF}{\sqrt{1 + THD_i^{\ 2}}} \quad (5)$$

Where:

Cos φ	:	Power Factor
P	:	Active Power (Watt)
S	:	Volt Ampere Reactive

Harmonics Standard (IEC 61000-3-2)In general, harmonic current is a sinusoidal current with a frequency that is an integer multiple of the basic electrical frequency or usually 50 or 60 Hz. Additionally, only fundamental frequency current produces active power, measured in watts, which can also be referred to as apparent power or true power.

Class A:	Balanced 3 phase equipment; household appliances excluding equipment identified as Class D; Tools (except portable), dimmers for incandescent lamp (but not other lighting equipment), audio equipment; anything not otherwise classified
Class B:	Portable power tools
Class C:	All lighting equipment except incandescent lamp dimmers
Class D:	Single phase, under 600 W, personal computer, PC monitor, tv receiver, etc.

3. RESULTS AND DISCUSSION

Measurement results using a measuring instrument with a power quality analyzer picture 1, the measurements obtained THDv and THDi values, with a waveform that is not sinusoidal, and the measurement image is as shown in the picture. 2.

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a. b.
a. Figure 1, Non-linear load measurement b. Figure 2, additional non-linear load

Non-linear load means that the output waveform is not proportional to the voltage in each half cycle so that the output current and voltage waveforms are not the same as the input waveform (distortion), as in table 1.

If the wave is discontinuous, there is only a finite number of discontinuities in period T. The wave has a finite average value in period T. The wave has a finite number of maximums and minimums in period T.

The large use of non-linear loads in the electric power system causes the current to become very distorted with a percentage of current harmonics. A high percentage of current harmonic content Total Harmonic Distortion (THDi) in an electric power system can cause several serious harmonic problems to arise in the electrical system, giving rise to various kinds damage to vulnerable electrical equipment and causing poor use of electrical energy.

Table.1 Non linier loads

Non Linier Load	Power Faktor	THDi (%)	3rd (%)	5rd (%)	7rd (%)	9rd (%)	11rd (%)
Fluoresce lamp	0,60	12,1	10,7	2,0	1,8	0,9	0,6
Amplifier	0,61	52,1	32,1	30,7	14,2	7,8	2,6
Television	0,83	42,5	55,1	36,8	20,3	11,4	10,8
Laptop	0,60	93,8	49,6	43,8	36,2	27,5	17,7
PC	0,70	70,1	52,8	43,5	31,6	19,3	8,4
Printer	0,40	73,6	46,7	41,3	36,2	28,6	21,5
Freezer	0,54	70,8	11,0	4,7	11,0	7,1	7,1

Picture of the comparative value between power factor and total harmonic current which exceeds the provisions in the Harmonics Standard (IEC 61000-3-2) can be seen in Figure 4.

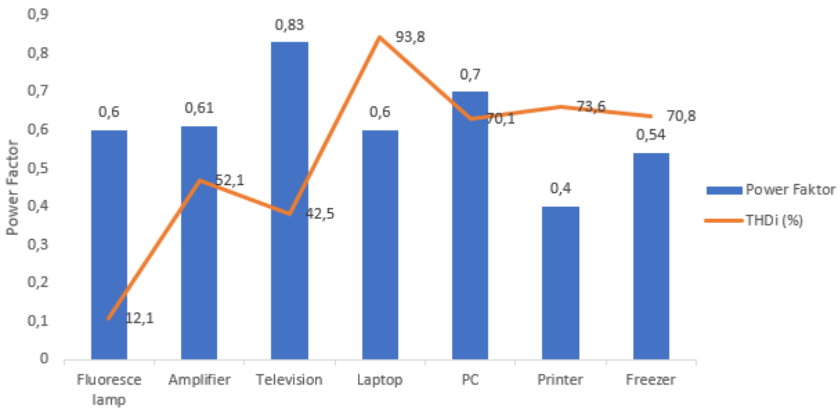

Figure 4. Power factor vs THDi

The form of voltage and current harmonics from the measurement results is not sinusoidal, so it gives rise to harmonics that must be reduced using filters. The total current harmonics and voltage harmonics can be seen in Figures 5 and 6.

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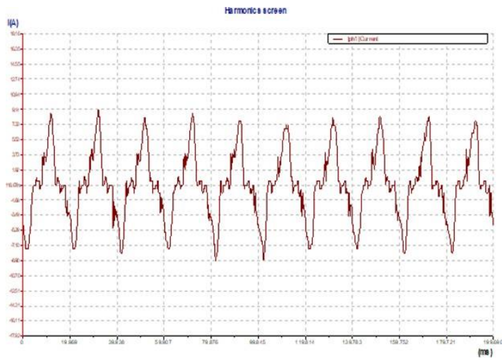
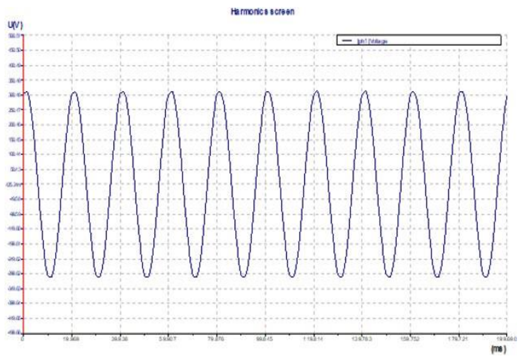




a. b.

a. Figure 5. THDi b. Figure 6. THDv

Simulation of reducing current harmonics and voltage harmonics using passive filters to reduce harmonic values and improve power factor on non-liner loads which can be seen in Figure 7. Power Factor or power factor is a comparison value between active power (P) and apparent power (S). Power factor is a comparison between good and bad electrical power quality. There is a difference between the power factor in harmonic-distorted and harmonic-undistorted wave conditions. A wave that is not distorted by harmonics will be sinusoidal, meaning that the power factor calculation does not involve harmonic frequencies in either the voltage wave or current wave.

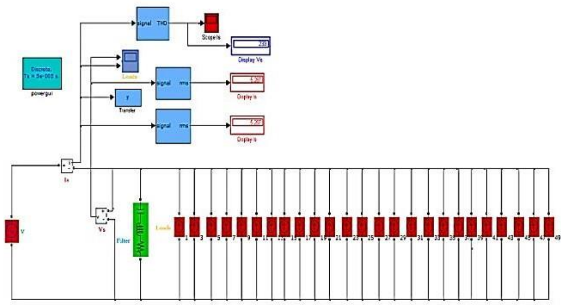
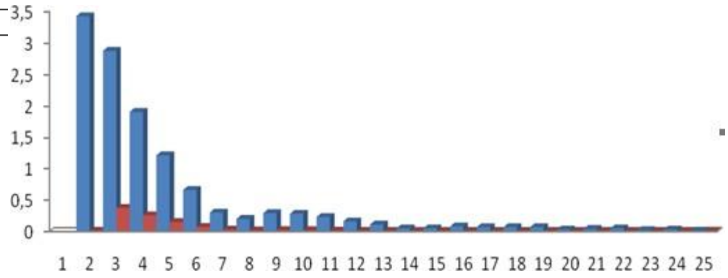


Figure 7. Simulation of reducing current harmonics

Simulation results with the results of reducing current harmonics by simulation. Odd order which based on measurements exceeds IEC standards, this graph shows a large decrease in the harmonic content of the current. The ability of the passive single tuned filter used in this research was able to reduce the Total Harmonic Distortion content from 78.8% to 10.72%. According to IEC standards, the standard limit is the Individual Harmonic Distortion (IHDi) value.

Orde	Standard IEC	THDi Before and After	
		Amp	**Amp**
3	0,07	0,05	0,003
5	0,07	0,08	0,003
7	0,06	0,07	0
9	0,06	0,07	0
11	0,06	0,07	0
12	0,05	0,03	0
13	0,05	0,04	0
15	0,05	0,05	0
17	0,05	0,02	0
19	0,04	0,03	0
21	0,04	0,01	0



a. b.

a. Figure 8, Standard Harmonic Vs Harmonic Currents b. Figure 9, Ordo HDi

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4. CONCLUSION

Based on the IEC 61000-3-2 class D harmonic standard limits, the harmonic orders generated by the Power Amplifier exceed the standard, namely orders 3, 5, 7, 9, 11, 13, 15, 17, 19, 21. The value of the passive single tuned filter used to reduce current harmonics and improve the power factor from 0.64 to 0.95 based on calculations used is a filter consisting of components R = 0.43 Ω, components L = 0.38 H and C = $4.02.^{10-5}$F.

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REFERENCES

[1] Mahmoud K and Lehtonen M, 2021, Comprehensive Analytical Expressions for Assessing and Maximizing Technical Benefits of Photovoltaics to Distribution Systems *IEEE Trans. Smart Grid*.
[2] Suriadi, Masri S, 2005, Minimization of harmonic current using double simmetric zig zag autotransformer Proceeding of robotics, vission, signal processing and power aplication.
[3 Gumilar L ,2020, Optimalization harmonic shunt passive filter using detuned reactor andcapasitor bank to Improvement power quality in hybrid power plant in AIP Conference proceedings Surakarta
[4] Merabet L, Salah S, Abdeslam D O, 2012, A comparative study of harmonic current identification for active power filter Int. J. of electrical power & energy systems pp 507-514 .
[5] Younis S A and Alyousif O M 2022 Electrical power system harmonics analysis using ETAP Al-Rafidain Engineering Journal (AREJ) pp 90-98 Eslami A, Negnevitsky M, Franklin E and Lyden S 2022 Review of AI applications in harmonic analysis in power system. Jour. of renewable and sustainable energy reviews
[6] Gusai A 2020 Harmonic analysis in PV connected power system Int. J. of engineering research and technology pp 474-477.
[7] Jain S K and Sing S N, 2011, Harmonic estimation in emerging power system key issues and challenges J. of Elect. Pow. Syst. research pp1754-1766.
[8] Zobaa A F and Aleem S H E A, 2014, A new approach for harmonic distortion minimization in power system supplying nonlinear loads J. of IEEE Trans. on Indust. Inform. pp 1401-1412.
[9] Jopri M H, Skamyin A, Manap M, Sukitno T, Shariff M R M and Belsky A, 2022, Identification of harmonic source location in power distribution network international J. of power electronic and drive system pp 938-949.
[10] Napitupulu J, 2019, Harmonic study in power substation hand book