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# Implementation of harmonics reduction filters in non-linear equipment at plastic manufacturing company

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## Abstract

Harmonics are produced by non-linear loads such as televisions, computers, microwaves, fluorescent lamps that use electronic ballasts and others. The harmonic content contained in non-linear loads causes the quality of electrical power to become poor and the quality of electrical power to decrease, the greater the use of non-linear loads, it is estimated that the harmonics generated will be greater and can disrupt the system performance of other electronic equipment and can also cause overheating of electrical power sources, plastic manufacturing company measurements, Source Voltage Balanced (V peak) Unbalanced (V peak) 312∠ 00, 311∠ -1200, 312∠ 1200, Phase R 3.23 Ampere, Phase S 3.24 Ampere Phase T 3, 24 Amperes as in figure 2a, and THD Current in Phase R 25%, Phase S 23% Ampere Phase T 24%, the total harmonic distortion was above 5% and the analysis for the single tuned filter was C value > 50.64 µF, L value > 10.093 H, and R value > 50.98 Ω. then after, harmonic values, a filter was installed to reduce the THD value to 1.4% and the overall THD value was below 5% in accordance with IEEE standards.

**Keywords:** frequency fundamental, Harmonic Spectrum, Single Tuned Filter, IEEE standard, power quality analyzer

## INTRODUCTION

Three-phase three-wire nonlinear loads generate sequential harmonic currents positive and negative. This harmonic current can cause resonance, voltage distortion, excessive heat, increase power losses, failure tool wear, premature failure of electrical equipment, etc. Burden single-phase nonlinearity which is generally connected between the phase conductor and the conductor neutral, giving rise to zero sequence harmonic currents, namely harmonics of order 3, 9, 15, 21… which are also called triple harmonics. Zero sequence harmonic currents generated by a single-phase load is summed algebraically on the neutral conductor and the magnitude can reach up to three times higher than harmonic currents sequence of zeros contained in the phase. Zero sequence harmonic currents, also give rise to typical problems such as those encountered in positive sequence harmonic currents and negative, can cause the neutral conductor to experience overload, occurring neutral voltage to ground, increasing phase voltage distortion, and heating overload on the transformer [1].

In a balanced three-phase system, the sequence of harmonic phases can be determined by multiplying the harmonic order number h by the direction of rotation of the sequence phase positive. For example, for the 2nd harmonic, namely h = 2, we get 2 x (0, -120°, +120°) or (0°, 120°, -120°), which is a negative sequence. For the third harmonic, namely h = 3, we get 3 x (0°, -120°, +120°) or (0°, 0°, 0°), which is a sequence of zeros. Phase sequence for all harmonic orders others can be determined in the same way. Complete phase sequence of harmonic current components in the distribution system Three-phase electrical power can be given as in figure.1 with frequency fundamental is 50 Hz [2].

Frequency at the basic value of the frequency that has the lowest value in one periodic waveform. the large value of the fundamental frequency is abbreviated as $f_0$, the lowest frequency will start from zero. The fundamental frequency value is denoted as $f_1$, or the earliest harmonic, fundamental frequency can be defined in a wave and vibration of an object for a certain frequency, the fundamental frequency is low and the harmonic value of the resonant frequency will be high.

Harmonics will form a picture of each integer multiple of the fundamental frequency [3,4].

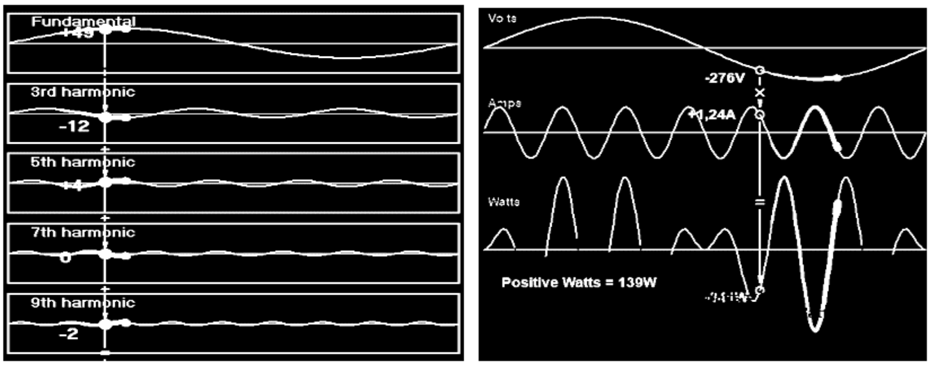


Figure.1 Simulation frequency fundamental

The problem that arises at plastic manufacturing company is an increase in harmonics in electrical power produced by non-linear loads that are not in accordance with IEEE Standards, namely > 5%, in overheating. The current produced by harmonics causes an increase in the amount of current in the power systems at plastic manufacturing company, this resulted in excessive heating of the transformer distribution equipment at plastic manufacturing company. Measurement data is carried out at the data source at the Voltage Source Balanced (V peak) Unbalanced (V peak) 312∠ 00, 311∠ -1200, 312∠ 1200, Phase R 3,23 Ampere, Phase S 3,24 Ampere Phase T 3,24 Ampere as figure2a, and THDi Current Phase R 25 %, Phase S 23 % Ampere Phase T 24% as figure 2b.

Figure 2a. Measurement Phase

2b. Measurement of harmonic distortion

## LITERATURE REVIEW

System conditions the voltage and current waveforms are sinusoidal. In on-site practice, non-sinusoidal currents occur when the current flowing through the load is non-linearly related to the resulting voltage [5]. a simple full wave rectifier load, current flows when voltage is applied and stored in the excess capacitor. This shows that there are harmonic indications that the waveform will be distorted from the initial sinusoidal wave as figure 3a and 3b [6].

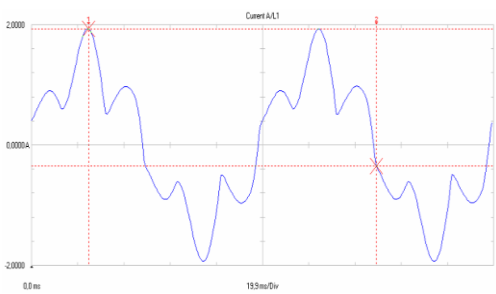


Figure 3a. Harmonic Current

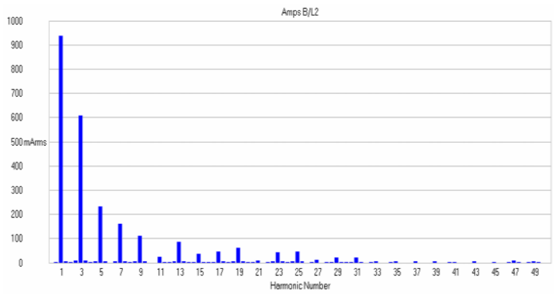


Figure 3b. Harmonic Spectrum

The high percentage of harmonic content of total harmonic distortion or abbreviated as THD in an electric power system can cause serious harmonic problems to arise in the electrical system, causing various types of damage to vulnerable electrical equipment and causing poor use of electrical energy, THDv and IHDv for voltage and current are formulated by the equation 1[7, 8]:

$$\mathrm{THDv} = \frac{\sqrt{\sum_{n=2}^{\infty}\left(\frac{Vn}{\sqrt{2}}\right)^2}}{\frac{V1}{\sqrt{2}}} \quad and \quad \mathrm{IHD_v} = \frac{\sqrt{\left(\frac{V_n}{\sqrt{2}}\right)^2}}{\frac{V_1}{\sqrt{2}}} = \frac{\sqrt{(V_n)^2}}{V_1} \qquad (1)$$

Current wave is not sinusoidal or in conditions containing harmonics, the power factor cannot be said to be a cosine value of the phase angle. The power factor for sinusoidal wave conditions is a power factor whose calculations involve harmonic frequencies in the voltage wave and current wave [9, 10].
a single tuned passive filter is a filter consisting of resistor (R), inductor (L) and capacitor (C) components connected in series figure 4, a single tuned passive filter will have a small impedance at the resonant frequency so that current that has the same frequency as the resonant frequency will be deflected through the filter. to overcome harmonics in industrial electrical power systems, the most widely used single tuned passive filter [11].

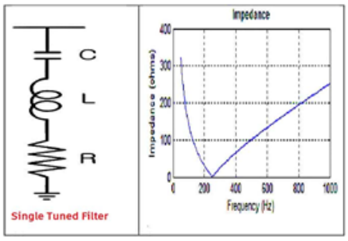


Figure 4. Single Tuned Filter

Determining the Capacitance of a Capacitor (C) equation 2.
C=  1/( 2πf_0 X_c    )f2)}        (2)

Determining the inductance of the inductor (L) equation 3.
L = X_L/( 2πf_0    )        (3)

Determine the resistance (R) of the inductor equation 4.
R = X_n/( Q    )          (4)

Determining the capacitor capacity (Qc) By determining the corrected power factor value (pf2) is 0.99. To calculate the required capacitor capacity equation 5.

Qc = P{tan(cos-1pf1) - tan(cos-1pf2)}        (5)
Determine the Inductive Reactance of an inductor (XL) at the fundamental frequency value, it can be determined using the equation:

## MATERIALS & METHODS

The method used in this research is direct measurement of non-linear loads, the measurement parameters are individual harmonic distortion current (IHDi), total harmonic distortion current (THDi), individual harmonic distortion voltage (IHDv), total harmonic distortion voltage (THDv), active power. reactive power, and power factor, which are produced by non-linear loads, then filter modeling is carried out as a harmonic inhibitor to reduce current harmonics [12].
a single tuned filter can reduce voltage harmonics (THDv) and current harmonics (THDi) by up to 10-30%. The amount of resistance R of the inductor can be determined by the quality factor of the inductor. The quality factor (Q) is the electrical quality of an inductor, mathematically Q is the ratio of the inductive reactance or capacitive reactance value to the resistance R. The greater the Q value chosen, the smaller the R value and the better the quality of the filter, where the energy consumed by the filter will be the smaller it is, it means that the heat loss of the filter is small, the quality factor value ranges from: $30 < Q < 100$.[13],
Knowing the magnitude of the harmonic value produced by the research object is done by measuring. This measurement is carried out using a Fluke SW43W power quality analyzer measuring instrument, the results of the measurement data are displayed in the form of data and wave graphs.
Before designing a passive filter, it is necessary to know the amount of reactive power required in the system. the reactive power of this system is needed to calculate the value of the capacitor needed to repair the system.
Measurements were carried out using a Fluke SW43W power quality analyser. From these measurements, the highest values of total current harmonic distortion (THDi) and total voltage harmonic distortion (THDv) will be taken and then compared with the IEEE standard THD tolerance of 5% figure 5.

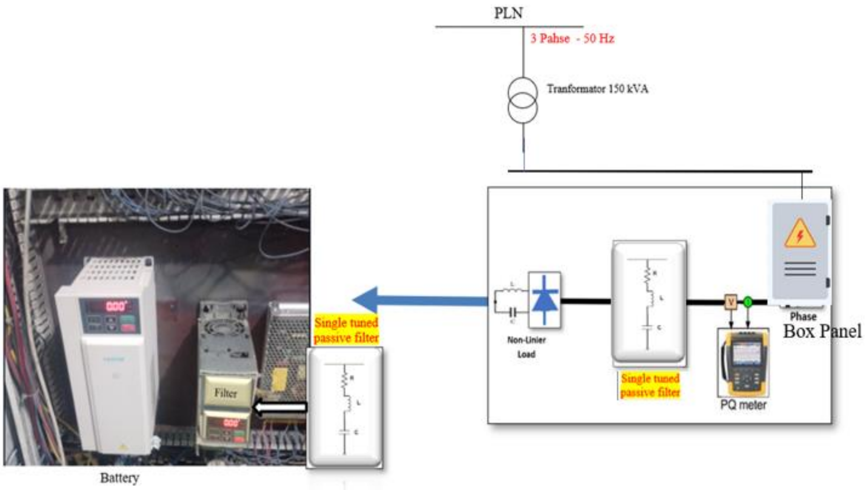


Figure 5. Implementation Filter Single Tuned

## RESULTS AND DISCUSSION

Filtering harmonics using filters, the use of a single tuned passive filter on all harmonic orders, namely 3rd order to 30th order harmonics, is reduced. Compared with the fundamental current, the highest harmonic content is found in 3rd order high harmonics as in Table 1.

the filter results, you can see the voltage and current waveforms produced after installing the single tuned passive filter as in Figure 5b. The current and voltage waveforms after installing the filter produce a waveform that almost resembles a sinusoidal wave, this shows that the harmonic content in the circuit is reduced.

| n | Voltage (V) | Current (R) | Current (S) | Current (T) |
|---|---|---|---|---|
| 0 | 0.000 | 0.000 | 0.000 | 0.000 |
| 1 | 100.030 | 70.040 | 62.201 | 65.012 |
| 2 | 0.000 | 0.302 | 0.023 | 0.035 |
| 3 | 6.030 | 5.042 | 3.032 | 2.053 |
| 4 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5 | 6.000 | 4.302 | 4.084 | 4,034 |
| 6 | 0.000 | 0.000 | 0.000 | 0.000 |
| 7 | 3.040 | 3.043 | 2,902 | 2.342 |
| 8 | 0.000 | 0.000 | 0.001 | 0.062 |
| 9 | 1.000 | 1.000 | 1.002 | 1.001 |
| 10 | 0.200 | 0.000 | 0.000 | 0.000 |
| 11 | 0.200 | 0.006 | 0.203 | 0.203 |
| 12 | 0.100 | 0.000 | 0.000 | 0.000 |
| 13 | 0.000 | 0.030 | 0.032 | 0.041 |
| 14 | 0.000 | 0.000 | 0.000 | 0.002 |
| 15 | 0.000 | 0.023 | 0.087 | 0.021 |
| 16 | 0.000 | 0.000 | 0.010 | 0.001 |
| 17 | 0.300 | 0.002 | 0.201 | 0.363 |
| 18 | 0.000 | 0.000 | 0.000 | 0.000 |
| 19 | 0.200 | 0.000 | 0.001 | 0.001 |
| 20 | 0.000 | 0.000 | 0.000 | 0.000 |
| 21 | 0.000 | 0.002 | 0.001 | 0.001 |
| 22 | 0.000 | 0.000 | 0.000 | 0.000 |
| 23 | 0.200 | 0.001 | 0.000 | 0.000 |
| 24 | 0.000 | 0.000 | 0.000 | 0.000 |
| 25 | 0.200 | 0.000 | 0.000 | 0.042 |
| 26 | 0.000 | 0.000 | 0.000 | 0.000 |
| 27 | 0.200 | 0.001 | 0.050 | 0.000 |
| 28 | 0.000 | 0.000 | 0.000 | 0.000 |
| 29 | 0.100 | 0.000 | 0.000 | 0.000 |

| | | | | |
|---|---|---|---|---|
| 30 | 0.000 | 0.000 | 0.000 | 0.000 |
| **THD** | **6.532** | **5.037** | **3.096** | **3.051** |

Installing the filter can reduce the harmonic shape of the voltage and current waves displayed by the graphic and in figure 6b the analysis tool almost does not form a sinusoid.

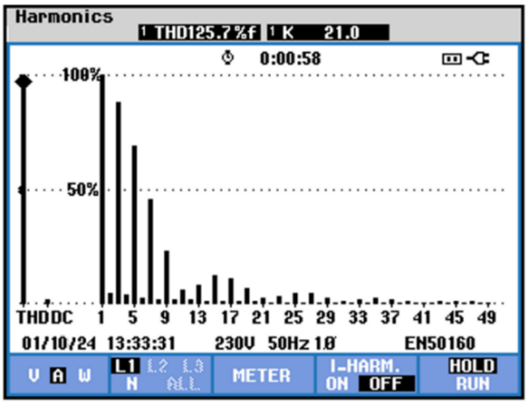


Figure 6a. Harmonic Current

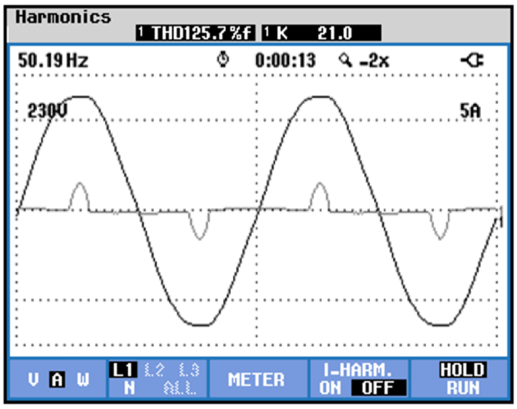


Figure 6b. Harmonic Spectrum

## CONCLUSIONS

The measurement results on the phase source obtained the initial measurement value before adding the filter, the total harmonic distortion was above 5% and the analysis for the single tuned filter was C value > 50.64 µF, L value > 10.093 H, and R value > 50.98 Ω. then after analysing the harmonic values, a filter was installed to reduce the THD value to 1.4% and the overall THD value was below 5% in accordance with IEEE standards.

## ACKNOWLEDGMENTS


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